# GROWING SCIENTISTS:

# A PARTNERSHIP BETWEEN A UNIVERSITY AND A SCHOOL DISTRICT

by

TERESA MARIE WOODS

B.A., Prescott College, 1988
M.S., Kansas State University 2006

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

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# Abstract

Precollege science education in the United States has virtually always been influenced by university scientists to one degree or another. Partnership models for university scientist – school district collaborations are being advocated to replace outreach models. Although the challenges for such partnerships are well documented, the means of fostering successful and sustainable science education partnerships are not well studied. This study addresses this need by empirically researching a unique scientist-educator partnership between a university and a school district utilizing case study methods. The development of the partnership, emerging issues, and multiple perspectives of participants were examined in order to understand the culture of the partnership and identify means of fostering successful science education partnerships.

The findings show the partnership was based on a strong network of face-to-face relationships that fostered understanding, mutual learning and synergy. Specific processes instituted ensured equity and respect, and created a climate of trust so that an evolving common vision was maintained. The partnership provided synergy and resilience during the recent economic crisis, indicating the value of partnerships when public education institutions must do more with less. High staff turnover, however, especially of a key leader, threatened the partnership, pointing to the importance of maintaining multiple-level integration between institutions.

The instrumental roles of a scientist-educator coordinator in bridging cultures and nurturing the collaborative environment are elucidated. Intense and productive collaborations between teams of scientists and educators helped transform leading edge disciplinary science content into school science learning. The innovative programs that resulted not only suggest important roles science education partnerships can play in twenty-first century learning, but they also shed light on the processes of educational innovation itself. Further, the program and curriculum development revealed insights into areas of teaching and learning. Multiple perspectives of participants were considered in this study, with student perspectives demonstrating the critical importance of investigating student views in future studies.

When educational institutions increasingly need to address a diverse population, and scientists increasingly want to recruit diverse students into the fields of science, partnerships show promise in creating a seamless K-20+ continuum of science education.

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# Dedication

Dedicated to all those who have a dream
and need to build bridges to create it.

# CHAPTER 1 - Introduction

A long and productive history of collaboration between university scientists and K-12 educators exits in the United States to benefit science education (DeBoer, 1991; Rudolph, 2002). These collaborations have served purposes such as curriculum development, professional development for teachers, research internships, science fairs, and career talks. Today, partnerships between university research scientists and K-12 school districts are increasingly encouraged through programs sponsored by federal agencies such as the National Science Foundation (2008) and the U.S. Department of Education (n.d.). Partnerships with universities and businesses are also seen as important to enhance science education in the context of "twenty-first century skills," a curricular movement being integrated into many state education standards. Generally speaking, "twenty-first century curricula" are promoted to prepare students in areas valued in modern society, such as science and technology literacy, foreign language proficiency, global studies, critical thinking, communication, innovation and collaboration, along with traditional course content (Bybee & Fuchs, 2006; S. P. Marshall, Scheppler, & Palmisano, 2003; Partnership for 21st Century Skills, 2011).

Partnerships between high school biology teachers and science researchers are promoted to help develop authentic inquiry experiences and curriculum material for the classroom, to offer tangible role models of scientists, to develop scientist mentors to students and teachers, and to help scientists learn how to talk about and teach science more effectively. In essence, partnerships are formed to accomplish things together in ways neither one can do alone, and they naturally involve groups that have different needs and resources which are matched for the benefit of both institutions (Cole, 2005).

Although scientists are often eager and enthusiastic to collaborate with schools and increasing financial resources are allocated to support such ventures, partnerships are often fraught with challenges in overcoming cultural differences between scientists and K-12 educators (Barstow, 1997; Drayton & Falk, 2006; Tanner, Chatman, & Allen, 2003). Differences between the two professional cultures include different institutional mandates, constituencies, levels of autonomy, criteria on which promotions and status rely, ways in which the scientific enterprise is experienced, expert vs. novice understandings, resources and resource allocation, power structures, and responsibilities in dealing with adults vs. minors (Cole, 2005; Eberbach & Crowley, 2009; McKeown, 2003; Mervis, 2010; Sussman, 1993).

Although the challenges to science education partnerships are well described by practitioners (Dolan, Soots, Lemaux, Rhee, & Reiser, 2004; Elgin, Flowers, & May, 2005; Granger, 2004; Shepherd, 2008; Sussman, 1993), and good theoretical work exists on such partnerships (Cole, 2005; Dolan & Tanner, 2005; Usselman, 2004), empirical research studies on science education partnerships between universities and school districts are sparse (but see Drayton & Falk, 2006; Tomanek, 2005), and calls for such research are being voiced (Dolan & Tanner, 2005).

Based on this need for empirical research in partnership development, I methodically investigated a unique science education partnership that I coordinated between a major Midwestern research university and a K-12 school district. This partnership was founded following many of the principles described in science education partnership theory. In my study, I investigated specific ways to foster a culture of partnership. Accordingly, this study can contribute to an understanding of how to foster educational partnerships among university scientists and school districts.

Through my own work with partnerships between natural scientists and K-12 educators, I have also found common challenges among participants, even though the individual contexts are diverse and personalities unique. For instance, teachers often defer to scientists as universal experts, even in pedagogical matters in which teachers' expertise is usually far greater. Learning is often perceived to be from scientists to educators and students, but not necessarily in a reciprocal direction too. Educators often take the initiative in understanding the scientist's world, but scientists only infrequently take the initiative to understand the teacher's world, even when the goals of collaboration focus on integrating science content into the constraints of a classroom. I find coordinating such collaborations requires attention to equity among the partners and to the resources each partner brings to the table and the benefits each derives from the partnership.

My experiences are consistent with what many practitioners working in university scientist / school district partnerships report (Drayton & Falk, 2006; McKeown, 2003; Mervis, 2010; Moreno, 2005; Tomanek, 2005). For instance, Tanner and colleagues (2003) report that scientist – school collaborations tend to be unidirectional in terms of learning, with scientists in the role of primary expert and K-12 educators as consumers of their expertise as a means to garner resources for their students. A growing set of scholars advocate a movement away from this one-way outreach model and toward partnerships that recognize that scientists in higher education institutions also gain in their perspectives and understanding (Dolan & Tanner, 2005; Tanner et al., 2003). Some of the benefits of partnership most often reported for scientists are an increased understanding of pedagogical approaches, how people learn, how to communicate to lay audiences, and even a greater understanding of their own scientific practices (Gengarelly & Abrams, 2009; Tomanek, 2005).

## Statement of the Problem

Many successful post-Sputnik science education reforms funded by the National Science Foundation established that "teachers and scientists working together are able to accomplish far more than either alone" (Rutherford, 1997). Today, universities and school districts are increasingly encouraged to collaborate for science education, and partnerships can be particularly fruitful when resources are scarce since expertise and resources can be shared. Yet knowing how to allocate limited funds and resources for the effective development and sustenance of partnerships is of concern, especially given the cultural challenges to science education partnerships commonly reported in the literature (Magolda, 2001; McKeown, 2003; Tanner et al., 2003; Tomanek, 2005).

The challenges confronting science education partnerships between scientists and K-12 educators are often based on perceptions of each profession. In an extensive study on scientists' views and perceptions of secondary science education, scientists held predominately critical views of K-12 science education, even though they had limited experiences with K-12 science education, and provided no "examples of evidence from observations in schools or from experiences working with teachers" (Taylor, Jones, Broadwell, & Oppewal, 2008, p. 1070). Even when scientists have a positive view of teachers and education, they are often surprised to learn of the limited resources, limited autonomy over curricula, and the competing priorities on their time, such as testing (McKeown, 2003; Mervis, 2010; Mitchell, 2000). Alternatively, teachers often defer to scientists, perceiving them to have higher status and power than teachers (Drayton & Falk, 2006; Tanner et al., 2003), with teachers often "in awe of and sometimes fearful of scientists" (Bellamy, 2005, p. 43).

Tanner and colleagues (2003) report that scientist – teacher collaborations tend to be unidirectional in terms of learning, with scientists in the role of primary expert and K-12 educators as consumers of their expertise for the benefit of their students. Yet lessons, activities or curricula prescribed by scientists to teachers without engaging teachers' expertise tend to be impractical to implement in classrooms, and are perceived as unsatisfying partnership experiences by teachers (Drayton & Falk, 2006; Elgin et al., 2005; Rudolph, 2005b; Tomanek, 2005). In contrast, when scientists engage with teachers with the intent to learn from their pedagogical expertise, scientists often report benefits such as learning to communicate to non-scientists better, understanding the learning process better, and even understanding their own research better (Gengarelly & Abrams, 2009; Siegel, Mlynarczyk-Evans, Brenner, & Nielsen, 2005; Tomanek, 2005). Further, scientists can benefit from partnerships in advancing their own research agendas by engaging teachers and students to collect data and work in their labs (Eberbach & Crowley, 2009; Sadler, Burgin, McKinney, & Ponjuan, 2010).

In order to foster greater success and sustainability in science education partnerships, leaders in the field are promoting a vision that moves away from individual outreach programs, and toward full institutional science education partnerships between universities and school districts that are mutually beneficial (Cole, 2005; Dolan & Tanner, 2005; Sussman, 1993; Tomanek, 2005; Usselman, 2004). This vision includes the following points: "1) the adoption of a mutual learning model of partnership, 2) the integration of partnership into the training of scientists, and 3) the development of sustained infrastructures for partnership" (Dolan & Tanner, 2005, p. 35). Further, arguments are being made to engage scientist educators who are professional hybrids with experience both as research scientists and K-12 educators to promote collaboration and communication among scientists and teachers (Bellamy, 2005; Shepherd, 2008; Sussman, 1993; Tanner et al., 2003). Finally, partnerships based on institutional commitment are promoted as a means for stability and sustainability (Granger, 2004; Shepherd, 2008).

While the challenges to collaborations between scientists and K-12 educators are well documented, and a model of institutional partnerships that are mutually beneficial is being promoted, research into specific ways to foster such science education partnerships are sparse. In order to identify policies and strategies to foster science education partnerships between university scientists and K-12 educators, it is critical that they be studied methodically and empirically.

## Purpose of the Study

The purpose of this study was to describe the dynamic culture of a unique science education partnership that implements recommended and innovative approaches to collaboration between universities and school districts in science education. Using case study methods and a post-structuralist philosophical framework, a detailed account of the inception, evolution and practice of the partnership has been produced, taking into account the multiple perspectives of participants. In doing so, the study aimed to identify means of fostering successful collaborations in university / school district partnerships in science education. For purposes of this study, the partnership was defined generally as the activities and engagement involving individuals from both institutions, as well as students participating in the activities generated by the partnership from its inception in Spring 2008 until Spring 2011. The findings from this case study can offer significant contributions to the literature by informing the science education community of ways to foster a meaningful, collaborative partnership between scientists and science teachers.

## Research Questions

I was interested in gaining insight into how scientist / educator partnerships develop in detail. My experiences as both educator and scientist have taught me that rich and unique contexts relate to each of these fields, and they come into dynamic play in partnerships between the two. Understanding a partnership at this point seems intractable from understanding its context. Therefore, the central question of this study was: *What is the culture of a science education partnership between a university and a K-12 school district?*

Questions that are embedded in this central question and that were addressed in the study were:

1. How has the partnership between the university and the school district developed?
2. What are the emerging issues, such as outcomes, successes and challenges, of the partnership?

3. How have multiple constituents (administrators, teachers, students, scientists) experienced the partnership?

## Overview of the Study

This research is a qualitative case study that aimed to understand the dynamics of a unique partnership between a Midwestern research university and a regional K-12 school district that focuses on high school curriculum and implements innovative approaches to institutional collaboration.

The nature of partnerships, by definition, is that individuals come together to share different perspectives in order to generate more than one could do alone. In order to highlight this essential plurality, I utilized a post-structural philosophical framework, which emphasized that a multiplicity of views, perspectives and contexts form a given reality. Post-structuralism is based on the recognition that assumptions, beliefs, values and practices differ from person to person, and that even when these are shared among individuals, they inevitably change over time. The overall approach, design and methods for data collection and analysis were informed by this framework. The findings of this study will help inform policy development for program design and funding, and inform effective learning practices for students, teachers and scientists engaged in high school science.

The partnership to be studied generated a number of programs, and these were given particular attention as embedded units of analysis. Therefore, I used a single-case, embedded case study design (Yin, 2009) in order to focus on the overall context of the partnership as well as individual programs. Data collection was from several sources. As coordinator of the partnership, I was in the role of a participant observer, collecting data on meetings, programs and events through field notes. To elucidate multiple perspectives, I conducted interviews with administrators, teachers, scientists and students, and conducted direct field observations over the course of six months. Additional data sources included documents such as meeting minutes and progress reports, archival records such as demographic data, and physical artifacts such as photographs and student work. By using these multiple sources, I aimed to capture and represent different individuals' perspectives, recognizing potential differences in perspectives based on professional culture, institutional rank, roles and responsibilities, and individual experiences.

Data was analyzed using analytic induction, which calls for finding the commonalities in data, leading to a description and then explanation of that phenomenon (Krathwohl, 2004). Yin (2009) refers to this as pattern matching and explanation building. Categorical aggregation using coding techniques was applied to find correspondence of themes and patterns across data sources (Stake, 1995). I created analytic memos and annotations to reference original data sources for re-examination. In addition, I relied on direct interpretation, the process of analysis and synthesis that Stake (1995) describes as "trying to pull it apart and put it back together again more meaningfully" (p. 75). To check against my assertions of patterns and explanations of phenomena, I explored potential rival explanations.

The research questions and embedded design structured the analysis as I looked for answers to the questions from an overall partnership perspective, as well as from the perspective of each embedded program. I created a time sequence analysis for the overall partnership to provide an analytic backbone to explain phenomena as they occurred.

## Significance of the Study

Although university / school district partnerships in science education have a long history, and are increasingly encouraged by policy-makers, with scientists and educators often eager to partner with each other, common challenges to implementing such partnerships are well documented. Yet understanding the means of fostering collaboration are not well studied (Dolan & Tanner, 2005; Drayton & Falk, 2006; Tanner et al., 2003). This study makes significant contributions to the literature on science education partnerships by informing the science education community of ways to foster a meaningful, collaborative partnership between scientists and science educators. It describes in detail the culture of an active science education partnership between a university and a school district, elucidating its inception, development, challenges, strategies, dynamics and outcomes. It draws upon recognized empirical methodologies and uses multiple data sources and represents multiple perspectives. Such studies are especially sparse in the literature base, which currently relies largely on practitioners' reports.

## Limitations of the Study

This study is limited by certain features. While case studies are immensely helpful for examining complex dynamics of a phenomenon, they are specifically situated in a unique context. This context limits generalizability in a number of ways. Both the university and the school district are considered suburban, therefore study findings may not be transferrable to urban or rural settings. Additionally, while students from both the university and school district are composed of some racial and ethnic diversity, both populations are predominately white. Therefore, study findings may be used to further reify the advantages of a white population rather than contributing to addressing the issues of educational inequalities. For example, the school district has placed high value on creating professional – technical high school tracks that students can choose. In addition, certain specialized resources are concentrated in these programs, allowing for advanced equipment and supplies that might not usually be found in general high school classrooms. Likewise, the university is a nationally ranked research university, and many universities and colleges do not have the same research resources. In these ways, this case is not representative or typical of other university / school district partnerships, even though it may serve as a model for what can work well.

My position as an insider might hinder providing insights that are free from a researcher's bias and subjectivity. I participated as an insider in this particular partnership, and I was in a unique position to enter easily into both the school district and scientist cultures. I experienced my own daily sense of success and challenge in the partnership. While I believe this perspective served more as a strength than a liability, there is naturally opportunity for inaccurate representation based on my biases. I relied on corrective procedures such as member checking and peer review of this work to present reliable and accurate findings.

## Delimitations of the Study

The case in consideration was a science education partnership between a Midwestern university and school district that took place within the context of a new satellite campus of the university with a focus on applied biological research, and a suburban school district in the same city. For purposes of this study, the partnership will be defined generally as the activities and engagement involving individuals from both the university and the school district, and students participating in the activities generated by the partnership from its inception in Spring 2008 until Spring 2011.

The embedded partnership programs to be studied are bound by two criteria. First, they constitute innovations that are unique and direct outcomes of the collaboration, rather than events such as field trips or lectures that already existed in each institution alone. Second, they focus on the integration of research with high school education.

## Definitions of Terms

**Case study:** A research study that investigates a specific, bounded person, institution, thing, or phenomenon in which multiple data sources are used to understand the case within its natural context.

**Categorical aggregation:** An analytic technique whereby categories of phenomena and issues are identified from the data and coded accordingly, so that aggregates of instances of such common categories are formed.

**Culture:** The set of shared ideas, customs, social behavior, attitudes, practices, common meanings and values that characterize the functioning of a group or organization of people.

**Education reform:** Efforts to change the practices of education in order to improve it, often driven by ideas or cultural trends.

**Equity:** (1) In terms of a relationship, such as in a partnership between organizations, the sense of fairly distributed inputs and outputs between partners, and the sense of fairly distributed power and value. (2) In terms of education, equity refers to ensuring everyone has a fair chance at the same opportunities, which may require investing more in disadvantaged students than in advantaged students.

**Partnership:** An agreement among organizations to cooperate and work together to advance their own interests and goals. For purposes of this study, the partnership will be defined generally as the activities and engagement involving individuals from both institutions, and students participating in the activities generated by the partnership, from its inception in Spring 2008 until Spring 2011.

**Satellite campus:** A campus associated with a larger university but that is physically distant and detached from the main large campus.

**Science education:** The field of education primarily concerned with sharing the content, practice, and history of science with students and other non-scientists.

**Scientist:** A trained professional engaged in systematic methods of acquiring knowledge, who engages with a community of fellow scientists to share findings, and who is recognized by them.  Although scientists practice in numerous fields, including social science and psychology, for the purposes of this study in science education partnerships, the term *scientist* is used primarily to refer to natural scientists (i.e., biologists, chemists, physicists, geologists, etc.).  University scientists also typically engage in research, teaching and administration.

**Standard-based reforms:** The educational reform movement driven by the idea that educational practices should be aligned to student achievement assessments that are based on concrete and measureable standards that identify what students should know and be able to demonstrate at specific grade levels.

**Time series analysis:** An analytic technique used to compile events chronologically with the goal of providing the basis for causal inferences of events and/or phenomena.

**Twenty-first century education:** Educational reform movements driven by the idea that modern students need to be educated to be effective citizens in a globally competitive workforce.  Twenty-first century education movements emphasize traditional subjects, and especially literacy in math, science and technology, geography and foreign languages, critical thinking and problem solving, communication, collaboration, and innovation.

# CHAPTER 2 - Literature Review

For such partnerships to work well, many different perspectives need to be considered. I situate this study within a post-structuralist framework as this philosophical tradition emphasizes the value of multiple viewpoints. In the first section of the literature review, I discuss post-structuralism as a theoretical framework. The history of science education and science education reform in the United States offers lessons in the legacy of multiple motivations, pressures and agendas science education faces today. In the second main section below, I review science education reform movements, especially in relation to the interactions of scientists and K-12 schools. The final section hones in specifically on scientist / school partnerships to understand some of the special considerations and strategies in collaborating between the two cultures.

## Theoretical Framework: Post-structuralism

Post-structuralism is a useful theoretical lens through which to orient this study, since this philosophical orientation attends to the multiplicity of views, perspectives and contexts that form a given reality. History reveals that perspectives change over time, and the fields of science and education are no exception. Even at the same point in time, we confront a multiplicity of assumptions, methods, values and practices when comparing distinct fields of science or cultural contexts of education (Anderson, 2007).

One needs only to recall the lessons of Copernicus and Galileo to recognize that the understanding and practice of science changes over time. Thomas Kuhn elucidates the subject in *The Structure of Scientific Revolutions* (1962), describing how scientific cultures and practices constrain and define what is considered knowledge and how such cultures change over time, affecting what is considered knowledge in any given point. In the present day, natural science embraces multiple forms of practice and assumptions, not just one method. In fact, much has been written on the myth of “the” scientific method and the fact that natural science research actually employs multiple methods that include descriptive, experimental, modeling, inferential, and theoretical techniques, depending on the context (Bauer, 1992; Rudolph, 2000, 2005a).

The field of science education is and has been the concern of diverse groups of people whose interests are often in tension with one another. Scientists, industry leaders and government officials are concerned with recruiting and maintaining a highly trained workforce in the sciences (National Academy of Sciences, 2007a). Many civic-minded people argue that science education is important for the maintenance of a scientifically literate and democratic society, not only for training scientists (Aikenhead, 2005; American Association for the Advancement of Science, 1990). Science teachers may be assumed to have a personal interest and often a passion for scientific subjects and for sharing these with students, as well as an interest in recruiting students into scientific fields (Hewson, 2007). Educational administrators have motives for including or excluding science education in their schools, for how science is positioned in the overall curriculum, and the resources made available to support science education (Rudolph, 2002). Educational experts, including those that train teachers in colleges and universities, provide recommendations and training platforms often based on current research in pedagogy (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Government officials pass laws, develop programs, impose policies, and allocate funding to science education based on current trends in society, the values of their constituents, expert advice, and perhaps even a measured long-term view of where they would like society to be in the future (Atkin & Black, 2007). Parents are usually deeply interested in the education their children receive, with many having their own views, positive or negative, about science and the role it might play in the lives of their children (Organisation for Economic Co-operation and Development, 2009). Finally, students themselves are at the center of science education, and they bring their own hopes, interests, desires, experiences, understandings and aspirations to not only their general education, but to science subjects they are exposed to (Donnelly, 2006).

Schwab argues that the history of science curriculum reform efforts can be seen in the light of various groups having greater or lesser power and influence: “the child-centered curriculums of Progressivism; the social-change-centered curriculums of the 1930s; the subject-matter-centered curriculums of recent reforms; the teacher-centered curriculums which may arise from unionism” (Schwab, 1973, p. 509). At times scientists control curriculum reform efforts, with the support of government leaders. At times educational specialists or schools have more power. Anderson (2007) argues for the validity of critical philosophical orientations (which includes post-structuralism) in relation to science education research, pointing to the dynamics of power between dominant classes and marginalized or “disadvantaged” populations, and how these affect student learning and understanding of science (pp. 21-26).

Since this study examines the various viewpoints of science, scientists, and science education, a post-structuralist theoretical framework was used to take into account the understanding that meaning is not single-sided, but a result of discourse – and the quality of discourse – among multiple stakeholders. Although post-structuralists draw from a variety of sources without necessarily sharing a set of uniform assumptions, they are united in their rejection of structuralism – a school of thought that is based on the principle of an external, objective and universal truth (Alvesson & Sköldberg, 2000; M. Peters, 1998). Post-structuralist philosophy, in fact, emerged from structuralism, and it is especially illuminating in relation to science and science education to understand this evolution. The following section discusses how post-structuralism evolved from structuralism.

### *From Structuralism to Post-structuralism: Piaget*

Structuralism, which originated in the field of linguistics, posits that knowledge and behavior are based on underlying structural foundations, for instance, brain structures, or an inherent conceptual structure native to a particular discipline (e.g., biology, chemistry, history). Peters and Burbules (2004) summarize structuralism this way:

> [I]n the same way that language is structured by a grammar and other rules that allow us to organize our speech intelligibly, *even when we are not aware of and cannot articulate those structures*, so too are cultures and societies organized by structures that their participants may not be aware of, but which nevertheless give their social practices and institutions coherence and meaning. (p. 15)

As implied above, structuralism was eventually applied to disciplines other than linguistics, including anthropology and psychiatry, and was related to the movement of European formalism, which became popular in the late 1950s and 1960s (M. Peters, 1998). Structuralism is based on a sense of realism – that the external world or laws exist independently of our representations of it. One of the most influential structuralists was Claude Lévi-Strauss, who published *Anthropologie Structurale* in 1958 (published in English in 1968 as *Structural Anthropology*), in which he described a method to find the "unconscious structure" or general laws of a cultural system.

The development of structuralism toward post-structuralism can be seen in the life of Swiss psychologist Jean Piaget, who published his book *Structuralism* in 1968. Piaget characterized a structure as a "system of transformation" that involves laws, emphasizing, according to Peters & Burbules (2004), that "the nature of structured wholes depends upon their laws of composition that in turn govern the transformations of the system" (p. 16). Embedded in this structuralist framework is Piaget's theory of cognitive development in children, wherein he identified progressive developmental stages that transform one into the next following natural laws. Piaget developed his theory of cognitive development through empirical research on how children's concepts of scientific principles change over time (Anderson, 2007). Throughout his lifetime, however, his theory became more nuanced and complex. In the end, Piaget became known as the founder of constructivism (M. A. Peters & Burbules, 2004), the learning theory that posits that a person's understanding and meaning is individually constructed based on previous understanding and new experiences.

Lev Vygotsky, a Russian contemporary of Piaget's, elaborated on Piaget's learning theory, placing more emphasis on the social component in learning, which came to be known as social constructivism. Vygotsky distinguished between spontaneous thinking, concepts that arise in a child's everyday experience, and scientific thinking, concepts that arise from work within a formal conceptual structure that may be explicitly taught for instance, in a social context either formally or informally (Bransford, Brown, & Cocking, 2000; Carlsen, 2007). While Piaget emphasized "how children learn from their interactions with the material world," Vygotsky emphasized "how children learn from their participation in activities with other people" (Anderson, 2007, p. 14). The trajectory of how social constructivist learning theory evolved from structuralism is similar to how post-structuralist philosophy evolved from structuralism. This evolution involves the recognition that multiple influences, perspectives and contexts help fashion understanding, and also that meaning is individually constructed, not necessarily conforming to external laws. Larkin (2004) notes, "Constructionists and post-structuralists share a postmodern rejection of such concepts as objectivity, reality and truth" (Origins section, third paragraph). In fact Burman (2007) argues that post-structuralist thought was directly influenced by the development of Piaget's learning theory.

Another important extension of Piaget's original learning theory is known as conceptual change theory, which emerged when investigators began to tie Piaget's work together with that of post-structuralists Thomas Kuhn and Michel Foucault (Anderson, 2007; Posner, Strike, Hewson, & Gertzog, 1982). Both Kuhn and Foucault emphasized the historical and cultural contexts of knowledge. Kuhn in particular discussed the shifts in scientific paradigms that occur when enough evidence conflicts with prevailing ideas, so that the ideas themselves change (Kuhn, 1962). This analysis of cultural shifts is similar to Piaget's analysis of individual cognitive shifts, which Piaget describes as occurring after individual experiences accrue that conflict with an internal concept, causing cognitive dissonance, which can then be resolved by accommodating a new view or expanded concept (Anderson, 2007). Posner and colleagues pulled the threads together between Piaget and Kuhn in a seminal paper (1982) describing conceptual change theory and spawning decades of subsequent research (Anderson, 2007).

Prominently known as a cognitive psychologist, Piaget also became widely recognized as an epistemologist, and even a "meta-epistemologist" (Burman, 2007; Tsou, 2006). The evolution of Piaget's theories was strongly influenced by Thomas Kuhn and Michel Foucault, both of whom were centrally involved in the emergence of post-structuralism from structuralism (Burman, 2007).

> As [Piaget's] interests became increasingly theoretical through the 1960s, Piaget had indeed turned to Kuhn in the course of expanding his own epistemological system. Furthermore, he had concluded that the paradigm concept was too limited to serve as a basis for a general theory of knowledge because it is merely descriptive of the intellectual trends that follow epistemic 'mutations.' The later works … are thus reflections of a long process of discovery; they are bound up with attempts at formalizing the theory underlying his earlier empirical work with children and generalizing psychogenesis in application to the social transmission of knowledge. But they are also based upon evolutionary-developmental processes with roots in both the history of biology and the history of psychology: Piaget's is a complex epistemology, biologically grounded and empirically informed. (Burman, 2007, pp. 721-722)

What Piaget, Kuhn and Foucault all wrestled with was the existence, or lack thereof, of unifying structures of knowledge and development within a multiplicity of social and cultural contexts. Piaget retained the strongest sense of organizing structure, as his theory integrated the biological view of melding phylogeny with ontogeny, an approach often termed genetic epistemology (Tsou, 2006). Piaget can be seen as a transitional figure between structuralism and post-structuralism, however the balance in his case must be tipped toward the former.

### *Post-structuralism: Kuhn and Foucault*

Although post-structuralism is often considered a counter-philosophy to structuralism, M. Peters (1998) argues that post-structuralism actually forms a continuity with structuralism by extending its boundaries. For instance, while structuralists see the world as having an inherent truth with individuals conceiving of that truth in a structured way, post-structuralists emphasize the *interplay between* the world and the individual within a cultural and social context as the means whereby knowledge is constructed. Post-structuralism finds its roots in Friedrich Nietzsche, who emphasized a multiplicity of perspectives and interpretation over universal truth, the important drive of the will to gain power or influence over others, the importance of discourse in constituting knowledge, and the fluidity of self-identity (M. Peters, 1998). Post-structuralism emphasizes that knowledge is historically and culturally situated, and can best be understood by investigating the conditions of its emergence. Thomas Kuhn and Michel Foucault, two transitional figures between structuralism and post-structuralism, are discussed below (Burman, 2007; M. A. Peters & Burbules, 2004).

Thomas Kuhn, in his book, *The Structure of Scientific Revolution* (1962), set forth an unorthodox perspective of science that emphasized the primacy of cultural context in scientific thinking. Kuhn was a physicist who conducted research on radar during World War II at Harvard, and continued to teach there after the war. He taught an introductory course in science for non-majors designed by James B. Conant, President of Harvard, and based on a series of case studies of scientists and their influence on society (J. B. Conant & Nash, 1957a, 1957b). In situating scientists and scientific knowledge within historical contexts, this curriculum directly challenged “the positivism and realism inherent in traditional science courses” (Aikenhead, 2005, p. 884). Kuhn expanded on these ideas, setting them forth in his treatise *The Structure of Scientific Revolution* (1962).

Kuhn describes “normal science” as the activity of puzzle-solving. He maintains that, to a large degree, the fascination for scientists in normal day-to-day research problems lies in this reality:

> Though its outcome can be anticipated, often in detail so great that what remains to be known is itself uninteresting, the *way* to achieve that outcome remains very much in doubt. Bringing a normal research problem to a conclusion is achieving the anticipated in a new way, and it requires the solution of all sorts of complex instrumental, conceptual and mathematical puzzles. The man who succeeds proves himself an expert puzzle-solver, and the challenge of the puzzle is an important part of what usually drives him on....
>
> What then challenges him [the scientist] is the conviction that, if only he is skillful enough, he will succeed in solving a puzzle that no one before has solved or solved so well. (Kuhn, 1962, pp. 36-38)

Kuhn suggests that each scientific discipline has its own rules and restrictions, which put together, can be described as the discipline's *paradigm*. These rules include undertaking problems that the community deems within its bounds, an established viewpoint or preconception. "A paradigm can, for that matter, even insulate the community from those socially important problems that are not reducible to the puzzle form, because they cannot be stated in terms of the conceptual and instrumental tools the paradigm supplies" (Kuhn, 1962, p. 37). These amount to scientific laws, concepts and theories. They not only set the parameters of the puzzle and the type of instrumentation to be employed, but they also limit acceptable solutions.

Kuhn describes, then, an *anomaly* as "new and unsuspected phenomena" that are uncovered by scientific research (Kuhn, 1962, p. 52). Yet he points out that an anomaly on its own likely never produces a change in the scientific paradigm. Rather, there tends to be "extended episodes" where anomalies are first noticed by researchers in the scientific community, but they don't cause an immediate shift in the conceptual framework. They are just noticed. Sometimes scientists suspect there was an error in their own work and try it again; sometimes the fact is tucked away as a puzzle to be solved; sometimes it is simply ignored. Kuhn points to a period, then, where these unexpected violations of the paradigmatic expectations are explored directly. Finally an adjustment is made in the scientific concepts so that "the scientist has learned to see nature in a different way," and those adjustments are incorporated into the scientific community (Kuhn, 1962, p. 53).

The similarities between Kuhn and Piaget have to do with shifts that occur in conceptual understanding. However, while Piaget's concern is the individual person situated within a single lifetime, Kuhn's concern is the scientific community situated within an historical cultural context. It is the emphasis on the historical cultural context, and the relativism of that, that places Kuhn as a post-structuralist.

In spite of Kuhn's work in the United States, post-structuralism is often considered to have originated in France during the decades following World War II, with Michel Foucault recognized as one of the most influential members of that founding generation. Foucault grew up in France during World War II, with the overbearing occupation of the Nazis and the horrors they inflicted on communities. Foucault undoubtedly reflected on the social acts of commission, omission, and compliance with the Nazis (Roudinesco, 2008). He originally trained in philosophy, but abandoned it for psychology, earning his license in 1951, and subsequently earning a diploma in psychopathology. Foucault worked in psychiatric institutions and prisons, taught and worked abroad, and finally completed his doctorate on "the history of madness" in 1964 (J. Marshall, 1998, p. 66). In 1968 he became Head of Philosophy at the experimental university at Vincennes, just in time for the student revolutions. The next years were turbulent with endless student protests, in which the philosophy department engaged and encouraged. These protests in France at this time nearly toppled the state government (J. Marshall, 1998).

Like Kuhn and other philosophers who are considered post-structuralists, Michel Foucault did not claim the label himself. Yet Foucault effectively defines himself as such in his critique of structuralism in *The Order of Things* (1973), in which he points out the fallacy of assuming every discipline has its own independent structural framework. While Kuhn was primarily interested in the progression of scientific thought, Foucault concerns himself with additional disciplines. In *The Order of Things* (1973), he compares the histories of economics, linguistics and biology as examples showing how the progression of ideas in one discipline influences those in the other disciplines, and how old ideas are replaced by new ones in progressing eras of time. In fact, Foucault argues that these three diverse fields – economics, linguistics and biology – have been more similar to each other during each era, than each field has been to itself in separate eras. Foucault calls the progressive eras "epistemes," proposing that in each episteme there are certain respected and understood ways of knowing (epistemologies), accepted kinds of knowledge that are valued, and accepted assumptions. In comparing previous epistemes to the modern one, he illustrates the transitory nature of any accepted epistemological framework in a given time, including the one we accept today. Foucault underscores the point that all human knowledge is socially constructed in relation to experiences of the world, and that diverse perspectives and cultural contexts must be taken into consideration to understand "knowledge" (Foucault, 1973).

More than Piaget or Kuhn, Foucault elucidates the transitory nature of understanding, especially regarding the dynamics of social context in constructing meaning. Foucault particularly argues that meaning and understanding is contextual, including identity of the self. He resists defining oneself, or structures of power, but rather is interested in the *relationships* and *discourse* by which knowledge and power exist. J. Marshall (1998) states, "According to Foucault's strict nominalism, power only exists when power relationships come into play" (p. 73).

Foucault was deeply interested in the dynamics of power, of the state, of how individuals are subjugated or subjugate themselves, and of how individuals are disciplined to conform to the norm. He argued, however, that he was primarily concerned with situating phenomena within historical cultural contexts, as he stated in an interview in 1980: "The goal of my work during the last twenty years has not been to analyze the phenomena of power, nor to elaborate the foundations of such an analysis. My objective, instead, has been to create a history of the different modes by which, in our culture, human beings are made subjects" (Rabinow, 2010, p. 7).

For instance, (bearing in mind his training in psychiatry) Foucault identified several modes of objectifying "the subject," including: 1) "dividing practices," such as the isolation of lepers during the Middle Ages, the confinement of the mentally ill, the classification of diseases and practices of modern medicine; 2) "scientific classification," the separation of understanding by different disciplines such as the natural sciences and humanities, whereby discourse is contained within the social practices and institutions within which they are embedded; and 3) "subjectification," the ways in which an individual actively turns herself into a subject, such as in engaging in psychoanalysis or medical treatment, or some other act of self-understanding mediated by an external authority figure (Rabinow, 2010, pp. 7-11).

Foucault's outlook reflected a continental philosophical approach that was concerned with the self and self-development. This reflexive orientation differed from an Anglo-American approach, as exemplified by Kuhn, that taught philosophy through its history of ideas (J. Marshall, 1998).

> The point of doing philosophy for Foucault was to work upon the self to transcend the intellectual, social, and moral cages that the enlightenment notion of freedom and emancipation through knowledge mistakenly offers. Teaching was not to fit the individual into a certain aspect of society but to permit individuals to change, to transcend the normalizing classifications and objectifications that permitted them to be allotted in appropriate docile positions in society. (J. Marshall, 1998, p. 71)

Kuhn and Foucault focus on the culture or the individual within a culture, while Piaget attends primarily to individual cognition. All are concerned that knowledge or understanding is situated within developmental, temporal and environmental contexts, and that understanding will shift when enough anomalies to the prevailing paradigm present themselves to effect an uncomfortable or puzzling disequilibrium, precipitating a fundamental shift in understanding – or in Kuhn's terms, a paradigm shift (Burman, 2007; Tsou, 2006). However, Foucault takes it a step further in situating knowledge in dynamics of power, of inclusion and exclusion. Kuhn implies this perspective when he illustrates how prevailing scientific theories or concepts are maintained within the mores of the relevant scientific communities. But Foucault explicitly sets the stage for what today in education are described as issues of diversity and differentiated learning. Anderson (2007), for instance, reviews the critical philosophical tradition in relation to science education, noting that scientific literacy means social and personal empowerment for many, as well as exclusion from such empowerment for others.

### ***Post-structuralist Implications for Science Education Research***

While Foucault's earlier work could tend toward the fatalistic and deterministic, he later affirmed the possibilities of freedom through resistance. J. Marshall (1998) notes that, according to Foucault, "Power can only exist where there is a possibility of resistance and, thereby, the attainment of freedom. Power is no longer an omnipresent and overarching presence but, rather, an open and strategic game" (p. 75). Hence, researchers using a post-structuralist framework will examine the discourse between individuals in given situations to analyze *how* power comes into existence and is managed, *how* institutions discipline their constituents into normative behavior, and *how* individuals find their own self-identity.

Foucault is adamant that education must be non-manipulative and must permit us to change at will. To do that we must be able to dissociate ourselves from the regimes of truth that have classified, objectified, normalized, and constituted our identity as beings of a particular kind (J. Marshall, 1998, p. 77). The construction of a genealogy, as Foucault accomplished in *The Order of Things*, or creating narrative analyses are methods suggested for elucidating the pluralities of meaning Foucault strove for (J. Marshall, 1998).

Peters and Burbules (2004) identify realms of post-structural investigation that are summarized here:

1. examining how the socio-cultural structures contribute to individuals' self-identities
2. examining the interrelations of constituent elements of environment and individuals that comprise a culture
3. examining the hidden structures or socio-historical forces that, to a large extent, constrain and govern behavior
4. examining the mutability of language, meaning and understanding
5. examining the plurality of interpretations by constituents (pp. 21-30)

The same authors further describe post-structuralist researchers being committed to social and political change, and "conceive of their work as making a difference to their research constituents, their colleagues, and themselves…. [and] a desire to want to change those aspects of the social world that are seen as unjust, unequal, or plainly oppressive" (M. A. Peters & Burbules, 2004, p. 99).

Post-structuralism developed as a reaction to a positivist view of science and the implications of the authority of one universal truth. Within the fields of science today, a plurality of scientific practices are recognized, and scientific conclusions are generally considered tentative, with new findings often shifting or expanding understanding (National Research Council, 1996a). In this view of science, post-structuralism is a helpful tool. Scientific research, however, is often a black box that can conjure a sense of awe, mystique or inaccessibility among many members of society, including students. How this sense of inaccessibility is constructed, and how it can be rectified so that science is more transparent, is of interest to many engaged in science education.

Post-structuralism informs this study through the recognition that the self-identities of partnership members, their perceived roles in the partnership, and the interactions of partnership members, are influenced by the professional cultures of science and education (M. A. Peters & Burbules, 2004). Additionally, how partnership members recognize the plurality of scientific practices, and how science becomes accessible to high school students, are of interest in this study.

Given the post-structuralist view of the importance of cultural context, a genealogy of the history of science curriculum reform efforts in the United States follows.

## Science Curriculum Reform Efforts

Education reform efforts evoke passionate local conflicts and social debates as curriculum changes directly affect children, reflecting the values of what and how we teach our children, and what we value most highly in each generation. Temporal political and economic issues drive reforms, and involve many stake-holders including government leaders and lawmakers, disciplinary experts, education leaders, teachers, parents and taxpayers. As reforms are often aimed at correcting previous excesses, curriculum reforms can appear to simply substitute one set of "errors" for another. Yet overall, the constancy of educational reform represents the tenacious urge to improve the educational system. That said, it is wise to take note of Aikenhead's conclusion (2007, p. 881): "We must not forget that curriculum decisions are first and foremost political decisions. Research can *inform* curriculum decision making, but the rational, evidence-based findings of research tend to wilt in the presence of ideologies …."

To provide context for this study, I trace below the continual ebb and flow of the direct influence of universities on the school curriculum in general, and particularly on the science curriculum in the United States.

### *Earliest Reform: Including Science in American Education (1700 – 1860s)*

Colonial America inherited the European template for schools, which historically educated the clergy. Colonists continued the practice of educating an elite student body with an essentially classical curriculum for older children and an emphasis on reading and arithmetic skills for younger children (Atkin & Black, 2007; Marsh & Willis, 2007). Benjamin Franklin, in contrast, emphasized the practical life when he established the Philadelphia Academy in 1750, by including agriculture, navigation, surveying, and all the known sciences. Several similar academies were built. For more than a century, these institutions grew steadily in number and importance in the new United States of America alongside other private or religion-based schools (at this time all schools were under local or private control). Franklin's lead in education reform placed science and related practical subjects squarely on the American education scene early in the development of the United States' system, and on a relatively large scale (Atkin & Black, 2007).

One of the intents of the academies was to open educational opportunities to the middle class "for a natural aristocracy of virtue and talent to flourish, rather than to help maintain an aristocracy of wealth and birth" (Marsh & Willis, 2007, p. 34). This orientation toward practical means of self-improvement helped the academies prosper within a climate of growing popular demand for universal elementary schooling. The idea of universal education mingled with the reality of needing to charge tuition created a natural tension and helped stir calls for a publicly funded education system. Concurrently, a growing sense of responsibility for participatory democracy in America, for the whole citizenry and not just for the elite political representatives, called for an educated population. These ideas converged to help spark what became known as the common school movement, "an effort to democratize American education by making the same kind of schooling available to all" (Marsh & Willis, 2007, p. 34).

The United States Constitution does not address the subject of education, so with passage of the Tenth Amendment, responsibility for education fell to the states. Starting with Massachusetts in 1852, each state enacted legislation leading to increased state control of and financial support for schools, as well as compulsory attendance laws. Public high schools tended to offer a great variety of traditional subjects such as classical languages, reading, grammar, spelling, writing, arithmetic, and history, as well as the liberal subjects of arts and sciences. The state-governed schools also tended to retain the pragmatic characteristics of the academies (DeBoer, 1991). When, in 1862, Congress passed the Morrill Act allowing for the establishment of land-grant colleges, the idea of a practically-based curriculum including the sciences was extended to higher education.

Meanwhile, science itself was coming into its own as a discipline distinct from philosophy. As evidence of this, the British Association for the Advancement of Science (BAAS), when it was founded in 1831, replaced the word *science* for *natural philosophy* in its title. Then in 1834, the president of the BAAS used the term *scientist* for the first time. Following the lead of the BAAS, the American Association for the Advancement of Science (AAAS) was established in 1848 (Aikenhead, 2005). Curriculum changes in both countries reflected the growing disciplinary tracking of science by "distancing itself from technology and ensconcing itself within the cloisters of university academia, where it could control access to its various disciplines" (Aikenhead, 2007, p. 882). And so began the teaching of science content in the context of separate disciplines.

### ***Standards and Methods: Consistency across the Country (1860s – 1910)***

According to Atkin & Black (2007), the teaching methods in the elementary and secondary schools in the early nineteenth century were based on various forms of "sense realism" – the idea that true learning arises from experience. Yet DeBoer (1991) notes that, consistent with early nineteenth century educational practices, the sciences were primarily taught by poorly trained teachers with limited equipment and supplies through memorization of limited and imperfect texts. During the mid-nineteenth century, an active debate brewed in Europe and the United States regarding the value of teaching the sciences, with particular focus on the value of teaching through laboratories.

Traditionally, laboratories were used strictly for research and were the domain of scientists; students were not admitted into them. However, German chemist Justus von Liebig successfully pioneered the practice of using student laboratories. His methods were championed in the mid-nineteenth century by proponents such as the British biologist Thomas Huxley, the British intellectual Herbert Spencer, and the German philosopher and educator Johann Friedrich Herbart (Rudolph, 2005a). Each eloquently described the unique value of using laboratory and field exploration in training the mind through direct observation of natural phenomena and inductive reasoning – or as Huxley said, bringing "the mind directly into contact with fact" (as cited in DeBoer, 2006a, p. 22). In the United States, Charles W. Eliot, a chemist and president of Harvard University from 1869 to 1895, became a vigorous advocate for science education using laboratory work at all levels as a way to "develop mental abilities and to empower persons for useful action in their lives" (DeBoer, 1991, p. 30). Eliot conceded that some science learning could be gained from reading texts, but believed that none of the mental discipline that science offers can be learned solely through books, and instead requires practical experience in the laboratory or field. He criticized teaching methods that excessively emphasized memory studies at the expense of developing observational skills (DeBoer, 1991).

By the 1890s, elementary school enrollment expanded rapidly as immigration peaked in the United States. By that time, attendance in elementary schools was largely compulsory, and the curriculum was broad. In contrast, attendance in secondary schools was voluntary, and only about ten percent of the secondary school age population were enrolled. Yet seventy percent of those enrolled went on to higher education institutions. Accordingly, preparation for college admission dominated the secondary school curriculum (Marsh & Willis, 2007).

College admission requirements varied widely, creating difficulties for secondary school leaders in setting their curricula. In 1892, the National Education Association (NEA) charged a group of university presidents, high school principals, and the U.S. Commissioner of Education to make recommendations for standardizing college admission requirements and to give consistent form to the high school curriculum. The group became known as the Committee of Ten. Charles Eliot was made chairperson (DeBoer, 2006a). The Committee coordinated nine separate subject-based conferences:

1. Latin
2. Greek
3. English
4. Other modern languages
5. Mathematics
6. Physics, astronomy, and chemistry
7. Natural history (biology, including botany, zoology, and physiology)
8. History, civil government, and political economy
9. Geography

Released in 1893, the *Report of the Committee of Ten on Secondary School Studies* made extensive and detailed recommendations regarding at which age each subject was to be introduced, and the number of years and hours per week each subject should be taught (Marsh &

Willis, 2007; Rudolph, 2005a). The classical languages assumed a diminished role in favor of "a relatively new subject, the sciences (including geography)" that now was to occupy 25 percent of the high school curriculum (Atkin & Black, 2007, p. 786). The influence of Charles Eliot is unmistakable. Each of the science groups strongly supported the use of the laboratory in science teaching to develop students' reasoning skills, emphasizing that students should not be taught dogmatically, but rather inductively, so they could acquire knowledge independently and free from authority (DeBoer, 2006a). Additionally, reflecting an egalitarian philosophy of the same education for all students, the report recommended that all students take all subjects, with the primary difference for the college-bound being the number of years a subject was to be taken (Atkin & Black, 2007).

In terms of using laboratories for teaching purposes, the Massachusetts Institute of Technology (MIT) and Johns Hopkins University led the way by establishing student labs. Other leading colleges and universities followed, and especially after the Committee of Ten report, high schools began to create student labs as well to prepare students for higher education in the sciences (National Research Council of the National Academies, 2006). Colleges and universities began offering summer laboratory courses to train teachers in lab methods. In 1886, the President of Harvard, Charles Eliot, asked physics instructor Edwin Hall to publish a detailed list of forty experiments that were to be completed as a condition of admission to study physics at Harvard. The list detailed the experiments, procedures and equipment necessary, and scientific supply companies began selling sets of the required equipment to schools. Other colleges and universities also started requiring completion of these same physics lab exercises for admission. Given the prestige of Harvard as the foremost institution of higher education in the United States, this list of forty physics experiments served as a *de facto* national standard for high school physics courses (DeBoer, 1991; Rudolph, 2005a).

Hall's systematic exercises were enthusiastically received and promulgated throughout high schools as *the* means to learn the inductive method of the empiricist. "The commitment to the inductivist approach was so complete that scientists and educators thoroughly denigrated anything that hinted at theoretical speculation" (Rudolph, 2005a, p. 352). The approach's purpose was to guide students in developing the mental discipline and habit of mind for careful and deliberate observation and measurement, with emphasis on the methodical accumulation of facts prior to drawing conclusions. Rudolph (2005a) argues that this instructional technique of learning science came to be referred to as *the scientific method*.

The influence of instructional laboratory methods extended to biology as well, with an increasing number of secondary school teachers enrolling in university summer courses to be trained in techniques of dissecting animals (National Research Council of the National Academies, 2006). The subject of nature study also became prominent in the primary and secondary curriculum, popularized by such figures as Louis Agassiz, a charismatic Harvard biologist often credited with the slogan "Nature not Books" (Atkin & Black, 2007). Cornell University's College of Agriculture had a remarkable influence on popularizing nature study as part of a social movement to glorify the rural life and counter the great migrations to urban areas. Starting at the turn of the 20$^{th}$ century, respected Cornell biologists and professors such as Anna Botsford Comstock and Liberty Hyde Bailey developed curriculum materials for children designed to instill a love of nature. These were published four times a year as the *Cornell Leaflets* (later the *Cornell Rural School Leaflets*), and were systematically disseminated across the country, continuing to be developed and distributed until the 1970s. Along with the laboratory method, the *Cornell Leaflets* represented one of the first broad-scale campaigns for infusion of an educational philosophy and technique in the United States (Atkin & Black, 2007).

### *Reform for the Practical (1910 – 1930s): Progressive Education*

From 1890 to 1910, high schools expanded to absorb a rapidly growing student population. High school curricula were still oriented toward college preparation, even though by this time fewer than ten percent of enrolled high school students were identified as preparing for college (Rudolph, 2005a). Dealing with the problem of "the masses in the high schools" was now a primary challenge (Rudolph, 2005a, p. 357).

Despite the great efforts to the contrary, "textbook-based methods remained the dominant mode of teaching at the turn of the century" (DeBoer, 2006a, p. 24). Additionally, backlashes developed against the Harvard laboratory teaching methods, as they were frequently taught by teachers not trained in implementing them, and were all together seen as too plodding and pedantic, especially for the majority of students not heading to college. By the end of the first decade of the twentieth century, high school science teachers commonly reported their distaste for and sense of irrelevance in having students learn the scientific method first-hand through the recommended laboratory techniques. Instead, they felt it more important to teach simply about science by illustrating its practicality and usefulness in society at large (Rudolph, 2005a).

While enrollment numbers in high schools swelled across the nation, nowhere were they rising faster than in Chicago. This city became the center of reform efforts when the University of Chicago physicist Charles R. Mann and other members of the Central Association for Science and Mathematics Teaching (CASMT) launched a complete overhaul of the physics curriculum, calling for a more dynamic curriculum with personal, practical and social relevance to students (National Research Council of the National Academies, 2006). According to Rudolph, it was also an opportunity for professional educators to *assert their independence from* college and university natural scientists in setting the science curriculum, and to "begin to shape a new mission for the high schools of the country" (2005a, p 357).

Educators were emboldened as professionals by the development of a new science of psychology. G. Stanley Hall, president of Clark University, was one of the first American psychologists, and he proved to be a leading advocate for the field of child study. He severely criticized the laboratory methods in physics, especially the focus on measuring and exactness, and stated that "boys of this age want more dynamic physics" (Hall, 1901, p. 652). Charles Eliot delivered an interesting response to Hall's address that would appear enlightened by today's constructivist understanding of learning, and soundly defended the laboratory methods in physics when used faithfully (Hall, 1901). Nonetheless, by the end of the decade, the public tide appeared turned and teachers began to use psychology as the means to justify a warranted change in the high school curriculum. Arguments for greater relevance and utility in the physics curriculum spread also to other science subjects with recommendations to incorporate more historical perspectives and biographies. The problem had been clearly framed as a polarity between utility and student interest *versus* learning the process of doing science (Rudolph, 2005a).

John Dewey, philosopher and educator (and one of the "new" psychologists incorporating scientific methods to studying human behavior) addressed the 1909 meeting in Boston of the American Association for the Advancement of Science (AAAS), calling for a solution to the conflict between those wanting to teach science for the scientific discipline of mind, and those wanting to teach science for more practical aims (Dewey, 1910). He criticized the methods commonly used to teach science and promulgated to educators by scientists themselves. Yet he extolled the virtues of science as a means to simply learn to think clearly on the basis of evidence – a quality apparently as much needed a century ago as it is today. He argued that decision-making on the basis of sound reasoning was imperative for a free-thinking society, and science methods were the *only* means to develop this (Dewey, 1910).

John Dewey was a natural arbiter of this debate, as he had a profound respect and understanding of scientific methods and was the quintessential pragmatist. He was a philosopher and educator, and his closest friends were natural scientists. He helped usher in the age of using scientific methods in the study of psychology. To test his educational theories, he established a laboratory school at the University of Chicago, seeking input from Chicago's eminent scientists. As head of the Department of Education, Dewey was involved in the activities of the CASMT reform efforts, and remained so even after he left Chicago (Rudolph, 2005a).

Dewey's philosophy of education helped form an important part of the intellectual foundation of the CASMT reform movement, contributing especially to the growing awareness of student interest in learning. Through his influence, the science curriculum became more focused on interesting facts and information to engage pupils, and yet others took this tendency further than Dewey was comfortable. In fact, he criticized much about the practice of "child-centered education" in spite of being credited with spreading the ideas. Rather, Dewey sought "to keep the focus on the *process* of knowledge construction, rather than on the knowledge itself, however interesting it might be" (Rudolph, 2005a, p 364). Additionally, Dewey argued that citizens in a democratic society should be inquirers regarding the nature of their physical and social environments and actively participate in the development of society. Dewey's influence led to greater use of inquiry-style teaching, and having students solve specific problems of social significance, what today we might refer to as project-based learning and the science-technology-society (STS) focus (DeBoer, 2006a).

In light of the changing nature of secondary schools, the National Education Association (NEA) appointed the Commission on Reorganization of Secondary Education. The Commission's report, *Cardinal Principles of Secondary Education,* was released in 1918 and recommended a complete reversal of the late nineteenth century trends toward increased disciplinary focus (DeBoer, 1991; Marsh & Willis, 2007). The commission recommended broadening the curriculum of secondary schools to encompass virtually all of life's experiences, not just academic subjects. They promoted far less focus on the traditional subjects in school programs, and instead emphasized the development of the individual student and his or her role in society. The report advocated a continuous view of education from kindergarten through university study, with greater attention to individual differences in interests and intellectual ability, greater student choice in courses they could take, and with more electives being offered (Atkin & Black, 2007; DeBoer, 1991).

Taking the child-centered philosophy to an extreme, experimental unstructured schools opened with the view that everything a child does is good and authority is not necessary, and that freeing children from restrictions and allowing them to discover unfettered is desirable (Marsh & Willis, 2007). These schools would later be held up as examples of the failure of a child-centered approach. Most schools, however, did not go to such extremes but simply shifted to focus on more practical topics related to everyday life. Science education moved toward helping students understand practical applications, especially in technology, such as electricity, central heating, refrigeration, and automobiles (Atkin & Black, 2007). In 1932, the Thirty-First Yearbook Committee of the National Society for the Study of Education (NSSE) outlined purposes for using the laboratory in science teaching, most with practical implications, although the committee also promoted the importance of understanding scientific principles and method (National Research Council of the National Academies, 2006).

As high school class sizes continued to swell, teachers struggled to use investigative projects and engage all students. They began to look for lists of specific projects with clear procedures and expected results. Standardized lists began to be published, and for those teachers who did use labs, another generation of standard labs was christened (National Research Council of the National Academies, 2006). In biology, what had been three separate courses – botany, zoology, and physiology – converged into one general biology course taken almost exclusively as a tenth grade subject (DeBoer, 1991). The diversity of organisms was studied inasmuch as they were useful to humans (e.g., yeasts were for creating bread), everyday analogies were used for all biological structures, and anthropomorphism was ubiquitous in nature studies (Atkin & Black, 2007; Rudolph, 2002).

Throughout the first decades of the twentieth century, school curriculum continued to be influenced more by the social sciences and less by the disciplinary experts, a movement that has come to be termed the Progressive Education Movement (DeBoer, 1991; Marsh & Willis, 2007). Where natural scientists played a large role in setting the science curriculum at the end of the nineteenth century, they had now become peripheral. According to Rudolph (2002), “The role of disciplined inquiry in the curriculum rapidly diminished, as did Dewey’s enthusiasm for the direction education was heading” (p. 21).

## *World War II and After (1940s – 1960s): Scientists Reform Curricula*

### *World War II*

In 1942, the United States government took control of an outdoor boys’ academy in the mountains near Santa Fe, New Mexico, transforming it into a top secret community of scientists and their families. There at Los Alamos, hundreds of physicists, chemists and engineers collaborated under the directorship of J. Robert Oppenheimer in a race to develop a nuclear bomb. The scientists successfully developed the weapons, which were dropped on Hiroshima and Nagasaki, Japan, in August 1945, hastening the war’s end and unleashing a physical force never before known. The nation stood in awe of the power of science. The scientists became national heroes, even as many of them realized the overwhelming destructive force of the bombs and advocated limitations on their use. Oppenheimer himself strongly lobbied for international rather than national control of nuclear technology (Bethe, 1997; J. Conant, 2005).

After the war, returning American GIs took advantage of government housing and education programs to work for the domestic dreams they had fought to secure. The ensuing baby boom soon filled the nation’s schools, straining their resources and facilities. Teachers were in short supply, and schools often resorted to hiring unqualified applicants. The child-centered, practical education approach that was prominent at the time drew fire from communities as it was often perceived as inadequate to prepare students for the competitive fields of more highly technical work ahead of them. Increasingly, local, state and federal tax levies were raised to help support schools. (President Truman even favored providing federal funds to schools, however that battle was lost in Congress.) Due to the tax issues, parents and communities engaged in education issues as never before (DeBoer, 1991; Marsh & Willis, 2007; Rudolph, 2002).

On an international level, the United States found itself in ever-increasing tension with the Soviet Union and the satellite countries under Stalin’s control. The announcement that the Soviets had tested their first nuclear weapon in August 1949 brought the conflict to a high pitch, with accounts of spies such as the Rosenbergs passing nuclear secrets to the Soviets fanning the flames of the Red Scare.  Scientists who worked at Los Alamos were under grave suspicion, tragically including Oppenheimer, with physicist Klaus Fuchs in the end being convicted of espionage, but not before Oppenheimer's national security clearance had been revoked (Bethe, 1997; J. Conant, 2005; Rudolph, 2002).  International tensions galvanized around ideological bearings: a contest between Soviet-dominated communism and American-style democracy. When mainland China came under the control of communism in late 1949, it seemed to Americans that conflict, with the expanding influence of communism, was unavoidable.  As President Truman declared in 1950, "The cause of freedom is being challenged throughout the world today by the forces of imperialistic communism" (as cited in Rudolph, 2002, p. 9).

The school curriculum became a tangible focal point upon which partisan ideological groups clashed.  According to Rudolph (2002), the curriculum battles tended to involve two camps:

> On the one side were the professional educators, who since the 1930s had secured the public school curriculum as part of their professional domain.  Adhering to the progressive-education-type philosophy that favored practical knowledge over academic subject matter, these educators disseminated a curricular approach that stressed education for life-adjustment for all students in the years after the war.  On the other side were the academic traditionalists, led by University of Illinois historian Arthur Bestor and his colleagues, who advocated just the opposite, a curriculum consisting of the long-established disciplinary subjects such as English, history, the sciences, and foreign languages. (p. 10)

Representing a commitment to education for *all* citizens, the U.S. Office of Education strongly advocated in the postwar years for a "life-adjustment curriculum," essentially an extension of the practically and socially-oriented curriculum developed in the early twentieth century (DeBoer, 1991).   The life-adjustment curriculum was characterized by a focus on democratic living, as well as personal and social development, with "almost complete abandonment of traditional subject matter" (DeBoer, 1991, p. 143).  Rudolph (2002) details how the curriculum was adjusted to include advances made by wartime psychologists who helped soldiers deal with the horrors and trauma of war.  Mental health campaigns in the military were comprised of films, books and pamphlets with such names as "Fear in Battle" or "How to Fight

Fear." Now in public schools, the focus was on more general problems, such as "How to succeed without bragging and to fail without making excuses" and "How to control and enjoy one's emotions" (Rudolph, 2002, p. 22).

Such "life-adjustment" programs came under intense fire by those advocating for a more rigorous engagement with subject disciplines, and were even seen as smacking of a communist, collective orientation. In the public battles that waged, the question became whether schools provided the necessary intellectual rigor to compete with the Soviet Union, and at the same time reinforced patriotism for American democracy (DeBoer, 1991; Marsh & Willis, 2007; National Research Council of the National Academies, 2006; Rudolph, 2002).

Meanwhile, scientists, and especially physicists, enjoyed an elevated status with the American public. As the atomic bomb had seemingly ended the war in the Pacific, the invention of radar was widely lauded as helping the Allies defeat the Germans. Other developments seen as contributing to the war effort included solid-fuel rockets, synthetic rubber, and the wide-scale production of penicillin. Science and technology had merged into a new social institution called research and development (R & D), and the new era was heralded as the "Age of Science" with the promise that science and technology would help solve the challenges of society (Aikenhead, 2005; J. Conant, 2005; Ramsey, 1996; Rudolph, 2002). President Roosevelt created several organizations during the war to coordinate funding for science and technology advancement, including the National Defense Research Committee and the Office of Scientific Research and Development (OSRD), the latter of which was intimately connected with the Manhattan Project at Los Alamos. The OSRD director, Vannevar Bush, was asked by Roosevelt to make recommendations for post-war efforts to further foster the government's commitment to science and technology. The report, *Science – The Endless Frontier,* delivered to President Truman in 1945, set forth a strong case for federal funding of scientific research and science education, indicating the nation would benefit from better health care, a more vigorous economy, and a stronger national defense (Kahle, 2007; Rudolph, 2002).

After five years of political negotiations, the National Science Foundation (NSF) was established in 1950 and assigned two broad missions: to support basic science research and to improve American science education (Atkin & Black, 2007). In 1952 the NSF awarded its first twenty-eight research grants with the $3.5 million Congress apportioned it (Rudolph, 2002). Between the NSF and the many federal departments with operational internal research programs, the federal government soon became one of the major sponsors of scientific research, a role previously held by private or public industrial interests (DeBoer, 1991; Rudolph, 2002). Within a few years, funding for science education accounted for nearly fifty percent of NSF's budget (Kahle, 2007).

While scientists were lured away from academia into the war effort and postwar government programs, the training of future scientists suffered. According to DeBoer (1991), "the number of Ph.D.'s granted in science dropped to 776 in 1945 compared to 1,900 in 1941" (p. 130). By the 1950s, "a growing number of scientists, science educators, and industry leaders began to argue that science education had lost its academic rigor and had become intellectually soft" (DeBoer, 2006a, p. 27). The status of teachers was low, salaries were meager, and there was a shortage of qualified science teachers. Opinions of teachers by scientists were also low: a survey of scientists in 1947 by the President's Scientific Research Board revealed that their impression of teachers was "that they themselves do not know enough about their subject; that they are pedagogically incompetent; that they are uninterested in their work and in the welfare of the students" (as cited in DeBoer, 1991, p. 134). The Soviet Union was investing heavily in science and technology in the postwar years, including in education, and many felt that for national security, the United States had to put greater efforts into training new scientists and improving science education (Atkin & Black, 2007; DeBoer, 1991; Rudolph, 2002).

Rudolph (2002) argues that a growing religiosity of Americans greatly affected scientists and education during this period. As the Red Scare intensified, the number of churches built exploded, with rapid growth in fundamentalist and evangelical denominations. While churches undoubtedly offered comfort at a time of great fear and uncertainty in society, attending church also overtly demonstrated one's patriotism and opposition to communist atheism. Congress reflected the public's mood in 1954 by adding the words "under God" to the pledge of allegiance, and in mandating the motto "In God We Trust" be marked on all U.S. currency (Rudolph, 2002). Secularism was often maligned as a move toward atheistic communism. For this reason, scientists who emphasized rationalism and secularism were suspect, often victims of outright hostility in attempts to undermine their professionalism and employment (Bethe, 1997; J. Conant, 2005; Rudolph, 2002). The climate was so hostile to scientists that in 1954, Vannevar Bush wrote a lengthy article in defense of scientists in the *New York Times Magazine* entitled "If We Alienate Our Scientists." Rather than having opinions based on hysteria, he argued, it was imperative that Americans see scientists as "partners in a great endeavor to preserve our freedoms" (as cited by Rudolph, 2002, p. 47). It became clear to many scientists that maintaining public sentiment in their favor was not only important for their immediate welfare, but also for the continued patronage of government funding and support for their research programs (DeBoer, 1991, 2006a; Rudolph, 2002). Further, many felt, like Dewey had decades earlier, that science was *the* means to learning rationality, open-mindedness, objectivity and independent thinking, and was a necessity in maintaining a democratic society (DeBoer, 2006a; Ramsey, 1996; Rudolph, 2002).

Faced with a diminished work force trained in science and technology, inadequate capacities for training new scientists, a wish to counter the irrationality of the day, and a desire to develop a public understanding for science – which was endemic to continued federal funding for research – the NSF turned its attention to science education reform (DeBoer, 1991; Lazarowitz, 2007; Rudolph, 2002). In 1955, the NSF program budget for science education was increased from $500,000 to $2 million, and in the following year increased to $10.9 million (Rudolph, 2002). Although strong concerns were voiced publicly about the federal government interfering with local and state governance of schools, the announcement in November 1955 that the Soviets had successfully detonated a hydrogen bomb underscored a sense of national crisis in science education. The NSF felt compelled to act (Marsh & Willis, 2007; National Academy of Sciences, 2007b).

As noted earlier, the low quality of trained teachers and the shortage of teachers being trained were identified as key problems in science education. Education programs and teaching colleges rarely had the funding or resources that other university programs had. Moreover, they were cited for lacking depth and intellectual rigor, instead consisting of required courses in educational methods rather than in the subject areas teachers would teach (DeBoer, 1991). To help bolster the education of its future workforce, industry had already begun investing in teacher training to improve the teaching of science, albeit with their own advertising included in educational materials. In 1945, General Electric (GE), for instance, established summer institutes for high school teachers to cover current topics in physics, and in 1949 Westinghouse started summer institutes in cooperation with faculty at MIT (Rudolph, 2002). University experts were also being asked to develop curriculum based on topics that corresponded more closely to ideas contemporary researchers found important. For instance, in the early 1950s, Max Beberman at the University of Illinois introduced a curriculum of "new" mathematics that included number theory and set theory (Atkin & Black, 2007).

The NSF also decided to focus on teachers already in the classroom and circumvent pre-service teacher training programs. First, it helped fund summer institutes offered to teachers across the country, offering ninety-one summer programs in 1957. Eventually, however, the NSF realized if it were to effect major reform in science education, it would have to focus directly on the curriculum experienced by students. The NSF turned its attention to drastically altering science curriculum to emphasize disciplinary rigor (DeBoer, 2006a; Rudolph, 2002). Scientists were determined to replace the applied, practical treatment of the sciences in the classroom with the cutting-edge science that had become so important for national security and economic development (National Research Council of the National Academies, 2006).

University scientists led numerous NSF-sponsored science curriculum reform efforts beginning in the late 1950s and continuing into the 1970s. These projects represent the largest intervention of university scientists in K-12 science education in the twentieth century. The development of the first two major curriculum reform projects supported by NSF are reviewed here: the first in physics due to the tremendous influence it had on subsequent curriculum reforms in the United States; and the second in biology because it illustrates important diversions from the first project, and because it is still widely used today. A third NSF-sponsored curriculum reform project in physics is reviewed as it presents an alternative viewpoint, and illustrates the on-going tension between emphasis in science curriculum on educating future scientists, and on educating all students for science literacy.

### *Physical Sciences Study Committee*

Leading with the thought that "science should be taught as it was practiced by scientists in order to give it the most authenticity possible" (DeBoer, 2006a, p. 27), the most accomplished scientists of the day were put in charge of the first curriculum project, the Physical Sciences Study Committee (PSSC). The initial project was revolutionary both in its development and product, and would become the template for all subsequent NSF-supported curricular projects. Chosen to lead the project was prominent physicist Jerrold Zacharias, who had extensive experience in MIT's Radiation Laboratory (Rad Lab) developing microwave radar, at Los Alamos as head the Ordnance Engineering Division (which later became Sandia National Laboratories), and as director of the Laboratory for Nuclear Science and Engineering at MIT (where he developed the cesium atomic clock) (Ramsey, 1996). He was a respected leader of intensive and successful collaborative initiatives, and appeared to be the perfect scientist to design an innovative new physics curriculum. In his wartime work, he was particularly successful at getting top-notch experts together, supplying them with a salary for an extended time so they could take leave of their regular duties, and setting them together on a common campus to maximize the formal and informal time they spent together collaborating. He employed systems thinking, focusing not just on the problem at hand, but taking into consideration adjacent technologies, applications, administrative structures, and social and political contexts to find the most effective ways of solving problems on a large yet relevant scale. He was familiar with the process of developing new technologies, including phases of research and prototype production and testing. He was also adept at securing the interest and support of Congress and the Eisenhower Administration (Rudolph, 2002). Zacharias brought all these skills and methods to bear in directing the first curriculum project NSF undertook, the PSSC, with an initial grant of $300,000. Expressing a long-standing commitment to education, he noted that “in order to save our democracy, we’ve got to educate the people who vote” (Ramsey, 1996, p. 143).

In the summer of 1957, Zacharias assembled nearly fifty university scientists and high school teachers at MIT, the institutional home for the PSSC, to work on the curriculum project, where “nearly all the PSSC participants and NSF administrators could trace their lineage back to the Rad Lab or Los Alamos” (Rudolph, 2002, p. 92). They had pointedly excluded many science educators, especially in education colleges, as they felt science curriculum needed to be decided by scientists themselves. The group concluded that the every-day applications in the current physics curriculum were outdated and were to be replaced with the latest physics theory. They thought that because most teachers were unfamiliar with and unable to teach these concepts, it would be imperative to create a curriculum composed of lessons and activities that anybody could deliver (Rudolph, 2002).

Based on the success of wartime propaganda campaigns, the PSSC decided to use the latest technology in film, and even consulted film industry experts such as Frank Capra and Walt Disney (Rudolph, 2002). One committee member claimed that “instructional films can do as good a job in this respect – if not better – than the average classroom teacher” (as cited in Rudolph, 2002, p. 96). They developed an extensive series of nearly sixty films with scientists demonstrating and exploring principles and concepts. Zacharias himself was featured in a number of them (Ramsey, 1996). To minimize any sense of awe and mysticism, and allow for the realism of a speaking human being, Zacharias insisted that the scientists speak the text themselves, rather than having a disembodied voice-over (which film experts advised would be easier to produce). The project members wished to counter their public image of scientists as eccentrics who were a bit crazed, potentially subversive, lost and alone in an ivory tower (Rudolph, 2002). Zacharias felt that to restore faith in scientists, the films should portray scientists as real people with occasional fallibilities. "The inevitable small blunders of hand and speech," he insisted, would be "humanizing" (as cited in Rudolph, 2002, p. 126).

The PSSC group felt that laboratory experiences were also critical for the students, especially to balance the passive activity of film-watching. They developed numerous labs for students to undertake, and ideally wanted students themselves to construct their equipment from inexpensive, readily-available materials. Upon field-testing, however, they learned that the extensive time it took students to construct their materials left little to no time to actually experiment. The PSSC group contented themselves with providing kits for classes. The labs were carefully coordinated with PSSC text, and were designed to give students a foundation of empirical observation, as well as to understand that there was a steady human interplay in science between theory and empirical testing (Ramsey, 1996; Rudolph, 2002).

Not long after the PSSC project was initiated, the Russian spacecraft *Sputnik II* launched in 1957, setting the nation on edge and heightening the sense of urgency in the science curriculum efforts. The NSF and the Alfred P. Sloan Foundation gave significant additional funding to the project. After a few short years of intense work, the PSSC physics course, designed by the scientific elite in the field, appeared in high school classrooms in the fall of 1960. With classic engineering design, Zacharias and his group developed a dissemination program for the curriculum, training a solid group of committed teachers in a summer institute, selecting twelve of those who wanted to teach it to others, and sending them out the following year to five summer institutes to train fifty teachers each. The subsequent summer, a larger contingent of trained teachers would teach in a larger number of summer institutes. This "highly efficient dissemination network … succeeded in reaching over half the physics teachers in the country by the late 1960s" (Rudolph, 2002, p. 173).

### *Biological Sciences Curriculum Study*

The PSSC physics curriculum would long be held up by NSF and others as the successful model and standard for all subsequent curricular reform. Yet even before the physics curriculum project was finished, the NSF turned its attention to developing curricula in other scientific disciplines. Biology was at the top of the list. Already in 1952, curriculum reform ideas in biology had been discussed in the National Academy of Sciences (NAS) Division of Biology and Agriculture. With funding beginning in 1958 from NSF and the Rockefeller Foundation, the NAS established the Committee on Educational Policies (CEP) to begin biology curriculum reform. The American Institute of Biological Sciences (AIBS) soon joined forces with them. Although the National Association of Biology Teachers (NABT) proposed an outline for such a curriculum, the NSF had no confidence in the rigor of their plan, and they were excluded from the new venture (Rudolph, 2002). With initial NSF funding of $143,200, the Biological Sciences Curriculum Study (BSCS) met for the first time in February 1959 in Boulder, Colorado, and soon followed the clear pattern established by the PSSC. The steering committee was composed of top scientists, led by zoologist Arnold Grobman and geneticist Bentley Glass, and the University of Colorado served as their institutional home. Various committees composed largely of biologists with some teachers were soon at work developing the many elements of the new curriculum. By 1963, they had received more than $6 million from NSF (Rudolph, 2002).

In response to criticisms that the older biology curriculum programs emphasized factual information, but gave little, if any, attention to underlying scientific principles, the committees of BSCS worked to develop broad-based, systemic reform involving content as well as the entire teaching-learning process. Scientific inquiry would be the model for classroom teaching and learning, much like that of the PSSC. The daily classroom lessons integrated traditional lab activities with "lab blocks" that sustained lab activity for five to six weeks (DeBoer, 1991, 2006a). Also in similar fashion to the PSSC, the BSCS created a comprehensive film series to serve three functions: 1) to present concepts and themes by scientists in an efficient and expert way; 2) to demonstrate important lab procedures to students and teachers (whom the BSCS assumed had little experience with such work); and 3) to describe the history and philosophy of the BSCS program (Rudolph, 2002).

The textbook itself would serve as the central guide of the program, yet this element of the project proved particularly confounding. Due to the wide diversity and disciplinary fragmentation of biology as a field, it was difficult to agree on a unifying theme (Rudolph, 2002). To complicate matters, recent advances in chemistry and physics precipitated major advances in each of the biology subfields, adding complexity and sophistication to their diversity (Lazarowitz, 2007). For instance, the ability to work with labeled atoms (isotopes) led to advances in following the path of carbon in photosynthesis, the metabolic paths of proteins, amino acids, sugars and fats, and the physiological processes within cells at the molecular level. The development of the electron microscope led to the proposal of the model of DNA. In ecology, sophisticated mathematical applications added new dimensions to field studies. The goal of finding a unifying theme in biology proved particularly elusive (Lazarowitz, 2007).

In the end, the BSCS resolved the issue by producing three independent textbook versions, each with a different emphasis. The Yellow Version emphasized developmental and evolutionary aspects of biology, and was the one most readily adopted by schools and teachers. The Blue Version emphasized molecular biology, and was perhaps the most revolutionary at that time. The Green Version emphasized ecology, and was primarily adopted by rural schools (Lazarowitz, 2007; Schwab, 1963). Being sensitive to concerns about not establishing a national curriculum, the NSF was supportive of the different versions the BSCS offered, as the three versions supplied teachers and schools with distinct choices for best serving their needs (Kahle, 2007; Rudolph, 2002).

Despite the disciplinary subdivision, committee members agreed that all three versions should be united in a common foundational view of biology, with two crosscutting themes, termed the “warp and woof” of biology (Schwab, 1963, p.32). The seven levels of biological organization were: molecular, cellular, tissue and organ, organism, population, community and biome. Intertwined with those were the unifying themes in biology:

1. Change of living things through time: evolution
2. Diversity of type and unity of pattern in living things
3. The genetic continuity of life
4. The complementarity of organism and environment
5. The biological roots of behavior
6. The complementarity of structure and function
7. Regulation and homeostasis: preservation of life in the face of change
8. Science as inquiry

9. The history of biological conceptions (Schwab, 1963, p. 31)

The emphasis placed on these themes was a departure from how biology had been typically taught in high schools, where health, physiology, and sometimes taxonomy, were favorites. Biology was also particularly vulnerable to influences from the general public, with controversial flashpoints such as human reproduction, evolution, and the use of live animals in the laboratory. The BSCS decided to confront these issues head on (Kahle, 2007; Rudolph, 2002). According to meeting minutes, one of the prominent members of the Steering Committee, Joseph Schwab, insisted that they "should not talk about what the schools want to do. As scientists our function should be to promulgate the ideas and concepts of our profession" (as cited in Rudolph, 2002, p. 145). A field test in Dade County Florida was stopped because the books contained diagrams of the human reproduction system. The BSCS refused to remove them (Kahle, 2007).

Evolution, however, stood as the flagship theme for biologists in combating irrationality and demonstrating the dangers of ideology. The union of theoretical evolutionary biology with advances in molecular genetics, termed "the modern synthesis," offered biologists greater rigor and explanatory power in demonstrating the unity of all living things. The Soviet Union, however, was officially opposed to the theory of evolution, declaring its incompatibility with the ideology of collectivism. Soviet geneticists were imprisoned and even executed, proving to American biologists the dangers of ideologies dictating science. Rather, the BSCS underscored the rational and empirical nature of science, including the theory of evolution, as free of ideology. This point was important in relation to domestic influences too. The subject was controversial enough in the United States due to religious reasons that, according to Rudolph (2002), half the teachers in the country at the time didn't teach it; and the majority of biology textbooks at the time failed to even use the term "evolution." It is not surprising, then, that the state Boards of Education in both Texas and New Mexico protested the inclusion of evolution in this new curriculum. However, the BSCS refused to remove the theme, and the curriculum was eventually included on their state adoption lists (Rudolph, 2002).

In contrast to the PSSC approach, the BSCS curriculum explicitly tied advances in the biological sciences to everyday applications, including the growing technology and industrialization of society, the deterioration of natural resources, pollution, radiation effects, agricultural industrialization, medical advances, and population growth. Rudolph (2002) argues that the reasons for this approach were that biologists were attempting to establish their discipline's importance and relevance to society (physics was by far most noted for techniques in winning the war and in advancing society), and to show the critical need for understanding biology in the management of public affairs. Further, because biologists received less federal funding than physicists or chemists, they were especially vulnerable to the public's understanding of their discipline and appreciation of it. Education was the best way to influence the values of society (DeBoer, 1991; National Academy of Sciences, 2007b).

That said, the way science was practiced by cutting edge biologists was meant to be depicted as much as possible, and the curriculum moved starkly away from descriptive biology toward experimental biology and post-war technology. The film series treated topics such as the isolation, purification, and identification of organic compounds, the effects of radiation on chromosomes, and nuclear transplantation in frogs (Rudolph, 2002). And now, rather than presenting science as a static body of facts to be learned and memorized, the BSCS, according to its Statement of Objectives, aimed to impart a sense of science as "an open-ended (ever expanding) intellectual activity and what is presently 'known' or believed is subject to 'change without notice'; that the scientist in his work strives to be honest, exact, and (part of a community) devoted to the pursuit of truth; that his methods are increasingly exact and the procedures themselves are increasingly self-correcting" (as cited in Rudolph, 2002, pp. 159-160).

As in the PSSC project, the BSCS curriculum centrally featured inquiry methods. Joseph Schwab, a member of the Steering Committee, shaped the BSCS inquiry approach. Schwab earned his Ph.D. in genetics, and served as an instructor in the University of Chicago's undergraduate general education program. His academic career focused on the central role of inquiry in the activities of science, and the role of science in education. His view of inquiry in science education was not constrained to lab experiences, although he firmly believed that hands-on activities were a necessary component. Schwab's unique and main thrust was to show science as a work-in-progress: Thought exercises, critical review of papers, discussion, tracing the history of scientific ideas, as well as lab, were all part of inquiry (DeBoer, 2006a). He stressed that science is filled with tentative conclusions, things unknown, and processes of investigation. Schwab, who prepared the BSCS companion handbook for teachers, explained that language used throughout the BSCS texts, such as "we do not know," or "we have been unable to discover how this happens," or "the evidence about this is contradictory" (1963, p. 40) most honestly related the open-ended nature of biological inquiry. Some of the films the BSCS developed were intended to run first for four or five minutes, presenting students with visual data, then the film was stopped so the class could discuss various interpretations and hypotheses before the film started again. Schwab's direct contributions of the "Invitations to Enquiry" components of the curriculum consisted of themes presented by the teacher with background and some data or other information. Students then engaged in analyzing the situation, with the teacher following up with "diagnostic questions" aimed at guiding the students to more logical responses (Schwab, 1963).

The three versions of the BSCS curriculum were officially released in the fall of 1963, and have been subsequently revised to the present day. Universities across the country hosted summer institutes where teachers were trained, and of all the NSF-sponsored science curricula, BSCS was the most widely adopted. Thirteen years later, in the 1976-1977 school year, 49 percent of surveyed school districts were using some form of the BSCS curriculum (DeBoer, 1991).

***Bruner's Discovery Learning***

Shortly after the BSCS project began, the NAS Advisory Board on Education pulled together scientific experts working on all the science curriculum reform efforts, as well as psychologists, anthropologists and other social scientists in a ten-day meeting in September 1959 at Woods Hole, Massachusetts, to take stock of the reforms underway, (DeBoer, 1991; Rudolph, 2002). Harvard cognitive psychologist Jerome Bruner, a veteran of the Psychological Warfare Division of the Office of War Information, led the Woods Hole Conference, as it came to be known (though officially it was the "Study Group on Fundamental Processes in Education"). He noted in a pre-conference memorandum that "it is worth drawing a parallel … to the experience of psychologists working in the armed forces at the beginning of World War II" (as cited in Rudolph, 2002, p. 98), and he called for application of a systems theory approach to address education reform. Rudolph (2002) argues that these curricular reforms bore the heavy influence of military thinking, again citing Bruner in a memo: "We introduced this subject for discussion today by suggesting the analogy to a weapon system – proposing that the teacher, the book, the laboratory, the teaching machine, the film, and the organization of the craft might serve together to form a balanced teaching system" (p. 99).

The conference report written by Bruner (1960), however, also outlines cognitive theory that, in addition to Schwab's work with the BSCS, helped support the NSF-sponsored reforms theoretically. Bruner argued that discovery or inductive learning was a potentially valuable way to teach fundamental ideas of a field, and suggested that students are naturally active problem-solvers, ready and motivated by a native curiosity in the world around them. He also introduced the idea of disciplinary structure as the fundamental principles of a field and the relationships among those principles, and elaborated significantly on this point. Students could only learn and remember ideas and concepts if they could organize it cognitively within a "structure." Scientists, argued Bruner, were the experts in understanding their disciplinary structure, and therefore should dictate the content and processes of the different curricula (Bruner, 1960). In essence, his argument was that the discipline was the pedagogy. Yet he distinguished between analytical and intuitive thought, and emphasized that although education tended to focus more on the former, most scientists relied heavily on the latter. In order to be able to bring intuitive thought to bear, one had to understand how ideas were structured in a particular discipline. Through his report, Bruner also introduced to an American audience the theory of stages of cognitive development proposed by Swiss psychologist Jean Piaget. Bruner applied these principles to science teaching in the classroom, noting that basic ideas of any field can be introduced to children at an early age, "provided that they are divorced from their mathematical expression and studied through materials that the child can handle himself" (Bruner, 1960, p. 43). The subject matter should then be presented to students repeatedly in later years as appropriate to their advancing stages of cognitive development, constituting what he called "the spiral curriculum" (Bruner, 1960; DeBoer, 1991).

Another important development in the NSF curricula reforms was the proposal of the "learning cycle", which included the *exploration* of a concept (often through lab experiences), *invention* of the concept (often through discussion of lab findings), and *discovery* or application of the concept (Atkin & Karplus, 1962), which was later adapted to the BSCS 5E model (*engagement, exploration, explanation, elaboration,* and *evaluation*) still used today (Bybee et al., 2006).

### *Harvard Project Physics*

The early NSF curricula reforms largely adopted a "science for scientists approach" (Duschl, 2006, p. 320). While hands-on experiences and inquiry were stressed, each field was largely given to educate students in the practice and knowledge of the particular science discipline. Much of the focus was on moving students through "the pipeline" into the science and technology work force, an ideology that Aikenhead argues guides and sustains school science today (2005). However, another perspective that influenced certain post-World War II reform efforts was the post-structuralist analysis of science itself that "tended to challenge the positivism and realism inherent in traditional science courses" (Aikenhead, 2005, p. 884), and that was often associated with Thomas Kuhn (1962). Duschl (2006) describes that:

> …[T]he development of Thomas Kuhn's ideas about paradigms, incommensurability and about science shifting between normal and revolutionary periods of inquiry occurred while he was working on a science education curriculum development project. Namely, *The Harvard Case Studies in Science Education* (J. B. Conant & Nash, 1957a, 1957b), directed by James Conant, then president of Harvard University. The spirit of science education at Harvard at the time is perhaps demonstrated by the fact that it was while engaged in the preparation of materials for a case study that Thomas Kuhn began to develop the ideas for this seminal work *The Structure of Scientific Revolutions.* (p. 320)

The Harvard case studies were developed by scholars in science education and history of science for the purpose of providing an alternative yet meaningful science education for non-major undergraduate students (J. B. Conant & Nash, 1957a, 1957b). This Harvard group had serious concerns with the "science for scientists approach" that the PSSC curriculum group at MIT had adopted for high school curriculum reform (Duschl, 2006, p. 320). Criticisms of the PSSC curriculum centered on the dominance of the scientific method rooted in experimentation rather than educational theory. The Harvard group advocated an interdisciplinary approach, "for an integration of philosophy, logic, statistics, and psychology frameworks that would inform the scientific knowledge and processes being packaged into PSSC and other NSF curriculum efforts. A particularly poignant issue was whether the teaching of the scientific method by getting students to operate as scientists was a significant educational objective" (Duschl, 2006, p. 322). The Harvard group proposed an alternative physics curriculum with a humanistic perspective, and received funding from NSF to develop what became Harvard Project Physics. This curriculum project, based on a historical and philosophical perspective on physics, was aimed at boosting student enrollment in high school physics by appealing to a broader audience.

Aikenhead argues it was “probably the most influential science education project to emerge from Harvard … [and] it stimulated many other humanistic curriculum innovations worldwide” (Aikenhead, 2007, p. 884).

### *Summary of Post-World War II Curricular Reform*

Several other science curriculum reform projects were sponsored by NSF, including others in physics, chemistry, earth science, physical sciences, environmental education, and general science, extending into junior high and elementary levels. The NSF eventually invested hundreds of millions of dollars (Shymansky, W.C. Kyle, & Alport, 1983). In fact, by 1966, there were 26 projects underwritten by NSF, 19 in science and 7 in math (Duschl, 2006). NSF did not endorse any specific curriculum, hoping that by supporting several choices they might avoid accusations of sponsoring a national curriculum. All the same, some had that impression, such as when Senator Gordon Allott from Colorado warned, “I don’t want these things rammed down the throat of educators” (as cited in Kahle, 2007, p. 917).

Numerous studies were conducted to assess the value and impact of the NSF-sponsored post-World War II curricula. Although some reports were contradictory, the meta-analyses conducted reported generally improved student performance in science achievement, process skills, problem solving and attitude through the NSF curricula compared to traditional curricula (Kahle, 2007; Shymansky, Hedges, & Woodworth, 1990; Shymansky et al., 1983). And yet, implementation was beset by hurdles, including district budget constraints for purchasing materials and training teachers, resistance from teachers, and resistance from communities. The attempts at “teacher-proofing” the curricula by providing detailed texts with scripts, teacher guides, and films and filmstrips to ensure the faithful execution of the curriculum contributed to teacher resistance (National Research Council of the National Academies, 2006). The inclusion of evolution in the biology curriculum elicited a backlash of local opposition across the country, with complaints that the curriculum was godless. These concerns reached Congress, contributing to a drop in federal funding (National Academy of Sciences, 2007b). Some also attribute the decline in funding to the perception that the work in influencing science education and appreciation had been completely accomplished, underscored by the successful Apollo missions and moon landings that defined the United States as the leader in space (Atkin & Black, 2007; National Research Council of the National Academies, 2006). The bottom line was that by 1970, U.S. students were performing well internationally, the sense of national crisis had abated, and funding for national curriculum efforts rapidly declined (Shymansky et al., 1983).

The NSF-sponsored science curricula developed during this time represented the most dramatic investment in science education ever seen in the United States, and they influenced curriculum reform in other subjects. The legacy of inquiry methods as the preferred pedagogy to teach the nature of science is very much alive today. The interdependence and tensions between scientists and teachers are still present. Controversies such as those of evolution and human reproduction continue to be lightning rods in curricula, and the tension between federal leadership in education and local funding and legal responsibility also have their modern incarnations. The role of teaching science in societal contexts versus as disciplinary training is still hotly debated. Yet all together, these science education initiatives invigorated a generation of science teachers, bringing them up to date with scientific developments and closer to science research and researchers. Perhaps the two most enduring outcomes were the development of a network of peers among teachers, and defining science education leaders who would be effective for decades to come (Kahle, 2007).

### *Standards-Based Reforms*

By the 1970s, new curriculum priorities emerged that moved educators away from relying on research scientists for leadership. The percentage of students completing four years of high school jumped from 25 percent in 1939 to 75 percent in 1970 (Atkin & Black, 2007). The civil rights movement and equal rights movement meant schools were one of the primary proving grounds of inclusion and integration. Historical inequalities based on race, ethnic background, gender, socio-economic status, and disabilities had become priorities to address in schools. The Supreme Court's decision in Brown v. Board of Education in 1954, and Title I of the Elementary and Secondary Education Act of 1965 targeting federal funds to students from low-income families, were part of the movement to equalize education opportunities (Tyack & Cuban, 1995). The growing unpopularity of the Vietnam War on top of the social upheavals in American society aroused discontent and frustration with many facets of society, with frequent violent outbursts during demonstrations. The Watergate scandal that eventually led to President Nixon's resignation added further cynicism to authority. DeBoer (1991) states:

> Given the social atmosphere of the late 1960s and early 1970s, the calls for intellectual rigor, for excellence, and for disciplinary study that had been made little more than a decade earlier sounded strangely anachronistic. Many educators who had been skeptical of the curriculum reformers' emphasis on the structure of the disciplines were quick to point to the failure of these courses to meet the new challenges of education. The new need was for an enlightened citizenry, not an educational elite. To these critics, the science curriculum should be relevant to the lives of a broad range of students, not just those planning careers in science, and the methods of instruction should demonstrate a concern for the differences in ability and interest of each individual student. (pp. 173-174)

Inclusion of diversity became a central focus of education, and greater curricular attention was given to student interest and social relevance, hearkening back to the progressivism of the first half of the century. This "new progressivism" resulted in practices such as open classrooms and elective courses for students (Marsh & Willis, 2007). The terms in science education that referred to educating not just the future scientist, but all students in science, were "scientific literacy" and "science for all." These themes were represented in the programs developed then in environmental education, humanistic education, values education, and the science-technology-society (STS) movement (DeBoer, 1991, 2006a, 2006b). Further, the United States found itself in difficult financial times, straining education funding, especially compared to Japan and other Pacific Rim countries that were thriving.

In 1979, Congress created a cabinet level office for the United States Department of Education with Democratic support and Republican opposition, and with President Carter signing the bill into law. The purposes of the new Department of Education were to organize federal funding programs for educational purposes, and to enforce federal laws regarding privacy and civil rights in education. One of the campaign promises of the 1980 Republican presidential candidate, Ronald Reagan, was to abolish the Department of Education, declaring it a federal intrusion on states' rights to determine educational policy. President Reagan was elected, and after being inaugurated in January 1981, he appointed Secretary of Education Terrel Bell, who immediately created the National Commission on Excellence in Education (NCEE) to examine the quality of education in America. The NCEE report released in April 1983 created such a firestorm of public reaction that Reagan embraced the report and cast himself as an education reformer, revising his plans to close the Department of Education (Marsh & Willis, 2007).

The report, *A Nation at Risk: The Imperative for Educational Reform* (National Commission on Excellence in Education, 1983), was released in an environment of perceived test score declines in America. It used crisis language, perhaps trying to recreate the same sense of urgency the Cold War and launch of *Sputnik* had created decades earlier (Marsh & Willis, 2007; Tyack & Cuban, 1995). The report recommended mobilizing the federal, state and local governments to raise the academic performance of American students in all areas, but especially focused on math and science. It opens with these words:

> Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world…. [T]he educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people…. If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. … We have, in effect, been committing an act of unthinking, unilateral educational disarmament. (National Commission on Excellence in Education, 1983, p. 5)

This report has since been soundly criticized for being based on poor statistical analysis and being politically motivated (Carson, Huelskamp, & Woodall, 1993; Stedman, 1994; Tyack & Cuban, 1995). It was effective, however, in grabbing the attention of educators, lawmakers and communities across the nation, and initiating the movement toward educational accountability for all students through standards. The report argued that neither mediocrity nor elitism was acceptable. It identified the "new basics," and made specific recommendations for the number of years high school students should learn English, math, science, social studies, computer science, and foreign language. It recommended that "schools, colleges, and universities adopt more rigorous and measurable standards, and higher expectations for academic performance and student conduct, and that 4-year colleges and universities raise their requirements for admission" (National Commission on Excellence in Education, 1983, p. 27). Specific recommendations were made that three years of secondary science education be required, and that it provide students an introduction to concepts, laws and processes of the sciences, to the methods of scientific inquiry and reasoning, to the application of science knowledge to everyday life, and to the social and environmental implications of scientific and technological development (National Commission on Excellence in Education, 1983, p. 25).

The Commission of Precollege Education in Mathematics, Science and Technology of the National Science Board, an advisory board to the NSF, issued a similar report five months later, echoing many of the ideas in *A Nation at Risk* (DeBoer, 2006b). The recommended strategy to address math, science and technology education essentially involved increasing student exposure to science, establishing national goals, and establishing a system to measure local accomplishment of those goals. At the same time, the commission was careful to emphasize its recommendations were not just for the intellectual elite, but for *all* students (DeBoer, 2006b).

Numerous other reports were issued throughout the 1980s, though none were more influential than *A Nation at Risk*, as it was strategically released through a media blitz, and was written not only to Secretary Bell, but intentionally as an open letter to the American people. Subsequent reports, according to DeBoer (2006b), "simply lamented the poor performance of United States students on national and international tests, especially in mathematics and science, and continued to link the nation's economic problems to the poor quality of the educational system" (p. 15). State legislatures and departments of education did adopt reforms in the structure of schooling, such as extending the school day and year, increasing graduation requirements, including more science courses, and increasing student testing and school assessments (DeBoer, 2006b).

An in-depth and comprehensive response to *A Nation at Risk* regarding science came from the American Association for the Advancement of Science (AAAS) through the establishment of Project 2061. Initiated in 1985, Project 2061 "is a long-term initiative of the AAAS to reform K-12 education in natural and social science, mathematics, and technology … [and] is developing a set of tools to help local, state, and national educators redesign curriculum in these areas and ensure its success" (American Association for the Advancement of Science, 1990, inside cover). Project 2061 was so named as that is the year Halley's Comet is due to return to the Earth's sky, returning after its last appearance in 1986. The project's long-term goals are to release several publications identifying national goals to inspire local implementation for science education reform. Its first publication in 1990, *Science for All Americans* (American Association for the Advancement of Science), represents a consensus view of what the scientific community thought was important for all students to know in science, math and technology upon leaving high school. In so doing, it gave structure and content to the concept of science literacy, addressing the nature of science, basic knowledge about the world from the perspective of science, history of science, and the "habits of mind" essential for science literacy. The report incorporated the most current research-based learning theory to inform its pedagogical recommendations and discussed educational reform with respect to the uniquely American tradition of local and state responsibility for implementation. The report read as a narrative and did not lay out grade-by-grade standards or benchmarks. DeBoer (2006b) lauds the report:

> In contrast to many of the reports produced during the 1980s, *Science for All Americans* did not propose a get-tough approach or that schools should teach *more* science content. Instead, it suggested that schools should focus on what is essential for science literacy – a common core of ideas and skills that have the greatest scientific, educational, and personal significance – and should teach that science better and for deeper understanding. (p. 16)

The strategy of national goal setting with decentralized implementation proved successful on many educational fronts. President George H.W. Bush met with state governors at the 1989 National Governors' Conference to discuss a national agenda for education. They agreed to establish clear national performance goals and a system of accountability for annual reporting of schools and districts in their progress toward meeting those goals. The states also secured greater use of federal resources to meet those goals. These agreements were articulated in the report released by President Bush in 1991, *America 2000: An Education Strategy* (U.S. Department of Education), which described a strategy to move the country toward the six national goals forged in the National Governors' Conference to be accomplished by the year 2000:

1. All children in America will start school ready to learn.
2. The high school graduation rate will increase to at least 90 percent.

3. American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.
4. U.S. Students will be first in the world in science and mathematics achievement.
5. Every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
6. Every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning. (U.S. Department of Education, 1991, p. 19)

The strategy for accomplishing these goals entailed developing an accountability package of national standards, national tests, reporting mechanisms and various incentives to encourage schools to measure and compare results and effect change when results were poor. President Bush also encouraged the development of national standards and goals in each subject area, and specifically used the AAAS project as a model (DeBoer, 2006b; U.S. Department of Education, 1991).

Since 1989, AAAS had been engaged, as part of the work on Project 2061, in developing maps of the knowledge and experiences a student had to have in grades K-12 to achieve the science literacy goals in *Science for All Americans*. The initial purpose of these strands or maps, asserts DeBoer (2006b), was to serve as “an internal document that would aid the curriculum development teams in their work” (p. 22). With President Bush’s push for national standards in each of the core subject areas and his specific recognition of the AAAS efforts, the focus of the Project 2061 group shifted to transforming these maps into benchmarks. By 1993, that work was complete and *Benchmarks for Science Literacy* (American Association for the Advancement of Science) was released, becoming completely identified with the standards movement, and forming a model standards document for a nation that “was poised to receive national standards” (DeBoer, 2006b, p. 23).

For educators, it must have been eerily reminiscent of the postwar science education reform movement to have the current reform being led by scientists in the AAAS. According to Collins (1998), the National Science Teachers Association (NSTA, the largest organization of science teachers in the country) appealed to the President of the National Academy of Sciences (NAS), as representing a prestigious neutral organization, to coordinate the development of science education standards, utilizing the expertise and experience of *both* the AAAS and the NSTA. In 1991, the Department of Education and the NSF agreed to fund the National Research Council (NRC), the operating arm of the NAS, to create national standards in science, and the advisory board for the project included representatives of both NSTA and AAAS (Collins, 1998). Five years later, after involvement by hundreds of people, "including teachers, school administrators, parents, curriculum developers, college faculty and administrators, scientists, engineers, and government officials," the *National Science Education Standards* (NSES) were published in 1996 (National Research Council of the National Academies, , p. 3). The document states:

> The *National Science Education Standards* present a vision of a scientifically literate populace. They outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels. They describe an educational system in which all students demonstrate high levels of performance, in which teachers are empowered to make the decisions essential for effective learning, in which interlocking communities of teachers and students are focused on learning science, and in which supportive educational programs and systems nurture achievement. (p. 2)

Indeed, the NSES offered not only content standards for students at particular grade levels, but they identified standards for teaching, for professional development for science teachers, for assessment in science education, for science education programs, and for science education systems, underscoring the importance of reform at iterative systemic levels. The importance of including multiple levels signaled the importance of teachers working within the context of school and community support. The document incorporated the ideals of standards of excellence for all students, as well as the emphasis on inquiry methods of teaching (though not as a single approach to teaching) (National Research Council of the National Academies, 1996).

It is thought provoking to ponder what would have happened to science education had the element of high-stakes testing not been attached to educational standards in America. As it was, the political wind was blowing toward accountability, and as the federal government had its hands tied as far as setting a national curriculum was concerned, it used funding as the carrot and stick to effect changes.

President Bush was unable to enact the specific proposals outlined in *America 2000* as he was defeated by Bill Clinton in the 1992 presidential election. Yet, as former governor of Arkansas, President Clinton had participated in the National Governors' Conference of 1989 and had agreed to the goals set forth there. When he took office in 1989, the Democratic Congress recast Bush's educational agenda and passed the Goals 2000: Educate America Act, which President Clinton signed into law in 1994 (DeBoer, 2006b). Also in 1994, he signed the Improving America's Schools Act (IASA), which reauthorized President Johnson's original Elementary and Secondary Education Act from 1965, with the additions that states were now mandated to:

1. Develop challenging content standards for math and language arts.
2. Develop performance standards for those content standards.
3. Develop and implement assessments aligned with the content and performance standards in at least math and language arts at grade spans third through fifth, sixth through ninth, and tenth through twelfth.
4. Use the same standards and assessment system to measure Title I students as the state uses to measure the performance of all other students.
5. Use performance standards to establish a benchmark for improvement referred to as *adequate yearly progress*. (DeBoer, 2006b, p. 26)

One can easily see here the roots of the No Child Left Behind Act of 2001 (NCLB), signed into law on January 8, 2002, by President George W. Bush. This bill again extended and revised the Elementary and Secondary Education Act of 1965, changing the legislation from 1994 to emphasize even greater public accountability with funding tied ever more directly to meeting standards (DeBoer, 2006b; Marsh & Willis, 2007). The NCLB legislation required states to create standards and assessment systems aligned with these standards to track student achievement in the state. By 2005-2006, states were required to test students annually in reading and mathematics between grades 3 and 8, and at least once in the span from grades 10 through 12. By 2007-2008, the subject of science was added to testing mandates, though government incentives applied only to math and literacy test scores. National assessments of grades four and eight were mandated to be administered every two years in math and reading to make national comparisons. As a signifier of federal control through education reform, states failing to comply with NCLB would lose federal financial aid, not just in education but in areas of highway construction and maintenance, as Vermont discovered before complying (Marsh & Willis, 2007).

One of the stated goals of NCLB is to raise reading and math proficiency to 100% for all students in the country by 2014, and NCLB requires schools to make *adequate yearly progress* (AYP) toward meeting these goals. Schools that fail to make AYP remain eligible for federal aid for two years, but after three years are subject to sanctions, including allowing students to transfer to another school (reducing school population and thus funding), staff changes, or a private or state takeover of a failing school (DeBoer, 2006b; Marsh & Willis, 2007).

The impact NCLB has had on science education has been enormous. Although gains have been made in closing the achievement gaps in reading and math of under-achieving groups such as minorities, the high-priority focus on these two subjects has severely reduced instructional time for subjects such as science, and has even precipitated complete removal of science programs from some elementary and middle school curricula (Griffith & Scharmann, 2008; Southerland, Smith, Sowell, & Kittleson, 2007; Taylor et al., 2008). The degradation in science education may be alleviated somewhat as science testing has been mandatory since 2008. Further, NCLB mandated the involvement of scientists and mathematicians from colleges and universities in K-12 education through the Math and Science Partnership program (U.S. Department of Education, n.d.). Teachers, however, continue to report that state science standardized tests require teaching to lower-level science knowledge (Southerland et al., 2007; Taylor et al., 2008). Although the *National Science Education Standards* outlined several types of standards, such as teaching, professional development, assessment, programmatic, and systemic standards, the only standards that have accountability attached to them are content standards (most states have aligned their content standards to those of the NSES). The NSES based their pedagogical recommendations on the best research in learning theory, yet the pressures of NCLB, both perceived and real, render many of these methods, including inquiry, difficult to implement (Marsh & Willis, 2007; Southerland et al., 2007; Taylor et al., 2008).

Meanwhile, the science curriculum itself changed. As illustrated by the publication of *Science for All Americans* (American Association for the Advancement of Science, 1990), the late 1980s and early 1990s saw a resurgence of emphasizing science education in the context of real-world applications and problem solving, often termed a Science-Technology-Society (STS) approach (Aikenhead, 2005). However, the trend toward increased computer technology education not only subsumed the practical industrial arts subjects, but also the technology context of science education. Computer science became its own discipline taught in high schools, with school districts investing great sums of money toward the goal of computer literacy for all students. By the late 1990s, STS approaches lost their momentum as science and technology largely became different curricular strands in schools. School science program budgets continued to shrink; and with the emphasis of content knowledge in state assessments, curricula shifted away from teaching science through real-world applications and toward lists of concepts in science disciplinary strands (Fensham, 2009; Taylor et al., 2008).

### *The Twenty-First Century*

Learning science in consideration of the workplace and national economy is not a new idea, but it has taken on new meaning in a new century characterized by increasing science and technology fields, increased globalization, and growing health and national security issues. In a new call for reform in science and technology education, Bybee & Fuchs (2006) reference familiar ground:

> While some express the fear that 'a new Sputnik' may be required to move the nation to action, we argue that we must not wait for such an event. It is important that the science education community recognizes the contemporary situation – the United States is in danger of losing its competitive edge in the global economy. (p. 349)

Bybee and Fuchs make a compelling argument. They note the different global environment than existed at the time of Sputnik, and admit that "the metaphor of competition is not entirely appropriate…. Nevertheless, to take advantage of the opportunities that will arise, our workforce will need the proper skill set" (pp. 349-350).

In 2007, the National Academy of Sciences released the influential report, *Rising Above the Gathering Storm* (National Academy of Sciences, 2007a), also warning that the United States risked losing its competitive edge in the global marketplace. Emphasizing the economic future of the U.S., the report made recommendations to improve and develop the workforce pipeline for the twenty first century in science, engineering and technology, which include: recruiting 10,000 science and math teachers annually by providing scholarships; strengthening teacher skills through professional development programs; and increasing the number of students who pass Advanced Placement (AP) and International Baccalaureate (IB) high school courses (National Academy of Sciences, 2007a).

Ironically, such calls for developing “twenty-first century skills” for workforce development take place in the context of increased standards and assessments which effectively narrowed the K-12 science curriculum to largely canonical content on which students are assessed, and marginalized science education all together – especially in the early grades (Griffith & Scharmann, 2008; Southerland et al., 2007; Taylor et al., 2008). In this cultural milieu, professional and business leaders increasingly weigh in on the debate for workforce development, emphasizing their interests in developing a meaningful workforce, with offers for support and partnerships with schools (Aikenhead, 2005; Bybee, McCrae, & Laurie, 2009; Fensham, 2009; S. P. Marshall et al., 2003; Millar, 2006; National Academy of Sciences, 2007a; National Research Council, 2010; Osborne, 2007).

Exactly how “twenty-first century skills” in science are defined is variable, yet the concept is rooted in definitions of science literacy and the familiar tension between science education to train future scientists, and science education for all students. (Fensham, 2009; Millar, 2006; National Research Council, 2010; Roberts, 2007; Shamos, 1995). Issues of teaching science to a diverse population are increasingly raised, not only to educate those who will not pursue science as a career but also to encourage students who might not otherwise be interested in science to pursue the subject. This includes members of groups under-represented in science, such as women, minorities, those with low socio-economic status, and students without family members having attended college (Lazarowitz, 2007; Lee & Luykx, 2007).

Aikenhead (2007) sees the revival of a humanistic approach to science curriculum in these calls for a twenty-first century science curriculum. He argues that the traditional science curriculum dominated by instruction and assessment in canonical knowledge can be blamed for the chronic decline in student enrollment in science, the loss of interest of strong science students to enroll in more than the required science courses, and students who are illiterate with respect to the nature and social aspects of science.

Similarly, Jonathan Osborne (2007) points out the weaknesses in "science education as practiced" by listing a set of fallacies promulgated in science education:

1. *The foundational fallacy*: the belief that student knowledge and understanding are assembled fact by fact while overlooking the big pictures and narratives
2. *The fallacy of coverage*: the belief that students must understand many concepts from all major scientific fields, rather than choosing exemplar samples
3. *The fallacy of a detached science*: the belief that science is an objective, detached and value-free enterprise
4. *The fallacy of critical thinking*: the belief that the study of science automatically confers critical thinking skills that can be transferred to other subjects of study
5. *The fallacy of the scientific method*: the myth that there exists a singular scientific method
6. *The fallacy of utility*: the myth that scientific knowledge has personal utility, especially in the mastery of technology use
7. *The homogeneous fallacy*: the assumption that one curriculum can serve all students best. (pp. 174-176)

Osborne (2007) calls for a twenty-first century science curriculum that can "break the knot that ties school education to serving the dual function of educating all students for citizenship and, simultaneously, educating the next generation of scientists" (pp. 180-181).

Osborne, from Kings College London, and Robin Millar from University of York, received approval in the late 1990s for an ambitious project to introduce a new Twenty First Century Science national curriculum throughout England and Wales (Millar & Osborne, 1998). In this approach, the two purposes of "scientific literacy for all and pre-professional training in science for some" are separated in different courses. First, all fifteen- to sixteen-year-olds take a core course that emphasizes scientific literacy for the "*consumers* of scientific knowledge," that is, educating citizens to deal intelligently and appropriately with scientific knowledge in the forms they encounter it – using technology safely and effectively, to make informed decisions, and to understand media reports and public information about topics and issues that have a scientific or technological dimension (Millar, 2006, p. 1505). This is done primarily through nine contextually-based modules that constitute the core course, which integrate disciplinary and nature of science content in real-world situations, relying heavily on media reports of science for topics. Secondly, those students who wish to pursue more advanced courses may do so through disciplinary and/or applied science courses (Millar, 2006; Millar & Osborne, 1998; Osborne, 2007; Ratcliffe & Millar, 2009). Preliminary evaluations of this curriculum indicate increased interest by both teachers and students in science, however teacher understanding of the nature of science, as well as teachers' willingness to shift pedagogical approaches, appear to limit the program's effectiveness (Ratcliffe & Millar, 2009), underscoring the important role teachers play in reform efforts (Crawford, 2007; Hewson, 2007; Loucks-Horsley et al., 2003; Osborne, 2007).

By design, the United States has no such national curriculum policy, although the National Science Education Standards (National Research Council, 1996a) identify recommended skills and understandings that students should achieve that incorporate both a citizen functionality in science issues as well as for training of future scientists. There is, however, no explicit recommendation for unraveling these dual functions, and implementation of curricula is by design decentralized in the United States. However, the call to train an increasingly skilled and competitive workforce in the U.S. has grown stronger.

Bybee and Fuchs (2006) reviewed and synthesized 12 major reports from business, industry, government agencies and associated groups in the United States to form recommendations for K-12 science and technology education to address policies, programs and practices that address workforce competencies, career awareness, equity issues, technology, science, and systemic alignment. The business, industry and government stakeholders identified the need for "high quality teachers, rigorous content and coherent curricula, appropriate classroom tests, and assessments that align with our most valued goals" (p. 350). Similarly, the Board on Science Education of the National Research Council, that also incorporated business and industry interests, identified preliminary definitions of twenty first century skills, which include: adaptability, complex communication / social skills, nonroutine problem solving, self-management / self-development, and systems thinking (National Research Council, 2010).

In 2002, the U.S. Department of Education, along with a number of corporations and other organizations, founded the Partnership for 21st Century Skills (Partnership for 21st Century Skills, 2011, http://www.p21.org/index.php) to advocate for "21st century readiness for every student," emphasizing the need for the United States to compete in a global economy. The Partnership for 21st Century Skills has created a framework for skills and knowledge that integrate "the three Rs (English, reading or language arts; mathematics; science; foreign languages; civics; government; economics; arts; history; and geography) and the four Cs (critical thinking and problem solving, communication, collaboration, and creativity and innovation)" (http://www.p21.org/index.php). Additional student outcomes include information, media and technology skills as well as life and career skills. This consortium provides assistance and support for state and local education structures, such as in development of standards, assessments, professional development offerings, and opportunities for businesses and industries to partner with education initiatives. The Kansas State Department of Education, for example, is developing new standards, models, and programs aimed at educating students with twenty first century skills and understandings (Partnership for 21st Century Skills, 2011).

Although science curriculum changes have occurred at national and regional levels, the emphasis on science education among the international community has likewise shifted. Student achievement in math and science are assessed internationally by various groups and techniques, perhaps the most well known being the Trends in International Mathematics and Science Study (TIMSS) in which students in fourth and eighth grades are assessed every four years (http://nces.ed.gov/timss/). However, an international assessment gaining increased attention is the Program for International Student Assessment (PISA) that administers an assessment to 15-year-old students every three years in countries around the world associated with the Organization for Economic Cooperation and Development (OECD) – for a total of fifty-seven developed countries in the world. The emphasis alternates every three years among Reading, Mathematics, and Science Literacy, and in 2006, it focused on Science Literacy. The PISA assessment involves a 2-hour test containing both open and multiple-choice tasks, as well as a 30-minute questionnaire of students, and a questionnaire of school principals. The PISA report on the 2006 assessments (2009) states that the goals of the PISA assessment is to not only find out what students have learned, but also how well they can apply their knowledge in novel settings.

> It measures the capacity of students to identify scientific issues, explain phenomena scientifically and use scientific evidence as they encounter, interpret, solve and make decisions in life situations involving science and technology. This approach was taken to

reflect the nature of the competencies valued in modern societies, which involve many aspects of life, from success at work to active citizenship. … Educational excellence is not only a goal in itself, but a key source of high productivity, innovation and individual and social well-being." (Organisation for Economic Co-operation and Development, 2009, p. 23)

The United States students had a mean score in science literacy that was significantly lower than the mean of students in all countries who completed the assessment. Student interest in science among top performers in the U.S. was also slightly lower than the mean of students in all countries (Bybee et al., 2009). Yet interestingly, overall U.S. student enjoyment of science, and interest in learning *about* science were higher than the mean for all countries (Organisation for Economic Co-operation and Development, 2009).

In terms of policy implications, the overall findings of the PISA assessment suggest that "student characteristics such as gender, origin, language, or socio-economic status are related to top performance in science but none of these student characteristics impose an insurmountable barrier to excellence. It is particularly encouraging that in some education systems significant proportions of students with disadvantaged backgrounds achieve high levels of excellence, which suggests that there is no inevitable trade-off between excellence and equity in education" (Organisation for Economic Co-operation and Development, 2009, p. 52). Further, it found the top performing students were dedicated and engaged learners who devoted more time to studying than other students, especially in school. They also frequently engaged in informal science-related activities and considered learning science a "potential career investment" (Organisation for Economic Co-operation and Development, 2009, p. 74).

Perhaps the most significant aspect of the PISA assessment for educators in the United States is how science literacy is defined and assessed. Science literacy is a goal frequently stated in science education, though there is no consensus on a definition of science literacy (Bybee et al., 2009; Millar, 2006; Roberts, 2007). Yet the OECD turned to their member nations, current research studies, and work-force stakeholders to help define the term, and in so doing, placed their working definition within the context of twenty-first century skills (Bybee et al., 2009). Additionally, students were assessed using not only multiple choice items, as is nearly ubiquitously done in American state assessments, but also by using open tasks in which higher-level comprehension could be gauged through student application of their understanding. Alberts, former president of the NAS, and editor-in-chief for *Science*, echoes this sentiment in his call for changing the way we assess science understanding in classrooms as a means for improving science education (Alberts, 2009).

Twenty-first century science education reform can be summarized as emphasizing citizen literacy through a humanistic curriculum (Aikenhead, 2007), emphasizing the workforce pipeline and training of future scientists (Bybee & Fuchs, 2006), and addressing both through a two-tiered approach through a national curriculum (Millar & Osborne, 1998). Assessments are finally being addressed as a major driver of the enacted curriculum with calls and examples for assessing core science concepts, engagement in scientific discourse and practice, and application of concepts in societal contexts (Alberts, 2009; Organisation for Economic Co-operation and Development, 2009).

## Science Education Partnerships between Universities and School Districts

### *Background*

The review of science education reform offers insight into the long and productive history of U.S. universities' involvement in high school science education, providing expertise to K-12 educators in science, education and psychology. University / school district partnerships can also offer reciprocal benefits to university researchers as they gain valuable perspectives in teaching, pedagogy, and education politics that they can apply to their own work (Barstow, 1997; Drayton & Falk, 2006). The cultures and interests are often so different, though, between universities and public school systems that well-intentioned partnerships can be mired in challenges (Drayton & Falk, 2006; Eckelmeyer, 2005). Sometimes the dynamics can be extreme, as Aikenhead, an advocate for a humanistic science curriculum, notes when stating that studies in power conflicts over curriculum policy show that often "local university science professors have a self-interest in maintaining their discipline and will boldly crush humanistic initiatives in school science policy" (Aikenhead, 2007, p. 895).

As Schwab notes, the history of education reforms can be seen as a progression of one legion of interests over another, including swings between disciplinary experts (e.g., scientists) and pedagogical experts (Schwab, 1973). Today, Eckelmeyer, experienced in numerous partnerships between researchers and school districts, presents a cautionary note to scientists:

> The worst mistake you can make is to approach teachers, students, or institutions with an arrogant attitude that implies, “You folks have really made a mess of things. I understand the real issues and will show you how to do it right.” Even if you’re correct (which you probably aren’t), you’ll have doomed your efforts to almost certain failure. Keep in mind that some teachers and administrators will be suspicious of your motives initially, defensive about their positions, and intimidated by your knowledge of science content, so any hint of arrogance on your part will be greatly amplified in their minds. (Eckelmeyer, 2005, "Adopt a Positive Attitude")

The need for such a warning bespeaks the care and attention necessary for university – school district partnerships to succeed. Such partnerships are formed for multiple reasons and purposes; below I detail several types as related to science education.

### *Purposes and Types of University / School District Partnerships*

Secondary science education in the United States has essentially always been influenced by university scientists, from college and university entrance standards determining high school science curricula, to education reform and curriculum development, to the development of national science education standards at the end of the twentieth century. University scientists become involved in K-12 science education for various purposes. Ostensibly, all aim at improving science education, whether it be for educating future scientists (Feldman, Divoll, & Rogan-Klyve, 2009), for improving our national defense (Rudolph, 2002), for economic development and workforce training (Bybee & Fuchs, 2006), for improving education for “science for all” (American Association for the Advancement of Science, 1990; Roberts, 2007), for recruitment of under-represented populations to science (Lee & Luykx, 2007; Montelone & Spears, 2006), or for educating whole and well-rounded students in the liberal education tradition (Donnelly, 2006). Much has been written on the inherent responsibility scientists have for being involved in K-12 education (Alberts, 2009; American Association for the Advancement of Science, 1990; National Research Council, 1996b). However, the decision in 1997 by the National Science Board to change the merit review criteria of research proposals to NSF, placing greater weight on the “broader impacts” of a proposed project, had an indelible effect on the engagement of scientists in education (http://www.nsf.gov/about/history/timeline90s.jsp#1990s).

This singular change "prompted an unprecedented number of scientists to seek opportunities to participate in precollege education and outreach" (Dolan et al., 2004, p. 1601). Programs in which scientists collaborate with K-12 educators include: programs for teachers, scientists working in classrooms, students working in labs, students collecting data within their classes, and curriculum development.

***Programs for Teachers***

Teacher training and professional development is one of the most popular means by which research scientists influence K-12 education (Moreno, 2005; National Research Council, 1996b; Sussman, 1993). This includes summer institutes in which teachers participate in research lab work, in learning new inquiry and research-based pedagogical methods for particular subjects, and otherwise interact with researchers in science departments and education colleges (Magolda, 2001; Pitman, 2003; Shepherd, 2008; Tanner et al., 2003). Scientists often conduct seminars or workshops at school sites during in-service days that are set aside in the school calendar for teachers to strengthen their own professional practice. Some universities have introduced a year-round model of teacher professional development programs in science, recognizing the need for consistent teacher support and community building (Haase, 2008).

Content knowledge for pre-service teachers is strengthened by scientists' involvement in workshops, science courses, and engaging the teachers-in-training in research, especially when a strong relationship exists between science departments and colleges of education (Brown & Melear, 2007; Haase, 2008; National Research Council, 1996b; Pitman, 2003; Shepherd, 2008). University partnerships with school districts come into play when pre-service teachers conduct internships in partner school districts. Additionally, university / school district partnerships are increasingly being advanced for joint teacher preparation in pre-service programs and in-service professional development, so that both practicing classroom teachers and university faculty prepare and guide the program (Scharmann, 2007; Shroyer, Yahnke, Bennett, & Dunn, 2007).

The NSF-sponsored Research Experience for Teachers (RET) program is specifically designed to give teachers summer opportunities to conduct research with scientists, engaging them intensively in the practice and culture of scientific research (Blanchard, Southerland, & Granger, 2009; Lockhart & LeDoux, 2005). Universities often have other similar programs. Apprenticeship experiences for pre-service teachers often take the form of semester-long courses, with a focus on either individual or group research projects (Sadler et al., 2010). Studies show that both teachers-in-training and practicing teachers report a better understanding of science research and the nature of science, as well as increased confidence in conducting research and in teaching science, after participating in such immersion programs. However, teachers report difficulty in translating their acquired research practices into science teaching fully, citing lack of time, equipment, financial resources and differing purposes as limiting factors (Blanchard et al., 2009; Brown & Melear, 2007; M. J. Ford & Wargo, 2007; Sadler et al., 2010). Further, questions of ownership of the research arise: is the question the scientist's or the teacher's? Sometimes teachers report experiencing themselves used simply as data-collecting instruments without having a hand in understanding the meaning of the work. The quality and degree of communication between teacher and scientist appears indicative of learning and satisfaction with the teacher apprenticeship experiences (Drayton & Falk, 2006).

Another approach to foster strong content knowledge of teachers is to encourage those with doctorates in science to enter the teaching field (National Research Council, 2002), exemplified at Vanderbilt University's program enabling Ph.D. scientists to earn a teaching certificate through internships in their partner school district (Shepherd, 2008).

### ***Scientists in the Classroom***

Scientists often get directly involved with K-12 students through university partnerships with school districts. Short-duration visits involve scientists serving as judges for science fairs, giving career talks, participating in science nights or career fairs, or providing prepared presentations (Mervis, 2010; Sussman, 1993). These are developed through informal contacts, a university's lecture bureau, or formal programs. The "Science Squad" at the University of Colorado is an example of the latter, and is comprised of four to six graduate students who present prepared hands-on science activities in hundreds of classrooms per year (Laursen, Liston, Thiry, & Graf, 2007). The positive impact of role models for students, and the sense that science can be fun, have been demonstrated in such programs (Laursen et al., 2007; Sussman, 1993). Another way of exposing students to role models is through newsletters, websites or videos that highlight diverse scientists, their practice, and their career paths (Bellamy, 2005).

Scientists also get involved directly in classrooms for longer durations. Teachers sometimes develop their own personal relationships with scientists and use them for informal or formal mentoring of projects or general advice (Sussman, 1993). Occasionally these relationships are formalized in "ask the scientist" or "virtual scientist" university programs that allow teachers and/or students to contact scientists for their expertise (Mervis, 2010; Shepherd, 2008). Graduate students and post-doctoral researchers often participate in K-12 classroom programs in lieu of principal investigators, whose time is often more limited. The NSF-sponsored Graduate Teaching Fellows in K-12 Education (GK-12) program, in which graduate-level university scientists collaborate with school teachers and students as a kind of scientist-in-residence has spawned numerous successful university / school district partnerships (Gengarelly & Abrams, 2009; Tomanek, 2005; Usselman, 2004). The Science and Health Education Partnership (SEP) program at the University of California, San Francisco, partners several graduate students with a high school science teacher to help develop instructional modules and activities and to interact with secondary students (Siegel et al., 2005). Such programs produce favorable evaluations, demonstrating positive results for K-12 students in understanding the nature of science and in having positive role models, gains for teachers in understanding the nature of science, and benefits for graduate researchers in improving communication and teaching skills and gaining pedagogical content knowledge (Gengarelly & Abrams, 2009; Siegel et al., 2005; Tomanek, 2005).

Partnerships also take the form of mobile labs, such as the Science in Motion (SIM) program at Juniata College that serves elementary through high schools in rural Pennsylvania (Mitchell, 2000). In this program, vans are equipped with kits of materials and equipment that specialists take to the schools and guide lab implementation. They are developed in conjunction with teachers, with professional development offered. SIM resources are then shared among school districts, with expert guidance from scientists at Juniata College (http://www.juniata.edu/services/ScienceInMotion/jc.html).

### ***Students in the Labs***

Science education literature stresses giving students experiences in "authentic" science, usually referring to inquiry investigations based on questions with unknown answers (Flick & Lederman, 2006). Getting students into practicing labs is another way of exposing them to authentic science. For instance, precollege students are often invited into scientists' labs on university campuses or field stations. Short-term summer programming can help target particular disciplines (e.g., biotechnology, ecology), or target particular groups of students (girls, minorities, urban) that may be under-represented in the STEM fields. Undergraduate or graduate students are frequently enlisted to assist in programming, and serve as "near-peers" to younger students who often appreciate talking to someone closer to their own age. Engaging precollege students in scientists' labs for short-term programs helps familiarize students with a university campus, offers insight into careers, connects them personally with scientists who might facilitate their interests further, and connects them with funding programs that could help finance higher education opportunities. Such programs can also enhance students' academic performance (Montelone & Spears, 2006; Shepherd, 2008; Sussman, 1993).

Precollege students, especially high school age, intern in scientists' labs for additional experiences in authentic science, where they take part in the experiments, daily tasks, and communication of the research lab (Charney et al., 2007; Hsu & Roth, 2010). "Near peers" such as lab technicians, graduate students or post-doctoral fellows can be particularly helpful in mentoring high school interns. Such internships allow students the opportunity of developing lab or field skills, of experiencing scientists as real people, and of experiencing the scientific process as usually a non-linear one. They immerse the learner "in a collaborative learning environment where problem-solving is connected to real science, alternative strategies are formulated, concepts are questioned, and problem-solving approaches are debated" (Charney et al., 2007, p. 196). Internships have been shown to increase student interest in science careers and to expand career options within science, to increase scientific content knowledge, skills and understanding of the nature of science, to increase confidence for doing science, and to improve methods of discourse about science. Additionally, scientists and lab personnel often gain in understanding the learning and mentoring process, as well as understanding their own lab and experiments better. The difficulty of ownership of the project, however, can arise: is it the scientist's question or the student's question being investigated (Charney et al., 2007; Hsu & Roth, 2010; Sadler et al., 2010; Widener, 2008)?

### *Students Collecting Data*

Citizen science projects provide opportunities for students to collect data for scientists' research projects, especially since the ubiquity of computers has allowed easy internet access in most schools. Citizen science projects may be specific to particular labs, such as the University of Kansas' Monarch Watch (http://monarchwatch.org/), Cornell Laboratory of Ornithology's Project Feeder Watch (www.birds.cornell.edu/pfw/), and Berkeley Lawrence Lab's Hands On Universe Project (www.handsonuniverse.org/). Alternatively, projects may involve a collaboration of scientists, such as the International Astronomical Search Collaboration (IASC) (http://iasc.hsutx.edu/index.htm), Earth Trek (www.goearthtrek.com/), and the Global Learning and Observations to Benefit the Environment (GLOBE) program (www.globe.gov/). These programs provide specific protocols for teachers and students to follow to collect data, which students then upload to an online database. Citizen science projects are especially utilized when phenomena such as animal migration patterns or invasive species expansion are spread over large geographical areas. Hence, scientists have many more eyes, hands and minds on these projects. When the protocols are clear enough to be easily replicated, results exceed what one lab can accomplish alone (Doubler, 1997; Eberbach & Crowley, 2009; Morse, 1997). They engage students in learning while they contribute to authentic projects, and many of these programs connect participating students to each other through online communication as well as sponsored conferences.

A more lab-based genetics program that started at Virgina Tech and grew to several universities collaborating is the Partnership for Research and Education in Plants (PREP) program, which focuses on the genetics of the model species *Arabidopsis thaliana*, the first plant with its genome sequenced. Mutant lines of plants in which one gene has been disabled along with unaltered plants are sent to classes. Students are asked to grow them in identical conditions (of the students' choosing) to try to understand the functions of particular genes (Dolan, 2003; Dolan & Tanner, 2005).

While such programs give numerous students direct and often exciting experiences in participating in research, some issues arise in the sophistication of data collection. For instance, evaluations of the early curricular versions of Project Feeder Watch / Classroom Feeder Watch showed no benefit for students' disciplinary knowledge or in their understanding of inquiry skills (Trumbull, Bonney, & Grudens-Schuck, 2005). When Eberbach & Crowley (2009) investigated further into the reasons for the lack of gains, they found that novice students were being asked to observe birds in sophisticated disciplinary-specific ways, and that curriculum developers and scientists under-estimated the scaffolding necessary to engage students in observations and data collecting. Further, helping teachers learn, rather than assuming they already knew the material, proved important. The original citizen science project developed for adults still exists, but the classroom curriculum for this program has undergone extensive evaluation and revision since its first version. It now exists under a different name: Bird Sleuth (http://www.birds.cornell.edu/birdsleuth).

### ***Curriculum Development***

One of the lessons learned from the early version of the Classroom Feeder Watch program was the unfortunate omission of teachers in the original curriculum development process. Today countless curriculum development projects involve partnerships between practicing classroom teachers in school districts, and science and pedagogical experts in universities. For example, Washington University in St. Louis, MO, has partnered with the local school district in a long-term curriculum development program, Science Outreach, designed to share the research from university scientists with local K-12 classrooms (http://www.so.wustl.edu/). The partners meet with curriculum developers and engage in a collaborative process of identifying topics, developing activities and supporting material, testing, evaluation and revision cycles, and final writing (Elgin et al., 2005). Other universities across the country engage with local school districts for similar curriculum development programs, including the Science and Health Education Partnership (SEP), a collaboration between the University of California, San Francisco, and the San Francisco Unified School District; and the Science House at North Carolina State University that partners with school districts across the state (Barrier, 2004; Siegel et al., 2005; Sussman, 1993; Tanner et al., 2003). Along with developing science curricula, such partnerships often create portable science kits that teachers can use for a lesson (or more), and provide professional development seminars or institutes in which teachers become familiarized with and trained in implementing the materials.

A novel type of curriculum originally developed through a university / school partnership at the Weizmann Institute of Science in Rehovot, Israel is based on Adapted Primary Literature (APL) (Yarden, Brill, & Falk, 2001). This approach takes a broad perspective on the definition of inquiry, and includes the processes of reading and writing that comprise on average 58% of scientists' professional time (Phillips & Norris, 2009). Proponents of this approach make the case that the process of doing science is not comprised of just the "hands-on" components (e.g., experiments, data gathering), but also includes the "minds-on" activities of reading and writing that are so essential to concept formulation. They advocate for having students read primary research papers, albeit in simplified form (Phillips & Norris, 2009). Scientific papers maintain much of the tentativeness in forming conclusions, exploration of alternate considerations, unanswered and new questions inherent in the research being reported, and speculations about the meaning of the results. These critical elements of the nature of science are largely absent in texts or other literature about science for lay people. However, as scientific papers are written by scientists for scientists, with the esoteric language and concepts inherent in each discipline and subdiscipline, they are essentially inaccessible to the lay person. Adapted Primary Literature is a means to take primary scientific papers and adapt the language to a lay person's level, while maintaining the bases of evidence, concept formulation, alternative hypotheses, and other nuances inherent in primary research reporting. Some initial gains in developing this approach have been made (Falk & Yarden, 2009; Norris, Macnab, Wonham, & deVries, 2009). Early evaluations show the greatest benefit for students when there is close collaboration among scientists, classroom teachers and students (D. J. Ford, 2009; Phillips & Norris, 2009; Yarden, 2009; Yarden et al., 2001).

***From Project to Partnership***

Tomanek (2005) notes, "Today, partnership models are replacing one-time summer courses and workshops as vehicles for improving science, technology, engineering, and math (STEM) education in the United States" (p. 28). How does a university outreach program in science turn into a partnership? What is the difference? Consider Dolan & Tanner's (2005) comments below:

> One would be hard-pressed to find a college or university in the United States without at least one outreach program designed to support science education in local K-12 schools. Over the last three decades, scores of thriving science education outreach programs have had significant and extraordinarily positive effects on K-12 science education. … Yet, they have been largely unidirectional in their goals and activities, focusing primarily on the challenges and shortcomings of K-12 science education. In looking forward, we propose that the role of institutions of higher education must change, moving from initial efforts in outreach, a stance characterized by offering expertise and supporting external reform, to a more enduring approach of partnership, which demands that both partners examine their own science teaching and learning and promote both external and internal reform. …
>
> In particular, we believe that three major shifts must occur: 1) the adoption of a mutual learning model of partnership, 2) the integration of partnership into the training of scientists, and 3) the development of sustained infrastructures for partnership. (p. 35)

Evaluations of several GK-12 partnership programs that directly place graduate scientists in K-12 classrooms reveal these as exemplar two-way partnerships: scientists report gaining insight, understanding and respect for the pedagogical understanding they gain from teachers and students (Gengarelly & Abrams, 2009; Tomanek, 2005; Usselman, 2004). Yet orienting to a two-way partnership is not necessarily automatic. Tomanek (2005) reports that in the first year of a GK-12 program, the understood idea was "to enhance the science curriculum with inputs created at the university" (p. 29). The resultant one-way flow of activities "from the university to middle and high school classrooms created little reason for teachers to take ownership of the project or to consider using the activities that had been developed in the curriculum" (p. 29). After reflection and modification, and ongoing assessment, the program changed in less than one year to be firmly bi-directional and collaborative.

While teachers have much to gain from scientists, such as learning about scientific inquiry, cutting-edge findings, methods, and scientific concept development, scientists also have much to learn from teachers about student cognitive development, communication skills and pedagogical strategies. Yet Tanner and colleagues (2003) note that the learning in collaborations among teachers and scientists has historically been uni-directional, emphasizing the high status of the scientists' expertise, and downplaying that of K-12 educators, with K-12 teachers contributing to the imbalance by primarily viewing the partnership as a means to garner resources for their students. Although scientists and teachers may come together voluntarily and with good will, larger professional and societal issues play a role in the partnerships as well, with cultural expectations and realities influencing how partners interact with each other. In order for partnerships to succeed for mutual benefit and learning, the commonalities and differences among the professional cultures must be taken into account, since more than anything, these create especially formidable challenges when not understood (Barstow, 1997; Bellamy, 2005; Magolda, 2001; McKeown, 2003; Tanner et al., 2003).

### *Two Cultures*

The famous lecture in 1959 by C.P. Snow entitled "The Two Cultures" describes, sometimes humorously, sometimes tragically, a gulf between scientists and those in the humanities so great that, at minimum, members of one group could hardly understand those in the other, and at worst, expressed outright hostility for the other (Snow, 1990/1959). Although it is safe to say the cultural conditions have changed considerably since then, some of Snow's premises are still worth considering, especially in light of partnerships among scientists and educators.

> At one pole, the scientific culture really is a culture, not only in an intellectual but also in an anthropological sense. That is, its members need not, and of course often do not, always completely understand each other; biologists more often than not will have a pretty hazy idea of contemporary physics; but there are common attitudes, common standards and patterns of behavior, common approaches and assumptions. This goes surprisingly wide and deep. It cuts across other mental patterns, such as those of religion or politics or class. (Snow, 1990/1959, pp. 170-171)

Scientists do indeed have definite cultures, as do educators in schools, and sometimes these cultural differences can cause difficulties and misunderstandings in partnerships. Each respective institution has its distinct mandates. Universities serve as research institutions that generate and disseminate new knowledge, as well as institutions of voluntary higher education. They are often funded through state revenues, but also charge students tuition and receive grants, especially to fund research. In fact, research often becomes a primary mandate of universities, sometimes to the point of eclipsing teaching, especially when grant funding is involved in research. University scientists are often on tenure tracks, requiring them to be productive in research and publication or risk not earning tenure and having their contracts terminated. Depending on the university, department and research appointment, a scientist's teaching commitment may be minimal, one or two courses a semester. Aside from teaching hours, scientists generally have relative control over their schedules. While they must be productive, they are relatively free to choose when they conduct research, when they take a lunch break, when they make appointments, and even when they use the restroom (Drayton & Falk, 2006; McKeown, 2003; Tanner et al., 2003).

In contrast, public schools work under a mandate of compulsory education and conform to curriculum standards and requirements set by district and state governing and administrative bodies – they often have little room for additional topics. Teachers are expected to teach a breadth of topics to a range of student levels, and be educated in learning theory and pedagogical methods as well as disciplinary content knowledge. Public schools are primarily funded through state and local tax revenues and are not allowed to charge tuition. The bulk of their budgets are therefore vulnerable to political and economic conditions. Teachers earn promotion and tenure through evaluations by direct administrators. Public school attendees usually are minors, which necessitates legal and supervisory responsibilities. Teachers are required to be present in classrooms, to supervise in breaks and lunches, to account for student attendance and behavior, and to get written permissions from parents for exceptions to the normal school day (e.g., field trips). A typical teacher's classroom schedule includes teaching five to seven hours a day, while planning, preparation, grading, conferences and meetings all occur outside these hours. They have little access to phones or personal e-mail during the day, usually have quick lunches, and have very few restroom breaks (Drayton & Falk, 2006; McKeown, 2003; Tanner et al., 2003).

Scientists have relatively abundant scientific resources, and are often surprised when teachers may be happy simply for running water in the classroom. School district budgets for procuring scientific materials and instruments are restricted, and teachers often purchase materials with funds from their own pockets. Public school testing drives much of the curriculum, especially since the implementation of NCLB with high stakes consequences tied to test scores. While cognitive and educational research in science teaching consistently favors pedagogical approaches that immerse students in inquiry-driven activities and discourse in developing scientific concepts, the classroom realities of the needed scaffolding for such activities, time limitations, scope of material needing to be covered, mandated curricula, and conformity to district and school requirements often means giving brevity to such approaches. Due to budget cuts and shifting priorities in many school districts, science curriculum coordinator positions are frequently eliminated, leaving science teachers with little institutional support (Duschl, 2008; McKeown, 2003; Mervis, 2010; Taylor et al., 2008).

Tanner and colleagues (2003) illustrate the differences in the cultures of science and education in Figure 2.1 below.

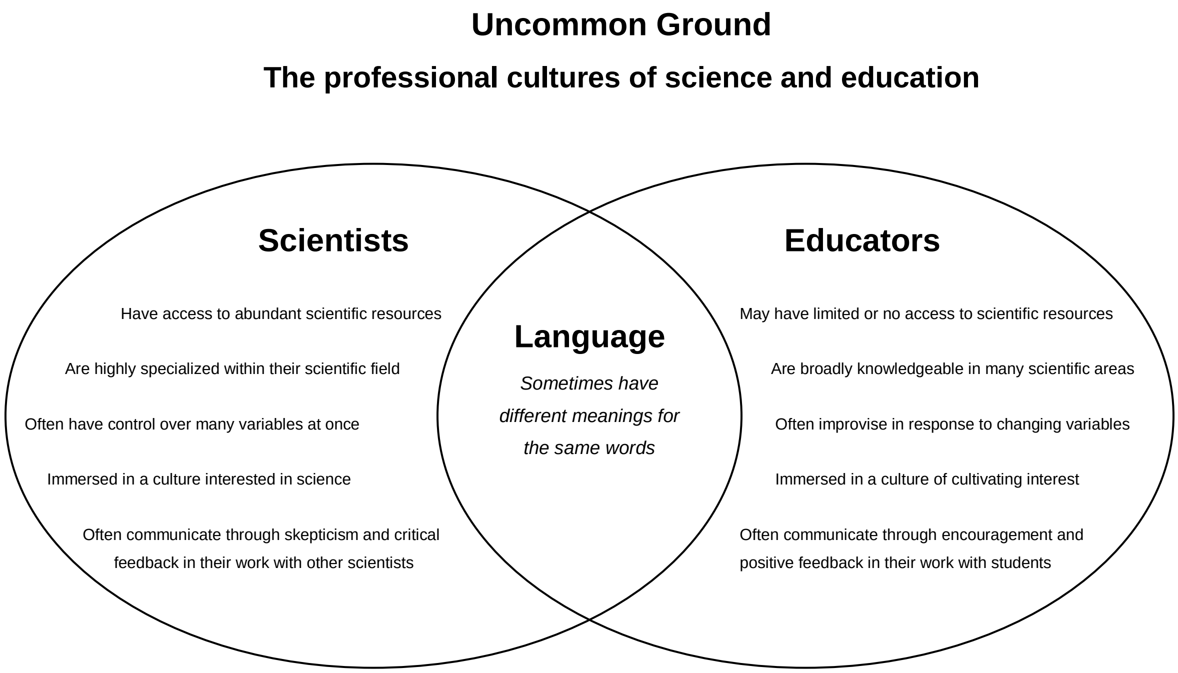


**Figure 2.1. Uncommon ground** – the professional cultures of science and education (after Tanner et al., 2003)

The intersection of the cultures in the diagram indicates that language may be the same, but mean different things. Just as England and America are often said to be two cultures separated by a common language, so too does a common language seem to separate scientists and educators. The same word can mean very different things. Styles of communication have also been noted to cause friction. "Scientists are professionally trained to be critical in their pursuit of scientific research and teachers are professionally taught to be nurturing in the development of their students and supportive in interacting with one another. … These differing approaches to communication can contribute to misinterpretations, such as scientists viewing teachers as complacent and uncritical about their work and teachers viewing scientists as unreasonable and never satisfied" (Tanner et al., 2003, p. 198).

Scientists and science teachers are often perceived in culturally typical ways. Scientists tend to have higher perceived status and power than teachers, and teachers are often "in awe of and sometimes fearful of scientists" (Bellamy, 2005, p. 43). Scientists often have unrealistic expectations that teachers will have knowledge and skill levels similar to their graduate students. Teachers may be intimidated by a scientist's depth of knowledge in one area, yet teachers are often surprised to find themselves possessing greater breadth of knowledge of different science disciplines and a better grasp of interdisciplinary fields than many scientists (Barstow, 1997; M. J. Ford & Wargo, 2007; McKeown, 2003; Tanner et al., 2003). Taylor and colleagues (2008) conducted an extensive study on scientists' and science educators' views of science education:

> With few exceptions the scientists in this study held distinct and often critical views of science education. But what is not clear is how these perceptions were formed and what evidence scientists use when making judgments about precollege education. The vast majority of the scientists interviewed had very limited experiences with K-12 science education. What little experience they had was limited to impressions they gathered from their children's schooling or from more vague notions of school quality. None of those interviewed gave examples of evidence from observations in schools or from experiences working with teachers. (Taylor et al., 2008, pp. 1069-1070)

In spite of the differences, scientists and educators fortunately have much in common. Both are passionate about their work, put in long hours, and prove adaptable to the unexpected. They both function in learning environments, base their work on evaluation and previous research, and are expected to solve complex problems within the constraints of scrutiny and regulation. Interestingly, they are both often mistrusted by the general public and can be the scapegoat of large societal issues. They both are educated formally in content knowledge, but learn much of their profession through formal or informal apprenticeships, though a teacher's internship is typically much shorter than a scientist's multiple years of graduate education and post-doctoral research (Barstow, 1997; Tanner et al., 2003).

Richmond (1998) argues that science, more than almost any other professional field today, uses the apprenticeship model in a way craftsmen or artisans did hundreds of years ago:

> Back then, … your training was orchestrated so that [your] skills increased in complexity along with the expectations your master had for your responsibility to the finished product. And while you were learning these increasingly complex tasks, what surrounded you in the workshop, in addition to other apprentices, were the pieces or finishes they produced. You overheard feedback from the master to other individuals as well as receiving it yourself. You conversed regularly about your work, that of our peers, and of those more expert in the craft. You commented on the quality and value placed by

> others on the master's work, which everyone understood was rarely a product of the master's hands alone, but of his along with those he had trained. … The parallels to the preparation of modern-day scientists are not difficult to make. (Richmond, 1998, pp. 583-584)

Although Richmond's grasp of learning the enterprise of science may be true, it may not be entirely unusual for learning sophisticated professions. For instance, Shulman (2005) provides a review of studies in the training of several diverse professions, including engineering, medicine, and law. He refers to distinct "signature pedagogies" in the professions, unique cultural traditions – from the way classes are conducted to the processes of internship and apprenticeship. In a nutshell, however, Richmond's comparison of the training of scientists to the apprenticeship of a master craftsman encapsulates what is so ineffable in learning the experiences of the nature of science: the "messiness" and nonlinearity of science (Sadler et al., 2010), the tentativeness of science (Phillips & Norris, 2009), and the socio-cultural context of science (Barstow, 1997; Duschl, 2008; Tanner et al., 2003).

Yet teachers perhaps underestimate their own "signature pedagogies" in forging their own expertise in combining pedagogical content knowledge and disciplinary knowledge with in-the-moment learning and tips from mentors that constitutes the nature of teaching. For example, after a presentation by a scientist at a professional development institute, a third grade teacher shared: "I feel so stupid when I listen to you talk. I took chemistry in college, and I don't recognize many of the terms you are using. I think I should know more." The scientist responded, "If I stood in front of your students, I'd be terrified, and I wouldn't have a clue how to teach them the chemistry I know in ways they could understand. I'd feel stupid. You have specialized knowledge and experience that I don't have, and that I envy. I also have specialized knowledge and experience, but in a different area" (Bellamy, 2005, p. 42).

So when studies reveal that teachers who take part in research experiences in scientists' labs do not implement all cultural elements of science research in their classrooms (M. J. Ford & Wargo, 2007; Sadler et al., 2010; Varelas, House, & Wenzel, 2005), should we be surprised? It seems it may, in fact, not be appropriate.

In fact, two relevant fields of study have influenced each other more may be apparent at first glance. These are 1) the field of the learning sciences, a group of disciplines focused on learning and learning environments, and 2) the field of science studies, a group of disciplines focused on knowing and inquiring in the context of science (Duschl, 2008). Current understanding of learning theory is based on socio-cultural or constructivist underpinnings which posit that we learn in the context of prior knowledge and experiences, that both content and context matter in new learning (including socio-cultural context), that scaffolding helps facilitate new learning, that understanding tends to progress from concrete to abstract knowledge, that externalizing and articulating understandings help clarify learning, as does reflection, and that there is a difference between novice and expert understandings (Duschl, 2008; Kelly, Chen, & Crawford, 1998; Lunetta, Hofstein, & Clough, 2007; National Research Council, 2000; Posner et al., 1982). Similarly, current understanding of the nature of science recognizes that science is practiced within a culture that identifies what counts as evidence, knowledge and discourse, that these elements differ in different fields and change over time, that understanding progresses from concrete to abstract knowledge (both in history, and as part of the process of developing theories), and that communication through presentations, writing and other discourse facilitates concept development. Educators and scientists may not operate in such foreign cultures after all.

A review of recent research in early childhood learning, Gopnik (2004) details the means by which infants observe and make sense of their worlds based on evidence and inference, often in very sophisticated ways, detecting patterns of probabilities and similar statistical patterns in their environments, carefully manipulating variables and drawing causal inferences. She draws easy and appropriate parallels to the practice of scientists, and titles the paper, "Finding Our Inner Scientist."

Barstow (1997) draws similar parallels between learning and doing science. His characterization captures this and its relevance to partnerships well:

> Students are taught to begin immediately with a hypothesis as if it were the first step in scientific research, then design an experiment, then collect data, etc. In fact, real science usually begins with a deep interest and curiosity about a topic, followed by a period of "messing about" – exploring, learning, and finding anomalies. Only then do scientists deal with hypotheses, trying to understand something that does not make sense. Through partnerships in authentic research, students will observe and experience this reality of

> scientific research. On the other hand, if the cross-cultural experience is effective, scientists will gain a better understanding of the teaching and learning processes and may even move from lectures to participatory learning in their own work with colleagues and college students. (Barstow, 1997, pp. 1-2)

The two cultures of science and education have a natural kinship. Under the right circumstances, partnerships between university scientists and K-12 school districts have enormous potential for benefits to all participants. The following section explores recommendations for creating such favorable circumstances.

## *Tips for Partnerships*

Those experienced in university / school district partnerships for science education, often for decades, have contributed to a body of scholarship documenting best practices in partnerships – as well as cautions. While the majority of reports are based on the wisdom of experienced practitioners rather than empirical studies, they are informative and provide important tips for establishing and maintaining effective partnerships between scientists and educators. Partnerships are increasingly distinguished from outreach efforts, as articulated by Tomanek (2005):

> …[P]artnerships today between university faculty and K-12 teachers imply something more than an instructional relationship based on a one-way flow of information from an expert to his or her novice students. The construct of "partnership" implies direct benefits for all parties involved. … The idea is that something is there to be gained by everyone. (p. 28)

Cole (2005) formalizes the definition of a partnership:

> A partnership is a voluntary collaborative agreement between two or more parties in which all participants agree to work together to achieve a common purpose or undertake a specific task and to share risks, responsibilities, resources, competencies and benefits. (p. 11)

Identifying the purpose of the partnership is critical, and may sound simplistic, but many partnerships begin through personal relationships and focus on activities without necessarily taking the time to clarify mutual goals. Cole (2005) notes that "one of the greatest urges of a partnership is the desire to 'fix' a problem before the partners either know precisely what is wrong or agree on what results they intend to accomplish" (p. 11). Given the multiple agendas of different institutions and limited resources, clarifying such elements is imperative to success, and starting with modest goals and a clear plan before embarking on large projects is recommended. Cole (2005) suggests the following list of questions as a guide for forging and sustaining a partnership:

- What is it?
- Why are we doing it?
- Who will do it?
- How will we do and pay for it?
- What happened as a result of doing it?
- Was it effective in satisfying the **Why**?
- What will we do with it **Now**? (p. 14)

Magolda (2001) also recommends thoughtfulness from the outset, recommending discussion on the preliminary topic: Is collaboration a good idea? "Posing the question engages stakeholders in a moral dialogue that encourages inquiry, rewards intellectual curiosity, allows for shared meanings to emerge, and reveals core assumptions about what is good" (p. 356). Similarly, Cole (2005) stresses the need to create a mutually agreeable plan with specified results as a way of keeping all partners on the same path. Institutions have multiple agendas, and bringing together partners multiplies those. Without having mutually identified goals and results, a partnership can be like "herding cats" (Cole, 2005, p. 11).

Defining goals collaboratively may seem obvious, but it is a serious enough stumbling block to warrant substantial discussion in the literature. For instance, Tomanek (2005) reports on a GK-12 project that had a difficult first year due to "the one-way flow of activities from the university to middle and high school classrooms" (p. 29). This created little ownership on the part of the teachers, and little incentive for them to use the activities created in the project. Evaluation after the first year brought the issue to light, and the project was modified and monitored to increase the collaborative work between teachers and scientists. Documented gains were substantial (Tomanek, 2005). This case may also indicate collaborative goals being set at higher administrative levels of both institutions (e.g., during the grant-writing phase), without the spirit of collaboration permeating the constituents who actually implemented the partnership, in this case, teachers and graduate researchers. Similarly, scientist-driven curriculum development projects inevitably lack consideration of elements teachers must account for. McKeown (2003) and Wormstead (1999) offer extensive collaboration advice for scientists wanting to contribute to curriculum efforts in public schools, from engaging teachers to address pedagogical concerns, to engaging administrators to address district adoption and implementation concerns. “Developing curriculum materials is of no practical value if teachers cannot implement them …” (Elgin et al., 2005, p. 33).

Much of the effort needed in forming mutual goals, and perhaps why it is so emphasized in the literature, has to do with the time and consideration it takes for each partner to understand the other’s professional culture. The consensus among scholars is that the success of partnerships depends on all stakeholders being involved in the design and implementation of a partnership, as well as in its assessment and renewal (Bellamy, 2005; Cole, 2005; Dolan et al., 2004; Dolan & Tanner, 2005; Drayton & Falk, 2006; Eberbach & Crowley, 2009; Eckelmeyer, 2005; Elgin et al., 2005; Magolda, 2001; McKeown, 2003; Moreno, 2005; Pitman, 2003; Shepherd, 2008; Tanner et al., 2003; Tomanek, 2005; Usselman, 2004; Wormstead, 1999).

Evaluating the achievement of common goals and objectives is critical to the success of partnerships (Dolan et al., 2004; Eckelmeyer, 2005; Granger, 2004; McKeown, 2003; Usselman, 2004), and Cole (2005) specifically maintains that focusing on results keeps all members of a partnership on a common path. Evaluation informs the revision of goals and programs, motivates participants, and demonstrates confidence for continued resource and institutional commitments (Cole, 2005; Dolan et al., 2004; Shepherd, 2008; Tomanek, 2005). Moreno (2005) also notes that evaluation sometimes reveals certain achievements and successes that were not identified even if original expectations were not fully realized.

Committing resources is necessary for partnerships, and most scholars recognize there must be a balance in resource commitment from all partners. Resources, however, do not necessarily mean financial resources; time, expertise, space, libraries and labs are valued resources as well (Cole, 2005; Usselman, 2004). A criticism often leveled at science education in high schools is that with the lack of laboratory and technology resources, students do not learn how science is actually practiced in the twenty-first century. Sharing lab equipment and technology can be a valuable means of contributing resources (Bellamy, 2005; Dolan & Tanner, 2005; Mitchell, 2000). Additionally, good will should not be overlooked as a resource, as Cole (2005) warns against the obstacles of turf, egos, "whose-idea-first syndrome," and lack of common language. "Be prepared to allow others to have all or much of the glory to ensure the objectives are accomplished as fully as possible. In other words, partners should be prepared to walk the high ground of accomplishment rather than seek individual organizational glory" (p. 12).

At institutions where tenure and promotion criteria are largely based on research performance, participating in outreach or partnership work has little professional reward incentive. Yet some universities are incorporating outreach and precollege education activities in their criteria (Dolan et al., 2004). Young scientists are increasingly involved in precollege education during their graduate training through such successful programs as the GK-12 initiatives. It might be expected that they will influence university policies and infrastructures in the future as they move into professor positions themselves to favor science education partnership efforts.

Some partnerships are formed through individual relationships, some through departments or colleges – including some through colleges of education, and some through science or engineering colleges – with individual departments often having separate programs (Haase, 2008; Shepherd, 2008). Among Granger's (2004) list of critical features for sustained support of science outreach is "a dean who is informed and committed intellectually and financially" (p. 45). But increasingly, higher education institutions are being called upon to synthesize outreach and partnership efforts across the college or university and create comprehensive programs (Dolan & Tanner, 2005; Shepherd, 2008; Tomanek, 2005). Thus, Granger (2004) adds to her list two critical features for sustained outreach support:

- An informed and committed provost, president, or chancellor who is willing to make science outreach a university priority.
- Permanent operational funding. (p. 48)

While partnerships may be initiated through grant-funded projects, short-term monies do not provide a sustainable infrastructure.  Many argue that for successful partnerships, “hard money” positions must be committed to provide the coordination and development necessary, and for which scientists and teachers do not have time (Granger, 2004; Pitman, 2003; Shepherd, 2008).

The structure, roles and expertise of such coordinators are gaining increasing attention in relation to what facilitates successful partnerships.  For instance, Pitman (2003) reports that while her university funds the educational specialist in their program, it is imperative for this position to belong equally to the university and public school system, and that the specialist “works with supervisors in both the university and school systems and has unhindered movement within them” (p. 60).  Bellamy (2005) underscores the crucial role of this individual: “This person must proactively arrange interactions among the teachers and scientists” (p. 43).  She states that both teachers and scientists have some natural reticence in being involved in partnerships, be it lack of time, intimidation factors, or lack of communication due to different areas of expertise.  The partnership coordinator can encourage teachers and assess needs, while helping scientists learn to “translate” what they know into information accessible to precollege students (Bellamy, 2005).  Sussman (1993) describes a new kind of professional:

> Science education partnerships are providing the training ground for … a new breed of hybrid professionals who have experience, respect, knowledge and skills in both the scientific research world and in the precollege education community. …Most scientists had very atypical experiences in their schooling and live in a very different world from elementary and high school classrooms.  Most teachers, especially at the elementary level, have a very limited background in science.  Even those who have taken more than one college course that includes a “laboratory” section have never experienced science as it is practiced in modern laboratories.  More [hybrid] people are needed to speak both languages and make the vital connections across both worlds. (p. 14)

Tanner and colleagues (2003) make an expressed argument for the professionalization of hybrid *scientist educators* “who have significant experience in both the professional cultures of scientific research and K-12 education.  Through their experiences in both realms, these individuals are able to cross the boundaries … bringing expertise in promoting collaboration and communication among scientists and teachers” (p. 200).  These authors also see scientist educators as promoting articulation and coherency across institutions in science education, from pre-college to college, and to foster understanding in both institutions for research-based practices in science education.  Figure 2.2 below illustrates their view of scientist educators cultivating the intersection of scientists and educators.

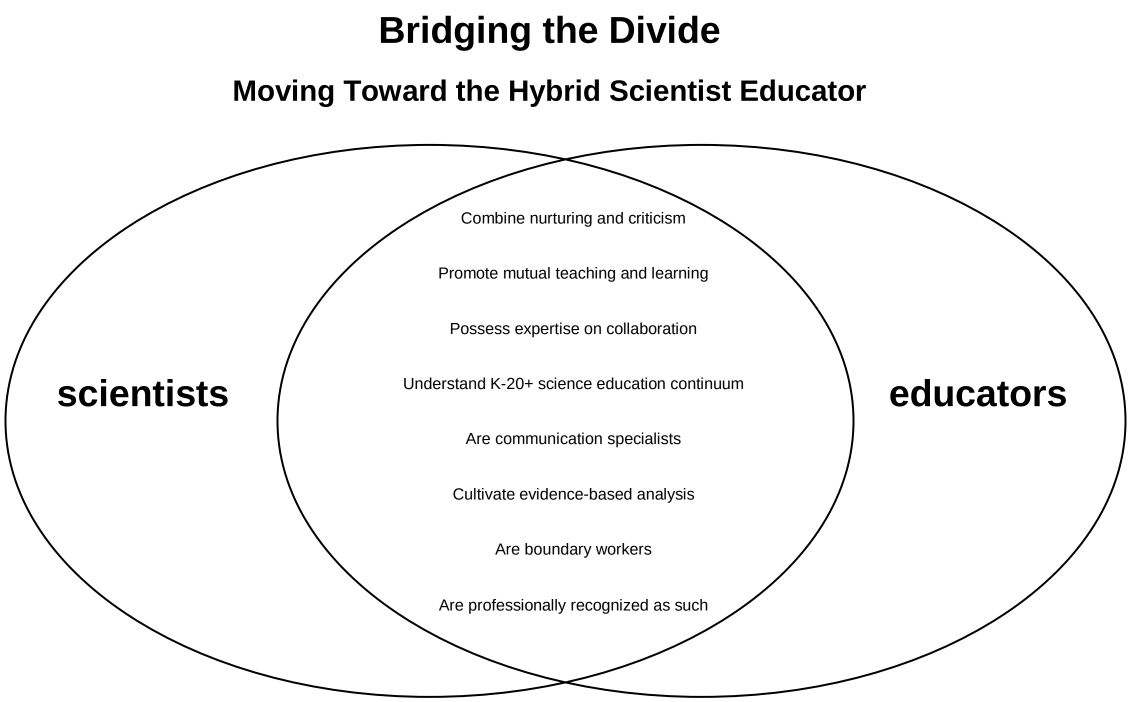


**Figure 2.2  Bridging the divide –** Moving toward the hybrid scientist educator (after Tanner et al., 2003, p. 200)

There is growing support for seeing partnerships as a means to consider science education in a seamless K-20+ continuum, wherein scientists and educators truly work shoulder to shoulder through an expanded professional mandate (Dolan & Tanner, 2005; Granger, 2004). This vision expands the skills of scientists to include competence in teaching, learning and communicating to lay audiences, which would be facilitated during their graduate training through such partnerships.  Incorporating pedagogical training into science graduate education through school district partnerships can support this goal on an institutional level.  Elgin and colleagues (2005) also make the point that curricula and programs developed for advanced high school students are often immensely appropriate for introductory undergraduate courses.

Shepherd (2008) highlights the challenge of frequent changes in leadership in both schools and universities, which can make long-term sustainability tenuous. Institutionalizing partnerships in infrastructure and personnel helps build resiliency around such shifts. Dolan and Tanner (2005) predict that as the number of institutionalized partnerships between universities and K-12 schools grows, so will the need for scientist educators, and they advocate for "professional ranking and reward equivalent to those available to research peers to facilitate recruitment and retention of high-quality professionals in these positions" (p. 1608). Further, they encourage the development of a community of scholars and expert practitioners engaged in partnerships through increased research, publication and conferences in the field. Dolan and Tanner represent the shifts toward increased institutional collaboration in the table below (Table 2.1):

**Table 2.1 Changing emphases** (after Dolan & Tanner, 2005)

| Moving away from … | Moving toward … |
|---|---|
| Outreach | Partnership |
| Reform of K-12 science education | Reform of K-20+ science education |
| Provider-Recipient model in which university scientists provide content expertise that K-12 educators receive | Mutual Learning model in which university scientists gain pedagogical skills and insights, and K-12 educators learn about the culture, content, and process of science |
| Individual, isolated science education programs and efforts | Institutionalization of multiple, coordinated programs and efforts within university science departments and K-12 school districts |
| Science education efforts as optional service by some scientists within some universities | Science education efforts as an integral part of the scientific endeavor in universities that is acknowledged and rewarded |
| Universities develop science education programs that are offered to K-12 schools | Universities and K-12 schools collaborate to determine disconnects across the K-20+ continuum of science teaching and learning and work together to develop mutually beneficial programs |
| Universities and K-12 schools operate in isolation | Universities host teachers learning scientific content and experiencing research, and K-12 schools host scientists learning pedagogy |

### ***Summary of Issues in Science Education Partnerships***

Science education partnerships with universities and school districts have been promoted as models of twenty-first century science education reform. Why and how science education partnerships between universities and school districts succeed or fail is not well understood. However, based on the growing body of scholarly literature, the following appear to be salient issues to address for partnerships to be successful:

- multiple agendas of the constituent institutions
- mutual articulation and agreement of common goals and objectives
- coordination of efforts within and among institutions
- distribution and/or matching resources and needs
- mutual flow of resources or information
- differences in perceived power and competence
- different levels of expert and novice understandings
- clarity in communication
- differences in professional cultures with limited overlap
- perceptions of each other’s cultures and areas of expertise
- equality and respect of all participants

# CHAPTER 3 - Research Methodology, Design, and Procedures

Scientists are often eager and enthusiastic to partner with schools. Increasing financial resources are allocated to support such ventures, especially in the context of twenty-first century curricula (Dolan & Tanner, 2005). In order to foster greater success and sustainability in science education partnerships, leaders in the field promote a vision that moves away from individual outreach programs and toward full institutional science education partnerships between universities and school districts that are mutually beneficial (Cole, 2005; Dolan & Tanner, 2005; Sussman, 1993; Tomanek, 2005; Usselman, 2004). This vision includes the following points: "1) the adoption of a mutual learning model of partnership, 2) the integration of partnership into the training of scientists, and 3) the development of sustained infrastructures for partnership" (Dolan & Tanner, 2005, p. 35). Further, arguments are made to engage scientist educators who are professional hybrids with experience both as research scientists and K-12 educators to promote collaboration and communication among scientists and teachers (Bellamy, 2005; Shepherd, 2008; Sussman, 1993; Tanner et al., 2003). Finally, partnerships based on institutional commitment are promoted as a means for stability and sustainability (Granger, 2004; Shepherd, 2008).

Although the challenges to collaborations between scientists and K-12 educators are well documented, and a model of institutional partnerships that are mutually beneficial is being promoted, research into specific ways of fostering such science education partnerships is sparse. This study addresses this need by methodically investigating a unique science education partnership between a university and a school district.

Using case study methods and a post-structuralist philosophical framework, I explored this science education partnership between a Midwestern research university and a suburban school district. Specifically, the central question investigated was: *What is the culture of a science education partnership between a university and a K-12 school district?*

## Purpose

The purpose of this study was to describe the dynamic culture of a partnership in science education between a large Midwestern research university and a suburban school district. Using case study methods and a post-structuralist philosophical framework, a detailed account of the inception, evolution and practice of the partnership was produced, taking into account the multiple perspectives of participants. In doing so, I aimed to identify specific ways to foster successful collaborations in university / school district partnerships in science education. For purposes of this study, the partnership was defined generally as the activities and engagement involving individuals from both institutions, as well as students participating in the activities generated by the partnership from its inception in Spring 2008 until Spring 2011. The findings from this case study can make significant contributions to the literature by informing the science education community of ways to foster a meaningful, collaborative partnership between scientists and science teachers.

## Research Questions

With a research field as new as science education partnerships, it is difficult to generalize among all such partnerships in order to identify questions relevant to conduct a generalized study with a large sample size. Instead, I am interested in gaining insight into how such partnerships develop in detail and in context. My experiences as both educator and scientist have taught me that rich and unique contexts relate to each of these fields, and they come into dynamic play in partnerships that bring individuals from these fields together. Understanding a partnership seems intractable from understanding its context. So rather than examining multiple partnerships, I aimed to research one partnership in depth to understand the complexities and dynamics involved this collaboration. Through data collection, analysis and interpretation of the findings, I have related the unique case with the general literature in the field in order to contribute to an understanding of partnership elements that may be studied in a more general manner.

The central question of this study was: *What is the culture of a science education partnership between a university and a K-12 school district?*

Questions that are embedded in this central question, and that were addressed in the study, were:

1. How has the partnership between the university and the school district developed?
2. What are the emerging issues, such as outcomes, successes and challenges, of the partnership?

3. How have multiple constituents (administrators, teachers, students, scientists) experienced the partnership?

## The Setting

### *The University*

The university was established in the mid-nineteenth century as a land grant college and at the time of the study had an enrollment of over 23,000 students. It had nine colleges, including five that house nationally and internationally recognized science research programs: Agriculture, Arts and Sciences, Engineering, Human Ecology and Veterinary Medicine. It also had a large and nationally recognized College of Education. The university's Graduate School offered over sixty master's degrees, over forty doctoral degrees, and over twenty graduate certificates.

For academic year 2010-2011, in-state undergraduate tuition costs ranged from $6,000 to $7,000; and in-state graduate tuition costs ranged from $7,000 to $7,500 for most programs, with veterinary student in-state tuition falling at approximately $13,500. Over $175 million in financial aid was awarded annually in the form of scholarships, grants, loans and work study.

Men accounted for approximately 52% of undergraduate student enrollment, and women 48%. Whites comprised 82% of undergraduate enrollment, Hispanics and African Americans 4% each, international students 5%, and Native American and Asian / Pacific Islander 1% each.

Among research faculty in 2009 (50% or more of their appointments involve research or public service), 74% were male and 26% female. Nearly 81% were White, nearly 13% Asian, 1% Native American, and less than 1% each African American and Hispanic. (Information procured from university website, 2010)

The satellite campus directly involved in the partnership was established in 2007, with a mission to develop research collaborations with industry partners and university researchers in the applied biological sciences including animal health, to develop graduate degree programs, and to develop K-12 educational programs. The construction of the first building on the satellite campus, which was intended to house offices and biological laboratories, was underway during this study and completed in Spring 2011. Personnel working at the satellite campus were located in temporary office space about three miles from the campus site. The satellite campus had a core staff of five full-time faculty and staff administrators and three part-time personnel including my half-time appointment as graduate research assistant and coordinator of the university / school district partnership. Research faculty were planned to be located at the satellite campus in the future, however at the time of this study, all faculty positions at the satellite campus were administrative. The portion of my appointment dedicated to this research study was the only active research at the satellite campus at the time. The scientists working programmatically with high school students in the university / school district partnership were primarily located at the main university campus.

### *The School District*

The school district was located in a rapidly growing suburb of a large metropolitan area, and was established in the mid-1960s when several small originally rural districts unified into one. At that time student enrollment was under 4,000 students; by 2009 it had grown to over 27,000.

Starting in school year 2010-2011, the district consisted of 34 elementary schools (grades K-5), 9 middle schools (grades 6-8), and 4 high schools (grades 9-12). Prior to that point, the district had been organized by elementary schools (grades K-6), junior high schools (grades 7-9), and high schools (grades 10-12). The shift to the middle-school model required expansion of all high schools to accommodate an extra grade level.

Student enrollment was comprised of 52% males and 48% females, with 20% economically disadvantaged, and 80% non-economically disadvantaged. Whites accounted for 76% of the district enrollment, Hispanics nearly 10%, and African Americans 6%. The district had a 95% graduation rate among all students. Average test scores of high school students on ACT and SAT exams were consistently and significantly higher than the state and national averages. Ninety-eight percent of schools in the district met AYP standards in academic year 2008-2009.

The district launched unique career and technical high school programs in the 2003-2004 school year, including transfer programs with specific schools hosting unique curricula (such as graphic design, engineering and life sciences), and enhancement programs located at all schools (such as in business, fine arts and international studies). These were developed with influence from the school reform movement to educate students for twenty-first century skills and were in fact called Twenty-First Century Programs.

### *The Partnership*

The science education partnership to be studied took place within the context of a new satellite campus of the university with a focus on applied biological research, and a suburban school district in the same city. Both the satellite campus and the school district are greater than 100 miles from the main university campus. The satellite campus was in the stage of early establishment and was being built on land donated to the university by the city through a land grant. As part of the memorandum of agreement of the land grant, the university committed to a partnership with the school district in the city in 2007. The nature of the partnership inception and subsequent development through Spring 2011 were considered in the study.

## Research Design

A priority for this researcher was to examine a phenomenon within its natural setting, in this case, a partnership between a university and a school district. I aimed to understand the culture of the partnership based on multiple perspectives of the various partnership constituents, incorporating multiple data sources such as participant observation, interviews, and documents to discern patterns and themes using interpretation inquiry of the data. The partnership investigated was one I was directly involved with, serving as coordinator of the university / school district partnership from fall 2008 to the end of this study. All of these elements suggested the use of qualitative research methods, and specifically, case study methodologies (Corbin & Strauss, 2008; Creswell, 2007; Krathwohl, 2004; Stake, 1995; Yin, 2009).

### *Qualitative Methods*

Krathwohl (2004) highlights the usefulness of qualitative (or naturalistic) research methods when one is trying to understand a phenomenon in its complexity and in its natural context. When our research intents are to humanize the issue and data, to portray complex personal and interpersonal phenomena, and to consider multiple meanings to phenomena, qualitative methods are immensely appropriate. In qualitative research, the focus is on a process or phenomenon and its internal dynamics or its strengths and weaknesses. It emphasizes a phenomenon's local causality in depth, with detailed descriptions that reveal their nuances and idiosyncrasies (Creswell, 2007; Krathwohl, 2004). Often, questions are revised and methods refined during a study as the researcher understands the phenomenon in increasing depth (Creswell, 2007). Corbin and Strauss (2008) emphasize that our goal as naturalistic researchers is to authentically represent events as the result of multiple factors converging and interacting in complex and often unanticipated ways. Yet given the nature of naturalistic studies, how do qualitative researchers counter the criticism of "radical relativism," the view that since no one version or interpretation can be proven, no assumptions nor conclusions can ever be made (Corbin & Strauss, 2008, p. 4)?

Stake (1995) puts it this way: "The function of research is not necessarily to map and conquer the world but to sophisticate the beholding of it" (p. 43). Just as quantitative research methods are continually refined to help interpret findings, so are qualitative methods continually refined to help interpret findings. Just as quantitative researchers consider alternative hypotheses, so do qualitative researchers consider rival explanations. "Qualitative study capitalizes on ordinary ways of making sense" (Stake, 1995, p. 72). The design and methods outlined below follow a tradition of rigor in naturalistic studies, with steps included to minimize bias while at the same time acknowledging its influence, to use multiple data sources, to make data analysis transparent, and to maintain a chain of evidence for interpretation (Anfara, Brown, & Mangione, 2002; Yin, 2009).

## *Case Study Methodology*

Yin (2009) presents an algorithm for deciding which social science method to use for different research purposes and questions (p. 8). Considering that the form of research questions of this study attempt to answer "how" or "why" questions, that the study does not involve control of behavioral events, and that it focuses on contemporary events, the case study methodology is the most appropriate to use in this study. Yin (2009) offers the following definition of a case study:

1. A case study is an empirical inquiry that
    - Investigates a contemporary phenomenon in depth and within its real-life context, especially when
    - The boundaries between phenomenon and context are not clearly evident.
2. The case study inquiry
    - Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result

- Relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- Benefits from the prior development of theoretical propositions to guide data collection and analysis. (p. 18)

In terms of being guided by theoretical connections, this study was informed by the literature on science education partnerships between universities and school districts, taking into account the salient issues listed at the beginning of this chapter. These issues were considered during data analysis, yet I also looked for unexpected insights and understandings. Because this study examined the various viewpoints of science, scientists, and science education, a post-structuralist theoretical framework was used to take into account the understanding that meaning is not single-sided, but a result of discourse – and the quality of discourse – among multiple stakeholders.

Stake (1995) distinguishes between *intrinsic* and *instrumental* case study types. The purpose of an intrinsic case study is to research a given situation or phenomenon for its own sake, one that specifically does not fit the norm, but may be considered an outlier in the context of similar cases. An intrinsic case is studied "because we need to learn about that particular case" (Stake, 1995, p. 3). In contrast, the purpose of an instrumental case study is to understand a situation or phenomenon not solely constrained by the one case, but to understand something broader by studying one case in depth – the particular case is instrumental to our broader understanding. This study is considered an instrumental case study as my purpose was to understand the dynamic culture of a unique partnership in order to shed light on other science education partnerships and to inform policies related to them.

### ***The Case***

The case in consideration was the science education partnership, which started in Spring 2008, between the Midwestern university and the regional school district. The partnership generated a number of programs, and these were given particular attention as embedded units of analysis. The partnership programs to be studied were bound by two criteria. First, they constituted innovations that were unique and direct outcomes of the collaboration, rather than events such as field trips or lectures that already existed in each institution alone. Second, they focused on the integration of research with high school education. These programs were: 1) the

Animal Health Twenty-First Century Program; 2) the Senior Biotechnology Project; 3) the Field Research Camp; and 4) the Lab Techniques Course.

In summary, the partnership as a whole was studied, with embedded programs given particular attention (see Case Study Design and Fig. 3.2 below).

### *Case Study Design*

Figure 3.1 shows four basic types of case study design, depending on the unit of analysis (Yin, 2009). The left column shows single-case designs, and the right column multiple-case designs. The top row shows holistic designs, that is, a single-unit of analysis, as contrasted with the bottom row showing embedded designs where within each case there exist embedded units of analyses.

The overall unit of analysis in this study was the single case of the partnership between the Midwestern university and the school district. While the partnership had its own over-arching integrity, it also contained various programs resulting from the partnership. Therefore, the single-case embedded design was most appropriate for this study (symbolized in the lower left corner of Figure 3.1 below).

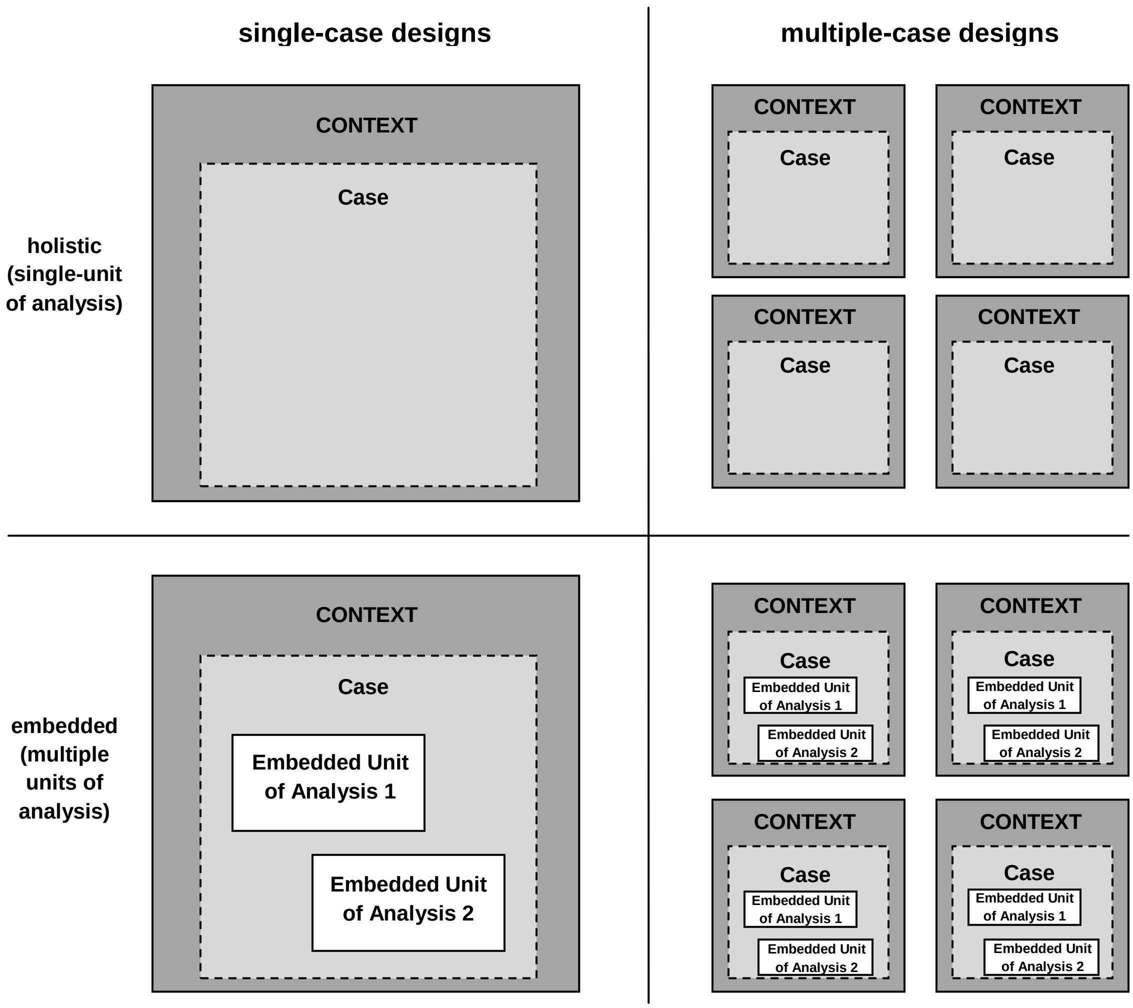


**Figure 3.1 Basic types of designs for case studies** (Yin, 2009, p. 45)

Specifically, then, the following units of analysis were considered for this case study:

- Single case = the unique university / school district partnership
    - Embedded unit of analysis 1 = Animal Health Twenty-First Century Program
    - Embedded unit of analysis 2 = Senior Biotechnology Project
    - Embedded unit of analysis 3 = Field Research Camp
    - Embedded unit of analysis 4 = Lab Techniques Course

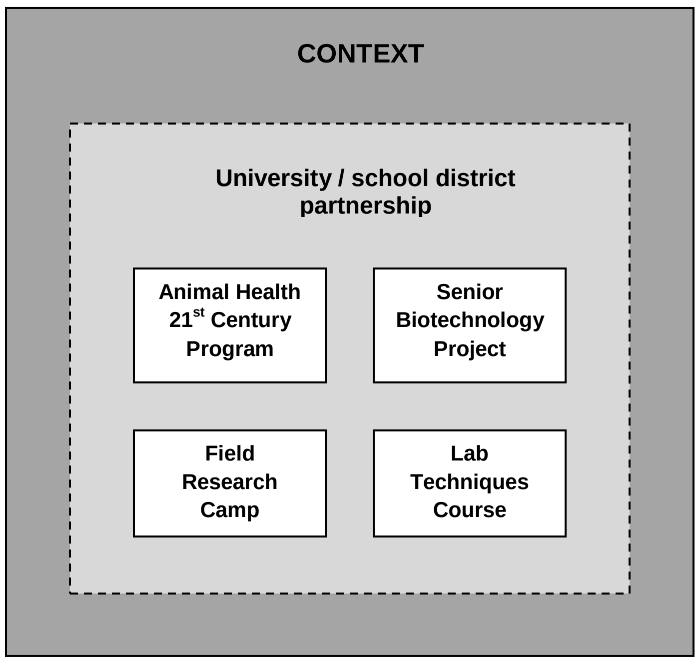


**Figure 3.2 Embedded single-case design for this study**

## *Sources of Data*

### *Multiple Sources of Data*

Gathering data from multiple sources is imperative for providing credibility and for elucidating multiple voices and the pluralities of meaning (Anfara et al., 2002). Sources of data consisted of:

- Participant observation from Fall 2010 to Spring 2011: my field notes, as I served as coordinator of the partnership
- Interviews: administrators, teachers, scientists, students

- Direct field observations:  high school, satellite campus, research lab
- Documentation:  meeting agendas and minutes, notes, reports of events, proposals, progress reports, curricula, lesson plans, assessments, media reports, memos, correspondence, calendars
- Archival records: organizational records, demographic records
- Physical artifacts: photographs, student work

Table 3.1 identifies the data sources I used for each unit of analysis.

| Units of Analysis | Data Sources | | | | | |
|---|---|---|---|---|---|---|
| | Participant Observation | Interviews | Direct Field Observations | Documents | Archival Records | Physical Artifacts |
| Overall Partnership | X | X | X | X | X | X |
| Animal Health Twenty-First Century Program | | X | X | X | X | X |
| Senior Biotechnology Project | | X | | X | X | X |
| Field Research Camp | | X | X | X | X | X |
| Lab Techniques Course | X | X | X | X | X | X |

**Table 3.1  Sources of data for each unit of analysis**

I established an electronic database separate from my analysis, and consistently backed this up in two additional electronic storage sites for a total of three copies (internal hard-drive, external hard-drive, internet-based “cloud” storage).  I also kept a researcher’s log to record the schedule and logistics of the study as they occurred, decisions with rationales, and personal reflection.

### *Participant Observation*

Collecting data through participant observation formally originated in ethnographic studies in anthropology in which the researcher would enter into a culture and participate in it in order to observe the culture as one who also experienced it (Creswell, 2007; Yin, 2009). More broadly, participant observation is used in qualitative research as a means of data collection when the researcher is not just a passive observer, but rather participates in the event, experience or phenomenon being studied (Creswell, 2007; Yin, 2009).

In this study, I was a participant observer as I served as coordinator of the science education partnership between the university and the school district. Participant observer data were collected through field notes, and include notes from meetings, programs and events. Notes were structured to include the elements of the event (date, time, location, who was present), descriptive elements (of physical space, activities and behavior), descriptions of interactions, and any informal interviews. These were followed by my reflections and interpretation of events. Notes on my reflections and interpretations were distinguished from descriptions in my field notes, as advised by Corbin and Strauss (2008).

Participant observation offers the advantages of covering events in real time, capturing much of the context of the case, facilitating access to sites and individuals, and offering insight into interpersonal behavior and motives. On the other hand, participant observation can generate selective data collection and be biased due not only to participant-observer's interpretation but also due to her manipulation of events in the field (Yin, 2009). The use, however, of multiple data sources, and member-checking techniques, whereby other participants are allowed to review and provide feedback on reported events, were employed to provide additional perspectives to triangulate and validate the views of the researcher to minimize bias.

### *Interviews*

The best and most direct way to gain rich and relevant data for understanding the partnership from multiple perspectives is through personal interviews of those involved. Interviews are preferable over surveys because each individual's involvement and perspectives in the partnership are different, and interview questions can be directed to their unique experiences. For instance, no single individual participated in every aspect of the partnership (i.e., embedded units of analysis). Interviewing allowed me to direct the questions in terms of their particular involvement, and to ask follow-up questions when I did not understand clearly their answers.  As such, the interviews were partially structured or semi-structured (Krathwohl, 2004, p. 287), with themes and questions chosen, but the order, modification and follow-up questions up to the interviewer.  The questions and areas to be covered are in Appendix B (p. 361), and are based on the salient themes derived from the science education partnership literature highlighted on page 78.

Participants for interviews were selected through purposive sampling to represent both institutions (school district and university) and to represent participant roles (in terms of responsibility and rank).  A total of twenty-two participants were interviewed, including seven employees of the school district (four administrators and three teachers), five employees of the university (four faculty members and one biology researcher), and ten students (eight from the school district and one at the university who was previously a student at the school district).  All interview participants were involved in the partnership in some significant way.   See Table 3.2 below for representation of interview participants and units of analysis.  Due to the large number of interview participants, only one interview was conducted per participant.  Each interview lasted from 45 to 90 minutes, and was digitally recorded for later transcription.  I also took notes during the interviews.

**Table 3.2 Interview participant sampling, representation, and relevant unit of analysis**

| Interview Participants, Affiliation, and Role | Unit of Analysis |
|---|---|
| *School District* | |
| Administrator 1 | Overall partnership |
| Administrator 2 | Overall partnership |
| Administrator 3 | Overall partnership<br>Animal Health 21st Century Program |
| Administrator 4 | Overall partnership<br>Animal Health 21st Century Program<br>Field Research Camp |
| Teacher 1 | Overall partnership<br>Animal Health 21st Century Program<br>Senior Biotech Project<br>Lab Tech Course |
| Teacher 2 | Overall partnership<br>Animal Health 21st Century Program<br>Field Research Camp |
| Teacher 3 | Overall partnership<br>Lab Tech Course |
| *University* | |
| Faculty Scientist 1 | Overall partnership |
| Faculty Scientist 2 | Overall partnership |
| Faculty Scientist 3 | Overall partnership<br>Senior Biotech Project |
| Faculty Scientist 4 | Overall partnership<br>Animal Health 21st Century Program<br>Senior Biotech Project |
| Post-doctoral Research Fellow | Overall partnership<br>Animal Health 21st Century Program<br>Senior Biotech Project<br>Lab Tech Course |
| *Students* | |
| School District | |
| 4 Students | Overall partnership<br>Animal Health 21st Century Program<br>Field Research Camp |
| 4 Students | Overall partnership<br>Lab Tech Course |
| University (and former school district student) | |
| 2 College sophomores | Overall partnership<br>Senior Biotech Project |

All non-student participants were interviewed in relation to the overall partnership and in relation to any specific programs in which they were involved. As such, interviews were semi-structured (Krathwohl, 2004; Kvale & Brinkmann, 2009), with questions geared to the units of analysis each participant was involved in. The interview questions and subquestions (see Appendix B, p. 361) were related to the questions of the study in the way highlighted in Table 3.3 below. Student interview questions were different from the institutional faculty and staff interview questions (see Appendix B, p.361).

**Table 3.3 Alignment of research questions with interview questions**

| Overarching Research Question: *What is the culture of a science education partnership between a university and a K-12 school district?* | |
|---|---|
| **Research Sub-questions** | **Interview Question** |
| **1. How has the partnership between the university and the school district developed?** | *Adult*: 1b, 1d, 1e, 1f, 1g, 2a, 2b, 2c, 2d, 2e, 2f, 3d, 3e, 5b, 5d, 5e, 5f, 5g, 6a, 6b, 6c, 6d, 6e, 6f, 7d, 7e<br>*Student*: 1e, 3a, 3d, 3e |
| **2. How have multiple constituents (administrators, teachers, students, scientists) experienced the partnership?** | *Adult*: 1a, 1b, 1c, 1e, 1d, 1f, 1g, 2a, 2c, 2d, 3d, 3e, 3f, 3g, 3h, 3i, 4a, 4b, 4c, 4d, 4e, 4f, 5a, 5b, 5c, 5d, 5e, 5f, 5g, 6a, 6c, 6d, 7d, 7e, 7f, 7g, 7h, 7i<br>*Student*: 1a, 1b, 1c, 1d, 1e, 2a, 2b, 2c, 2d, 2e, 2f, 2g, 2h, 2i, 3a, 3b, 3c, 3d, 3e, 3f, 3g |
| **3. What are the emerging issues, such as outcomes, successes or challenges, of the partnership?** | *Adult*: 1a, 1b, 1d, 1e, 1f, 1g, 2c, 2d, 2e, 2f, 3a, 3b, 3c, 3d, 3e, 3f, 3g, 3h, 3i, 4b, 4c, 4d, 4e, 4f, 5a, 5b, 5d, 5e, 5f, 5g, 6c, 6d, 6e, 6f, 7a, 7b, 7c, 7d, 7e, 7f, 7g, 7h, 7i<br>*Student*: 2a, 2b, 2c, 2d, 2e, 2f, 2g, 2h, 2i, 3a, 3b, 3c, 3d, 3e, 3f |

### *Interview Protocol*

Protocols for conducting interviews entailed the following:

- scheduled the interview for 60-90 minutes depending on level of participation in the partnership of each individual
- for minors, gave two copies of parent consent form, one to return signed, and one for parent to keep (see Appendix A, p.358)
- met participant in a comfortable setting for him or her (ideally in his or her own office or school)
- presented my credentials
- presented the informed consent form, explained form and asked for signature (see Appendix A, p.358)
- kept signed copy, and gave a copy to participant
- minor students required prior contact and signed consent by parent, as well as signed assent by student – only students older than 14 years of age were interviewed
- proceeded with semi-structured interview following the list of questions (see Appendix B, p. 361)
- finished interview by thanking participant, and asking if he or she had any concerns or questions

## *Data Analysis*

Data were entered into and coded in the electronic software program NVivo (QSR International, 2011). Data were analyzed using analytic induction, which calls for finding the commonalities in data, leading to a description and then explanation of that phenomenon (Krathwohl, 2004; Miles & Huberman, 1994). Yin (2009) refers to this as pattern matching and explanation building. Categorical aggregation using coding techniques was applied to find correspondence of themes and patterns across data sources (Stake, 1995). At the same time, I aimed to highlight multiple perspectives of participants, and consideration of these was worked into the coding processes. Coding techniques can be useful for reducing data to be able to find patterns, but they also can pull themes out of context. Therefore, I also created analytic memos and annotations to reference original data sources for re-examination. In addition, I relied on direct interpretation, the process of analysis and synthesis that Stake (1995) describes as "trying to pull it apart and put it back together again more meaningfully" (p. 75). To check against my assertions of patterns and explanations of phenomena, I examined and recorded possible rival explanations.

Analysis was structured in four major ways. First, the research questions provided primary structure in data collection and analysis in order to answer and find explanations for each question. Second, a time series was created for the partnership as a whole and each embedded element, to provide an analytic backbone to help explain phenomena as they occurred. Third, the single-case, embedded case study design (see Figure 3.2, p. 95) provided tertiary structure in that research questions were addressed in terms of the overall partnership, as well as in terms of each of the four embedded programs (Animal Health Twenty-First Century Program, Senior Biotechnology Project, Field Research Camp, and the Laboratory Techniques Course). Finally, elucidating perspectives from multiple participants who represented different roles and responsibilities added context and additional meaning to the case study description.

In order to assure valid representation of participants' perspectives, member checking was used wherein interview participants and others in the partnership reviewed my transcripts and analysis to provide feedback and corrections. Additionally, in my reporting, I presented tables representing common themes, and which data sources contributed to the development of those themes.

### *Trustworthiness*

The concern of every researcher is the question of accuracy, of representing the case studied with fidelity to its "true" nature, and presenting valid interpretations of the findings that are not somehow whimsical or unjustified speculations of the researcher. In Stake's (1995) terms, the question is, did we "get it right?" (p. 107). And Creswell (2007) asks, "How do we evaluate the quality of qualitative research?" (p. 201).

A researcher using traditional natural scientific approaches would be concerned with internal and external validity, reliability, and accuracy often involving statistical methods applied to quantitative data. Guba (1981), and Guba and Lincoln (1981, 1982) proposed criteria appropriate for qualitative research that would address similar issues. Given, however, the fundamental differences in epistemological bases between quantitative and qualitative inquiry approaches (Guba & Lincoln, 1982), the term *trustworthiness* is used to encompass the appropriate means employed in qualitative or naturalistic studies. Although many qualitative researchers emphasize using terms about research quality that are distinct from quantitative studies (Anfara et al., 2002; Creswell, 2007; Guba & Lincoln, 1981, 1982), other qualitative researchers use the same or similar terms (Krathwohl, 2004; Stake, 1995; Yin, 2009). The appropriateness of using terms primarily used by quantitative researchers for qualitative studies is hotly debated (Anfara et al., 2002; Creswell, 2007). However, because my study may well be read by traditional quantitative scientists, I used both types of terms so that I can be understood by the broadest audience.

The following methods and techniques were employed to assure trustworthiness, that is, fidelity, accuracy, consistency, authenticity and justification, to the findings of this study.

### ***Credibility or Construct Validity***

Credibility or construct validity is concerned with identifying sound operational procedures in which to study the concepts in question (Anfara et al., 2002; Creswell, 2007; Krathwohl, 2004; Yin, 2009). Data were gathered from multiple sources for two interrelated purposes of credibility: to triangulate data sources, and to integrate multiple voices (Anfara et al., 2002). While one source of evidence could lead one to certain conclusions, having multiple sources of evidence that converge (triangulate) with the same or similar conclusions lends credibility to the findings of the study. Prolonged engagement in the field, approximately six months, also allowed for multiple visits and data collection from multiple events.

I was interested from a post-structural approach in considering how different individuals experienced the partnership from their unique vantage points, and so expected some perspectives to not necessarily converge with others'. Some data were acquired from teachers, some from administrators, some from scientists, and some from students. I anticipated the same event having more than one meaning attributed to it, depending on the person. Perceptions of oneself and others are integral to behavior and individual meaning within institutions and partnerships (J. Marshall, 1998). Gathering data from multiple sources is imperative for elucidating multiple voices and the pluralities of meaning (Anfara et al., 2002).

Member checking was employed to check my notes and perceptions against that of others, both in the process of data collection (such as during meetings or field observations), and once the data were analyzed and the case study written.

### ***Transferability or External Validity***

Case studies may appear to be unsuited for generalizing or transferring findings of the one case to all (or most) other similar cases. However, the purpose of case studies is to research a particular case in contextual detail to understand through deep study what is difficult to learn through studying many cases at once, for instance, in a sample size of thirty cases that might be considered statistically valid using quantitative methods. Yin (2009) notes that external validity is “defining the domain to which a study’s findings can be generalized” (p. 40). Interestingly, in a qualitative study it is *through* the rich and detailed description of context of an individual case that allows its transferability. By providing thick description of context, readers of the study can discern whether this particular case may or may not be similar to, or relevant to, another case of interest. Stake (1995) refers to this as naturalistic generalization, and places the emphasis on researchers to present case studies in such detail that readers engage in the case inwardly as if to experience it, and incorporate it in their collection of similar experiences from which to make generalizations. Creating a case study that can be incorporated by readers this way requires enough detail and credibility for readers to come to their own interpretations, even if those interpretations are different from the researcher’s (Stake, 1995). The purposive sampling technique used for identifying interview participants also contributes to the transferability of the study by providing multiple perspectives through which a reader can consider.

Yin (2009) also argues that case studies can be used as a basis for analytic generalization, “in which a previously developed theory is used as a template with which to compare the empirical results of the case study” (p. 38). Yin continues that individual case studies resemble individual experiments, and that multiple cases resemble multiple experiments, and warns against thinking of a single case study in the same terms as a single respondent in a survey or a single subject in an experiment. “If two or more cases are shown to support the same theory, replication may be claimed” (pp. 38-39). Lacking in a singular theory, I have compared the emergent themes and perspectives of this study with those gleaned from the literature.

### ***Dependability or Reliability***

If the goal of reliability is “to minimize the errors and biases in a study” (Yin, 2009, p. 45), the objective is to make it possible for another investigator to come to the same conclusions by following the same procedures to conduct the same case study. Essentially, this means leaving an audit trail so that a researcher's methods and analyses are well documented, transparent, and understandable. Yin (2009) recommends two main ways to accomplish this: 1) having a case study protocol; and 2) developing a case study database.

The case study protocol consists of the proposal of the study (overview, statement of the problem, purpose, research questions, literature review, and methods). These have been developed and reviewed as a process of the dissertation research proposal. I established an electronic data base as well as files documenting the analysis in the software program. I consistently backed these up in two additional electronic storage sites for a total of three copies (internal hard-drive, external hard-drive, internet-based "cloud" storage).

Additionally, in reporting the case study, I aimed to describe and illustrate the data sources on which conclusions are based, and document established chains of evidence. I maintained a researcher's log which records the schedule and logistics of the study as they occurred, decisions with rationales, and personal reflections.

## *Ethical Considerations*

Access to the partnership in terms of field sites, members, documents and records, and artifacts is primarily possible by virtue of the professional role I have as coordinator of the educational partnership. However, official consent was procured from both institutions to use documents, records, field observations and artifacts as part of the research study.

To ensure the protection of participants and compliance of policies at Kansas State University, an application for Institutional Review Board approval was made using the information described in this chapter of the dissertation proposal, and approval given under "exempt from review" status. Official approval was likewise granted by the school district research review board.

Risks for interview participants were minimal, however one that might have been relevant was if participants revealed more information than they were comfortable with, or which they felt might compromise their positions within their institutions or leave them vulnerable. For instance, if they were critical of any aspect of the partnership, they might have felt they were violating the professional expectation of their superiors. They might have felt their positions in the institution were at risk. Therefore, confidentiality of comments was maintained by replacing names of interviewees with codes in my files, and by destroying the audio recordings after the study is complete. Although direct quotations may be used from interview participants, the source remained confidential.  Participating in an interview was strictly voluntary, and the most effective means of realizing voluntary participation was by allowing participants to exercise the rights of withholding information or withdrawing from the study (Seidman, 2006).  Participants had the opportunity to review their comments after they were transcribed, and withhold any material they provided prior to publication of the study.  They also had the right to withdraw from the study at any point prior to publication.  Interview participants were given informed consent forms that outlined these protective stipulations, and which were explained to them prior to the interview (see Appendix A, p. 358).  They were asked to sign if they agreed to be interviewed.  Student interview participants who were minors needed parental consent, as well as personal assent to participate (see Appendix A, p. 358).

# CHAPTER 4 - Results

## Introduction

"How can I be a veterinarian and a research scientist too?"

This auspicious question was posed to Susan Rasmussen by a high school student. Susan was guest lecturing in the biotechnology class at Vista North High School, describing the wide field of animal health careers possible for students interested in the field. As both a veterinarian and a research scientist herself, she was thrilled with this question coming from the teenage girl, telling me later that it was like asking, "How do I get to be you? The most flattering question that a student can ever ask a mentor or teacher." There were also deeper reasons that this question inspired Susan. She had just been charged by Middle Western University (MWU), where she was Chief Academic Officer, with developing a science education partnership with the Vista School District (VSD). As an accomplished research scientist and innovative administrator, she had a long track record of recruiting students from under-represented groups into science, technology, engineering and math (STEM) fields. She had developed graduate, undergraduate and K-12 programs to this end, and was nationally recognized for these efforts. Further, she was committed to a broad and interdisciplinary view of animal health, one that embraces the interconnectedness of animal, human, and environmental health, and that saw roles for veterinarians that went beyond traditional clinical practice. Her message that cutting edge science research is integral to animal and human health resonated with this student, who happened to be African-American in an economically disadvantaged area. It was a moment Susan seized.

She suggested to the student and her teacher that an independent research project could be developed in collaboration with an MWU laboratory – that an authentic question could be investigated. The teacher, Steve Graham, thought it would be most effective if a few students worked together on the project.

The university was in fact two hours from the school, a detail that would prove to be quite a challenge for the project. The school was located in Vista, a suburb of a large city that offered important industry resources to the university. However, the city and metropolitan region was within the jurisdiction of another state university, the state being carved into regions in which each university served. The jurisdiction issue had made it problematic for MWU to consider opening a satellite campus in the area. However, by focusing on MWU's unique strengths, such as animal health, an agreement was struck that allowed MWU to open a campus in the metropolitan area. The university could offer only programming at the graduate level and for K-12 schools so as not to compete with the other state university for undergraduate programs. The new campus was to focus on innovations, especially in partnering with industry and other educational institutions. Susan's role as chief academic officer for the future satellite campus involved developing the graduate and K-12 programs. The question, "How can I be a veterinarian and a research scientist too?" fueled her enthusiasm in partnering with the Vista School District, and it set in motion a pilot collaborative project between the school district and the university. Other collaborative programs grew and developed. This case study focuses on the overall partnership and four collaborative programs considered innovations of the partnership.

As illustrated in the vignette above, meaningful face-to-face interactions between students, scientists and teachers sparked the characteristics of the partnership. Remarkably, a number of individuals had the freedom and support to create something together that was unique and yet that would be institutionalized within the partnership infrastructure. The challenges faced and successfully navigated in the project would inform subsequent efforts. And much of the collaborative energies would focus on program and curriculum development that engaged students in learning sophisticated scientific concepts and skills in a meaningful way.

In this chapter I will present the case study findings of the science education partnership that developed between MWU and VSD from spring 2008 to spring 2011. My central research question is, *What is the culture of a science education partnership between a university and a K-12 school district?* In this chapter, I will address one by one the three sub-questions related to this.

## Development of the Partnership (Research Question 1)

*How has the partnership between the university and the school district developed?*

In this section, I will first describe the development of the overall partnership, and then address the development of each of the embedded programs that resulted from the partnership. The timeline in Figure 4.1 (p. 115) will be useful to refer to.

### *Development of the Overall Partnership*

#### *External Political Drivers: The City of Vista Mandates the Partnership, 2004-2008*

> I watched [the partnership] begin when I was down at City Hall and watched President Mayfield [from MWU] shake hands with Mayor Newell [City of Vista]. And I didn't know anything about it, except my wonderful mentor and our former superintendent Alice Hughes said to me, "You want to be there to watch this." So OK. Because she said big things are happening. So I of course went down and watched that handshake and you could tell big things were happening. Having a major research university bring a significant part of its research to Vista? Very exciting. And so I think then the wheels started turning. And of course in Dr. Hughes' brain, the wheels were turning, and this just made them turn a little faster. You've gotten to know her, and when opportunity knocks, well –. *–Joyce Lancaster, former Science Coordinator at VSD*

A deal was struck. Discussion began in 2004 regarding the university acquiring land to build a satellite campus in the metropolitan region, and an agreement was signed in 2007 with the suburban city. It had been the vision of the former president of MWU and his administration, along with leaders of the City of Vista. Within the vicinity of the large metropolitan region that included Vista was a thriving animal health industry, and leaders at MWU wished to establish a satellite campus to serve as a portal between the university and the animal health industries. However, the metro region lay in the jurisdiction of another state university, and according to state laws, MWU was ineligible to establish a satellite campus for undergraduates. Nonetheless, the common interests of MWU and the metro region animal health industries had already spawned collaborative working groups and research initiatives, even though MWU was two hours away. Eventually, through strategic planning and development of relationships, a workable agreement was formed that could satisfy numerous interests. It would allow MWU to establish a satellite campus in the metro region with research labs focused on animal health – an area of expertise not shared with the other major state university. It would be dedicated to "integrating education, research and entrepreneurship focused on animal health … to address the needs of a rapidly changing world." Additionally, the proposed MWU satellite campus would only focus on graduate education and K-12 education, so as not to compete in undergraduate education with the other state university that had jurisdiction in the metro region. In so doing, K-12 education became part of the mission of the new MWU-Vista campus. This mission was reinforced when the City of Vista granted MWU the land on which to build the new satellite campus. They did so with the stipulation written into the memorandum of understanding that MWU would partner with the Vista School District.

> They [the city] deeded thirty-eight acres to MWU. … Those people that put that first memorandum of understanding together were very insightful. It had in it specifically that you will have a relationship and engage the school district in Vista. … It said, we're talking about education. *–Phillip Hendricks, Dean at MWU-Vista Campus*

Exactly how MWU should partner with the school district was left "nebulous," according to Phillip, yet some engagement was mandated. With the agreement in place for the land grant, planning commenced for the new campus that was to connect MWU to vital interests in the animal health industries in the metro region.

Since the new MWU campus could not rely on undergraduate tuition, it needed another revenue stream to finance it. Again, in a spirit of innovation and collaboration, a consortium of higher education and research institutions in the county came together and proposed a sales tax to raise revenue to be shared among them. The leaders of the institutions, including Phillip Hendricks, dean of the future MWU-Vista campus, campaigned with other civic leaders for citizens to approve a county-wide sales tax during the November 2008 elections. In spite of the sudden economic downturn at that time, the sales tax ballot measure passed, ensuring a revenue stream from which the new campus building and labs could be built and maintained. In order to raise the tax, commitments were made to the citizens of the county that the institutions for higher education would invest in local education, including in K-12 schools. Vista School District was the largest school district in the county.

***Getting Acquainted: Sharing and Educating Each Other, Spring 2008***

Former superintendent at VSD, Alice Hughes began meeting with Phillip Hendricks privately in early 2008, "kind of checking each other out," as she told me, "his sharing and educating me as superintendent on what MWU's vision was. And I learned a lot about animal health sciences….  I had a lot to learn from him, and I'm seeing all sorts of connections.  I mean it was just quick."  She continued:

> This was a leap of faith on MWU's part.  They had land, and they had a couple staff members up here, and they were living in Chamber (of Commerce) offices, and they had us at the school district.  *–Alice Hughes, former Superintendent at VSD*

Sharing and educating each other about each institution was important so that members could gain a sense of what resources each partner had in place as a foundation to plan together. Beginning in March 2008, tours of high school classrooms in the district were arranged for the leaders of the MWU-Vista campus.  Most impressive to these university leaders was the innovative educational approach of the district's Twenty-First Century Programs.  These were transfer programs based in the four district high schools and that focused on specific professional learning tracks such as engineering, geosciences, environmental design, culinary arts, and biotechnology.  Not every high school student had to choose to enroll in a Twenty-First Century Program – they were options that existed alongside and within the comprehensive high schools. However those that did experienced an innovative curriculum oriented to twenty-first century skills.  These programs relied on the interactions of district teachers and administrators with business partners, higher education, students and parents to create novel curricula, creative projects, and leading-edge internship opportunities that allowed students to explore their interests while gaining valuable workplace skills and rigorous content knowledge.  The university faculty leaders, with backgrounds in biology and biotechnology themselves, were astonished to see the expertise in the high school biotechnology classroom.

> It had a very rigorous curriculum with a robust laboratory component.  The students worked with DNA and protein in the classroom, and the classroom was equipped with state-of-the-art equipment, very similar to what was in the university labs.  The teacher was a highly experienced scientist-educator, had won teaching awards and had experienced university research labs during the summer.  And career exploration was very much encouraged, as per the story I told you – this is how I got into it. *–Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The classroom visit included the former Chief Academic Officer's talk on animal health careers to students, and this was the context in which the student mentioned at the start of the chapter asked the question about whether she could do veterinary research.

> And with that question, the wheels started turning in my mind: What could we do in the context of the existing infrastructure that will give us some pilot data, perhaps open our eyes to where some of the road bumps and where some of the good times are going to be in this collaboration, and perhaps get us some data to write a grant? – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Susan initiated a pilot project to respond to this student's question, arranging with the biotechnology teacher to have a few students work on an authentic research question through one of the animal health laboratories at MWU. This would be known as the Senior Biotechnology Project, and was started even before formal strategic plans were made for the details of the partnership. Susan and the district administrators agreed it would be an informative project for the overall partnership. While Susan worked to gather resources for the pilot project, and arranged to have students visit the main campus of the university to tour labs during the summer, formal planning for the larger institutional partnership continued.

***Committing to Mutual Learning: Moving Beyond the "Shotgun Wedding," Spring and Summer 2008***

The overall land deal was made, and a partnership between MWU and VSD was stipulated in the memorandum of understanding as part of the agreement. Yet the nature and form of the collaboration was not delineated. In order to develop an overall partnership plan, people from both institutions met to get to know one another and find common goals, and this process was formal and guided. Alice Hughes integrated the partnership planning with VSD's own strategic planning effort by enlisting the external firm who guided the district's planning, Vision Lead, Inc., to also oversee the partnership planning effort.

The initial large formal meeting on June 3, 2008 included members from both institutions. The VSD superintendent, associate superintendent, program directors, and curriculum coordinators were present, as were the MWU-Vista dean, chief academic officer, and key science and education faculty members at MWU who were experienced in K-12 STEM outreach. The dean of MWU-Vista and the superintendent of VSD presented each institutional perspective, and charged a committee through the facilitation of the Vision Lead team, to move forward with planning the partnership. From that point on, the dean of the MWU-Vista campus left the leadership of the partnership on the university's side to Susan Rasmussen, chief academic officer of the MWU-Vista campus. Alice Hughes, superintendent of the school district, would still be involved in the partnership, though relying largely on the district administrators for the day-to-day implementation. The committee reported back to the dean and superintendent in August, and the general situation in building a collaborative relationship was formally articulated:

> With the new MVU-Vista campus, the opportunity for Middle Western University and the Vista School District to work closely together has presented itself. To be successful, this partnership will require nurturing and learning together. *–Vision Lead Notes from August 26, 2008 meeting*

Having a third party lead the initial and subsequent planning meetings allowed members from both institutions to focus on getting to know one another, identify common goals, share what assets each had, and develop common focus. The facilitators wisely asked the group to consider whether or not they truly wanted the partnership, since it was designed through external political drivers. One VSD administrator jokingly described the political arrangement as a "shotgun wedding." Yet when asked what some important agreements were made at the beginning of the partnership, she responded:

> I just think the commitment to make it work…. I think everybody agreed, 'yeah,' which was a conversation we had at the very beginning. Do we want to do it or not? We really did kind of weigh it – you know, here could be some plusses, and here could be some minuses, so is it a good thing or isn't it a good thing? And from that conversation I think we realized it wasn't just that somebody was telling us we had to do this. We really were ready to buy into it and commit to it to make it work. *–Beatrice Price, Director Secondary Programs at VSD*

The school district personnel brought to the table considerable experience in developing partnerships with business and higher education entities, particularly in relation to their 21$^{st}$

Century Programs, and their guidelines were distributed. The Vision Lead facilitators shared additional information on the principles of successful partnerships. These templates were discussed in the initial meetings and included the elements of shared values, commitment from institutional leadership, open two-way communication, management system for planning, mutual respect, trust and honesty, written descriptions of roles and responsibilities, a point person identified to manage the partnership, mutually beneficial goals and expected outcomes, and time to understand each other's culture and procedures. These principles, made explicit from the start, were integrated into the planning processes, especially through the guidance of the Vision Lead facilitators. By carefully cultivating a sense of respect and common agreements, partnership members began to develop a strategy for producing tangible outcomes of their work together.

> I think that the initial meetings were where we really – very heartfelt – articulated sort of a larger mission and a dedication to collaboration. *–Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

***Creating the Vision, Summer and Fall 2008***

The Vision Lead facilitators organized the joint strategic planning meetings to address the following (from meeting notes):

- Context and situation
- Vision
- Elements of partnership activities or infrastructure
- Criteria and/or data to inform planning
- Concrete steps, projects and activities

This structure was used to not only focus the planning of the overall partnership, but also to iteratively plan particular program areas and the collaborative relationship as they developed. When addressing the context of the overall partnership, several things came to the fore, especially the contextual factors related to the innovations each of the partners were implementing on their own. These included the school district's Twenty-First Century Programs and the university's new Vista campus dedicated to animal health research.

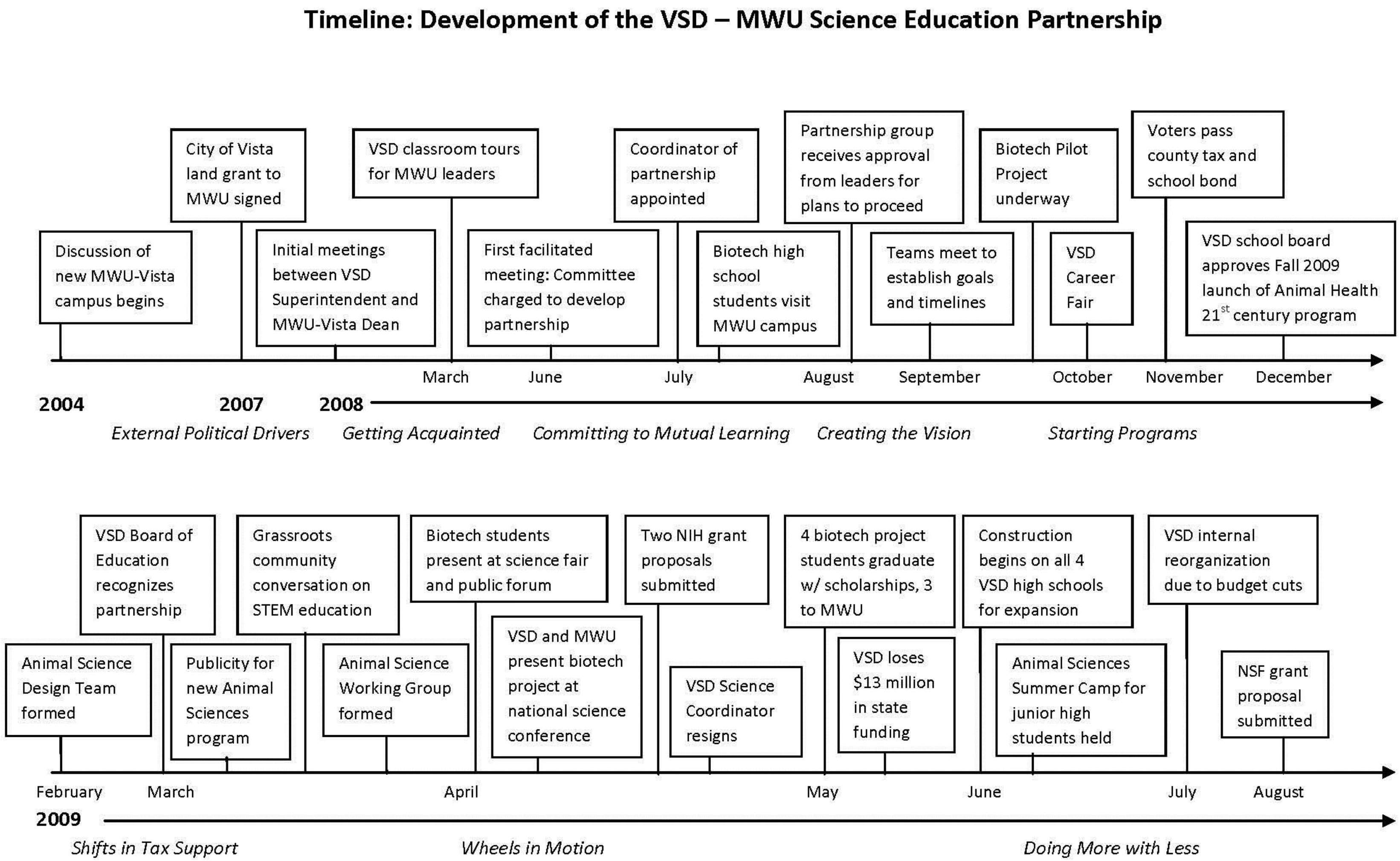


**Figure 4.1 Timeline of the development of the science education partnership between MWU-Vista and VSD –** Continued on next page.

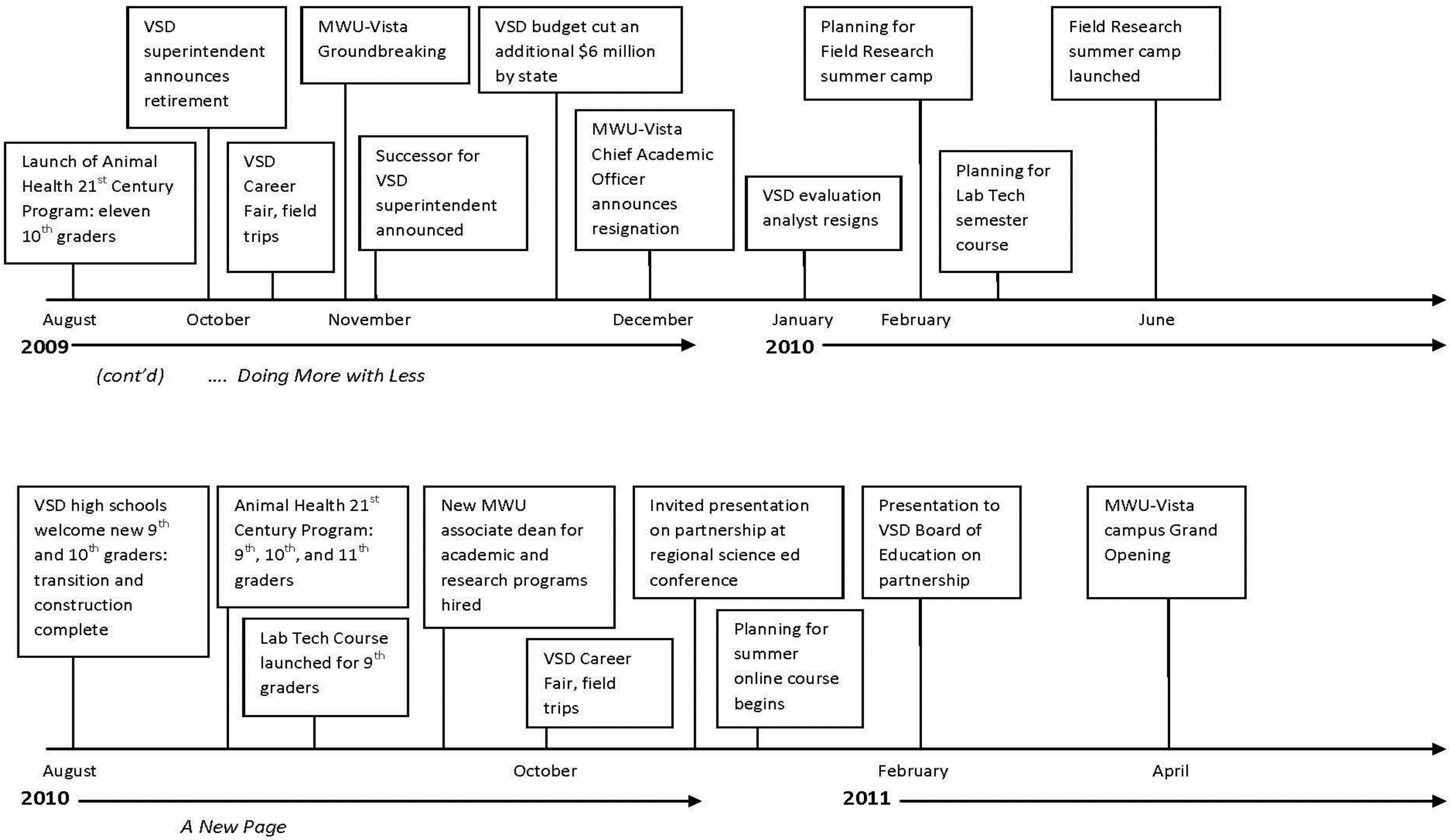


**Figure 4.1 (continued) Timeline of the development of the science education partnership between MWU-Vista and VSD.**

The leaders of the MWU-Vista campus had already been impressed by their tour of the district's Twenty-First Century Programs. They learned that in 2003, the school district launched these programs to address twenty-first century skills through professional learning communities. They were transfer programs within the four main high schools that oriented student learning to career tracts that included among other themes electronic communications, engineering, culinary arts, sports medicine, geosciences, and biotechnology. General comprehensive high school programs remained intact, and only students who wished to enroll in the Twenty-First Century Programs did so. In turn, students who did enroll in these programs had the opportunity to earn endorsements in the professional focus area. The endorsements consisted of a certificate documenting a student's completion of the program with special skills in addition to his or her high school diploma. The endorsements served as a signal to employers and higher education institutions that the student had met rigorous program requirements.

Prior to the launching of the Twenty-First Century Programs, citizens of the school district had approved a school bond to finance the new infrastructure needed to accommodate these programs. State-of-the-art equipment, new classrooms and teacher training were funded for these purposes, and partnerships were forged with relevant businesses, industries, and higher education institutions to support these programs. The Vista School District was among a wave of schools across the nation investing in the concept of educating students with twenty-first century skills. These skills include experience with relevant and real-world applications to learning, interaction with community members as mentors, interaction with faculty at higher education institutions, experience working in collaborative teams, skills to integrate technology and international awareness, and practical knowledge of contemporary career options. Given the success of the Twenty-First Century Programs in the Vista School District, and the wealth of experience administrators and teachers had with this approach, it seemed natural that members from VSD would see these programs as a natural point to interface with the university.

Alternately, the Middle Western University-Vista campus had a natural interface point given their mission to " integrating education, research and entrepreneurship focused on animal health … to address the needs of a rapidly changing world," as described above. The location of the MWU-Vista campus in the metro region was strategically poised to build relationships with the relevant industries in the area. Because of the close working relationships MWU-Vista leaders had with these groups, important credibility and access to regional animal health businesses followed, including advice that would benefit workforce development. In summer 2008, partnership members met to find natural areas of collaboration.

> My recollection is that at the first [group] meeting we kind of batted around [the idea of] – What are twenty-first century programs, for those of us who were ignorant. And then also, what might MWU bring to the partnership, you know, what would be within our capabilities of contributing, and what would the district be interested in pursuing? I think that was the subject of that first meeting – kind of, where's the fit? *–Barbara Shepard, MWU faculty scientist*

By August, 2008, the vision for the MWU and VSD Partnership was articulated as together striving to:

- Demonstrate a national model for pre-college outreach that is first to market and ranked #1 nationally
- Create new and better relationships between college faculty and K-12 teachers
- Continue to help students connect their classroom learning with contemporary issues and career opportunities
- Continually demonstrate that students can be contributors
- Support Science, Technology, Engineering and Math (STEM) workforce development both for the region and for national competitiveness
- Advance a shared vision of scientific and mathematical literacy
- Develop the infrastructure to sustain our partnership connections

*– Vision Lead notes from August 26, 2008 meeting*

While key individuals were important to success, it was recognized and stressed in those early meetings that sustainability of the partnership would depend upon creating reliable infrastructure within both organizations.

> We understood that we needed a system and structures that would be both flexible and sustainable. It couldn't be about individuals – it had to be about infrastructure, about personnel's roles and responsibilities rather than about their personalities or specific individual skill sets. *–Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The group identified elements of the partnership infrastructure that would:

- Link educators, K-12 teachers and MWU professors
- Explore ways to link the research that takes place at MWU with the K-12 classroom
- Continue helping professors share the broader impact in what they are doing
- Engage teachers in grant opportunities
- Explore learning opportunities in which the teacher's role is shifted to facilitator or coach
- Address and minimize real and perceived barriers that hinder the development of the above foci

*– Vision Lead notes from August 26, 2008 meeting*

The strategic planning group decided together that an initial goal for the partnership would be to develop an Animal Health Twenty-First Century Program within VSD to be launched in fall 2010. Subsequent focus areas for new Twenty-First Century Programs would be assessed in the future, though university contributions in other areas could be integrated into existing school programs immediately. These other areas are not the focus of this study, as they did not result at the point of data collection in innovative programming.

All participants interviewed for this study who sat in the strategic planning meetings stressed that decisions were made jointly and by consensus, though admittedly within institutional constraints and given resources. For instance, in reference to choosing the animal health focus, Barbara Shepard notes:

> [The decision for] those focus areas were made unilaterally by the university, not in consultation with the school district, but in terms of what the campus's focus would be. The decision to develop the … 21st century emphasis areas or programs was obviously made in consultation with the district. They had to make that decision. But they could have chosen to only develop one, or to modify to some extent, say, 'Well, we're interested not in animal health per se, but this.' So it wasn't imposed on them but it was presented I believe probably at the very first [private] meetings that these are our focus areas that we're mandated to be working on." *–Barbara Shepard, MWU faculty scientist*

The group also identified the need to specifically focus on "building the collaborative relationship," with a vision articulated to:

- Broaden existing system linkages and create new ones
- Leverage the collaborative relationship to enhance student success
- Create the system and structures that result in a flexible and sustainable collaborative relationship
- Explore new ways to link MWU teacher education with K-12
- Engage the business community in these efforts to both enrich learning opportunities and address critical workforce needs
- Establish evaluative measures for our collaborative efforts

*– Vision Lead notes from August 26, 2008 meeting*

In a public presentation, Susan Rasmussen reflected on the process of learning about each other's organizations:

> The assets that we counted in place were many…. So together we felt we had a pretty good foundation to build upon, and yet we knew it was still very important to make what we built such that the whole was more than the sum of the parts. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Participants recognized that in order to realize the vision they articulated, they would need a partnership coordinator to synthesize the respective resources and give the partnership the attention it needed on a day-to-day basis. A half-time coordinator position was created that would be financed by the university and housed within the district. Dedicating a new position required the support of the university, and the position was originally created for a graduate research assistant. I was recruited by Susan Rasmussen for the position.

> We decided if this was really going to work, we were going to have a need for a translator and a coordinator, someone who could really walk the walk of K-12 and the walk of the university. So we dedicated a coordinator position, and we were able to hire someone with K-12 classroom experience and a master's degree, a research-based master's degree in biology who was already working on a dissertation in education. So I

> think who the individual is, is much less important than the fact that we understood we would need someone to be a liaison, someone who could help manage the cultural clash that would be nobody's fault but that would result from the differences, and someone to keep us on track. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

I was originally given an office in one of the high schools so as to have access to teachers, classrooms and students. As a former teacher myself, I was familiar with school systems, their structures and culture. Additionally, having spent at that point five years working at MWU as a graduate student both in biology and in education, I was familiar with the systems, structures and culture of the university. I began attending the partnership meetings in September 2008.

***Starting Programs, Fall and Winter 2008-2009***

By the start of school in fall 2008 the Senior Biotechnology Project, which was sparked by the student's question to Susan Rasmussen, was underway. Four students were identified the previous spring to work on this as their senior project. Two of the four toured the main MWU campus during the summer and met with researchers, and a project was identified. A post-doctoral fellow was dedicated to the pilot project to direct the research, and to work with the teacher and partnership coordinator to help the students execute the research. The partnership planning committee received regular reports on the project's progress.

Meanwhile, the strategic planning group designated a design team to begin "drafting a joint outline of how a Twenty-First Century transfer program in animal health could be developed … utilizing a target date of 2010 as it begins to explore what this effort would involve (Vision Lead notes from September 29, 2008)."

Cultivating interest for the new Twenty-First Century Program could be done through the annual ninth grade career fair (the year before students choose high school programs) and through summer camps for junior high school students. These were two tangible outcomes to work on, and I worked as the MWU representative with two district administrators to realize these goals. Other activities such as engaging the students in the electronic communications twenty-first century program to develop a website and videos for a university researcher were also initiated.

> We looked at existing opportunities for integration and innovation.  We looked at what was already in place on both sides.  And we saw that there were already career fairs, opportunities for classroom visits to talk about careers.  There were summer camps.  And there were the twenty-first century programs which provided us opportunities to participate in existing programs and new programs.  And I very much remember the day that the working group met to talk about this…. And I remember sitting at the table and thinking, you know, we have a lot of very busy people sitting at the table here.  And we want to make sure that what we do first is going to succeed. … And I thought, we could do career fairs.  You know, I mean how hard is it to make a poster and put something up, and we all like talking to kids about their future.  – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The district-wide career fair for ninth grade students held on October 7, 2008 consisted of representatives from regional businesses, organizations, and services at designated tables with whom students could visit.  In addition, it featured displays and tables highlighting the district's twenty-first century programs with the teacher facilitators and advanced students present to talk with ninth graders who were interested to learn more.  Researchers and representatives from MWU were also featured with the Twenty-First Century Programs to showcase the partnership and the developing Animal Health Program.

> These tables will be 'branded' with signs that include both entities' logos and indicate a partnership effort brought these together.  –*Vision Lead notes from September 29, 2008*

The career fair catered to over 2,000 students as well as their teachers during the school day.  In the evening hundreds of district parents attended with their children to learn more about the twenty-first century programs, many of them noting the partnership with MWU on display.  These initial concrete activities gave individuals from both the university and the school district focused opportunities to interact, to establish lines of communication, and to represent themselves together to their constituencies.  By working with the Vision Lead facilitators, meetings were opportunities to reflect on the events and collaborative relationship, and set new goals.

> [Decisions] were carried out by the people that assumed responsibility for doing it. And I think that was part of the conversation around the table too: "Who's going to take the lead?' 'What roles are different people going to assume, and different organization – either, between the two organizations—going to assume?" – *Beatrice Price, Director Secondary Programs at VSD*

The partnership strategic planning committee met every six weeks initially, but as activities were underway, a quarterly meeting schedule was agreed upon at the September 29, 2008 meeting. The Senior Biotechnology Project was well underway, and recruitment and curriculum planning for the Animal Health Twenty-First Century Program were also being worked on. National grant requests for proposals were reviewed by team members for joint application. An online repository for meeting agendas, minutes and reports was created using MWU's framework which allowed both university and district personnel to access it. And a concerted effort by team members was made to document the activities as they occurred.

***Shifts in Tax Support Affect Partnership, Fall and Winter 2008-2009***

As the partnership gained momentum and program development continued, the nation started tumbling through the tumultuous economic decline that would become known as The Great Recession. The impacts on the partnership institutions, both supported by tax dollars, were not yet fully known, except it was understood they would be significant. This gave the tax initiatives that each partner institution was campaigning for in 2008 extra weight.

Two years earlier, MWU-Vista campus leaders had joined with leaders from two other major institutions in the county to form a consortium for higher education and research. The consortium campaigned for a county-wide tax to help provide a necessary revenue stream to each institution. This would form a key revenue source for the nascent MWU-Vista campus. Whether county citizens, who were themselves feeling the sting of the economic downturn, would approve of such a tax seemed increasingly uncertain.

Also being put to the vote was a VSD bond proposal to implement a major change advocated by the Vista Board of Education in spring 2007. The proposal was to switch the district from using a junior high school model to a middle school model, that is, to move district sixth grade students from the elementary schools to middle schools for grades six through eight, and move district ninth grade students to high schools for grades nine through twelve. Up to this point, the high schools housed just grades ten through twelve.

> They chose to do this for three reasons: to relieve crowded elementary schools; to provide expanded opportunities to students; and to cut operating costs by a minimum of $1.25 million annually. *–MWU-Vista campus report to MWU Dean's Council, April 13, 2009*

Remarkably, both taxes were passed by the county citizens on November 4, 2008.

> I've had people calling me from all over that cannot believe that that could happen. They said, "Wow, what a testament to [the] county's commitment to education."
> *–Phillip Hendricks, Dean of the MWU-Vista campus (media report)*

With this revenue now assured, planning for construction of the first building on the MWU-Vista campus began in earnest. And with the school bond passing, plans were implemented for the district changes, which would include additional construction to all high school facilities to accommodate an extra grade of students. The transition to a district middle school model would take effect in fall 2010.

Following these successful voter outcomes for both partners, VSD administrators approached MWU-Vista about launching the new Animal Health Twenty-first Century Program in fall 2009, a full year earlier than proposed. The district leaders recognized that in fall 2010, they would be executing a major change in welcoming new ninth graders as well as new tenth graders at the four high schools – half the students would be new to each school. They reasoned that it would be advantageous to launch the Animal Health Program a year in advance of this change so that the program could become established before integrating two new cohorts of students at once. The district administrators proposed this plan in a November 2008 meeting, and the MWU participants agreed to the plan. In that same meeting, the decision was made to house the new Animal Health Program at Vista North High School, one of four high schools in the district and the one with the largest degree of diversity and the highest level of economically disadvantaged students in the district. Personnel, coursework and relationships with other programs were explored.

The next major step was to gain approval from the district's board of education to start a new Twenty-First Century Program the following fall. The district superintendent had already been keeping the board abreast of the developing partnership with the university, and had considerable support. She discusses the process of consensus-building with the board.

> It was easy – this was not like getting people to vote for a bond. This was easy. The reason it was easy is because … there was what I would call good branding…. Having a regents' institution locate in the Vista School District in the City of Vista was good branding …. The Vista School District is a good brand. *–Alice Hughes, former Superintendent at VSD*

While the branding may have been good, the economic times were getting harder, and the board of education was preparing for major cuts in state income the following year. The district leaders were well aware of the likely response from the board had they asked for new expenditures. Therefore, in the process of gaining board approval to launch a new twenty-first century program, the associate superintendent, who made the presentation, assured the board that no new expenditures would be required. As well as communicating the commitment of MWU to deliver lessons, mentorship and field experiences to district students as part of the partnership, the following points were made in a written proposal presented to the Vista board of education in December 2008:

- No new coursework will be added for the sophomore year. Coursework will be comprised of courses already in existence in the District's science program and science coursework only available at Vista North, such as Forensic Biotechnology.
- Cost effective implementation: Existing staff will be used for this new transfer program. It is anticipated the 15 or more students who are accepted into this program will complement and enhance enrollments in other 21st century high school science-themed programs at Vista North High School. Current resources will be re-allocated from existing budgets."

*– Presentation to Vista Board of Education, December 2008*

Details of the development of the Animal Health Twenty-First Century Program and other programs will be outlined in the "Embedded Units of Analysis" sections. For our purposes here, it is important to note that the contexts of both institutions were quickly changing due to the national economic crisis combined with the local mandates attached to the school bond and university tax that voters had just approved. Both institutions started experiencing the uncertainty and constraints of extensive budget cuts, of dollars needing to stretch further, and of staffing cuts. In addition, both institutions had increased demands due to the ambitious projects to which they had each committed. Leaders, however, were optimistic.

> And so we're not asking for a budget increase. And we had to do it under those – not the level we wanted if we would have had the funding, but we did it with what we had and redesigned and reprioritized. Those were kind of the official steps. Any of us know once you get your foot in the door, you can grow it. If in fact it's successful. You know, if the door's not open wide enough, it can close real quickly. But if you get it open wide enough, and it's successful and people still see the need for it, you then have a chance to institutionalize the innovation. *–Alice Hughes, former Superintendent at VSD*

***The Wheels in Motion, Winter - Summer 2009***

By the next meeting in February 2009, two programs were fully underway: the Senior Biotechnology Project with the four high school seniors was in full implementation; and the new Twenty-First Program focusing on animal health was to be launched in a matter of months. The working group for the Senior Biotechnology Project was formed essentially *ad hoc* and met frequently to keep the project moving. An Animal Health Twenty-First Century Program design team was officially formed in February, consisting of VSD administrators and teachers, and MWU-Vista faculty scientists, and junior scientists including me as the partnership coordinator. Joyce Lancaster, VSD science curriculum coordinator, took the lead on this design group, calling meetings, generating agendas, posting notes on the online repository, and synthesizing concrete plans for the new program. Soon a smaller working group for the new Twenty-First Century Program was formed composed of a smaller number of VSD administrators and teachers, and me as the MWU liaison. Meetings with groups from both projects occurred regularly, and reports from them formed the majority of the large partnership meetings. A regular rhythm began to form between working in small groups to convening again in the large group.

> Remember, we'd do the bigger group, we'd to the smaller group, we'd – you know, the MWU group would have conversations, and we would have VSD conversations, and we'd come back to the table. I think there was a lot of that going on. I don't know if we

recognized that at the time, but that's what really was happening. – *Beatrice Price, Director Secondary Programs at VSD*

In addition to the main partnership projects, other events helped strengthen the working relationships. Due to the access I had as coordinator of the partnership to both the district and the university, I was able to help realize requests that came from teachers. For example, we were able to have MWU faculty from the Journalism and Mass Communication department take part in a festival sponsored by the Electronic Communication Twenty-First Century Program in the school district in February 2009. Also in the spring, MWU scientists and outreach staff participated in a VSD district Family Science Night.

Throughout the fall of 2008 and winter of 2009, I served along with VSD district administrators on a planning committee for a collaborative grassroots project throughout the county focused on a community conversation about science, technology, engineering and math (STEM) education and workforce development. Other school districts and institutes of higher education in the county were also represented on the planning committee, and the event brought hundreds of business and industry leaders, parents, educators and students together to discuss the issues. The conversation was focused on outcomes the community wanted to see based on the county-wide tax the citizens just passed to benefit the MWU-Vista campus and two other institutes of higher education and research. The community responded overwhelmingly that they wanted to see greater relevance in education to real-world needs and work-force development, greater integration of K-12 education and higher education and research, and greater integration of business and industry with both K-12 education and post-secondary education and research. Not only did the VSD and MWU personnel feel we were doing what the community wanted us to through the partnership, our work together in this project bonded us even more as we became part of a shared community with a common vision.

The Vista School District board of education formally recognized the MWU-VSD partnership and lauded its accomplishments in its public meeting in March 2009. The students in the Senior Biotechnology Project presented the research they conducted with the MWU lab at the metropolitan science fair, as well as in an evening public forum at their school. Not long after, the biotechnology teacher, the post-doctoral researcher and I presented the project at a large national scientific meeting. Our travel, lodging and the teacher's substitute were underwritten by the MWU-Vista campus.

In order to explore long-term funding and data gathering opportunities, meetings occurred between the VSD evaluation analyst, the MWU director of external evaluation, and Susan Rasmussen. They reviewed data collection processes for the district's twenty-first century programs, and began to think about research questions that could be addressed through the partnership efforts. The VSD analyst prepared to track graduates and college success rates. These conversations helped develop plans for grant proposals. Two major grant proposals in support of the partnership were submitted to the National Institutes of Health in April 2009 and another to the National Science Foundation in August 2009.

> It was great that we had evaluation components from the school district and MWU speaking together from the beginning. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The final large strategic planning partnership meeting of the year facilitated by Vision Lead occurred on April 28, 2009, and it consisted mainly of reports from the very active working groups.

***Doing More with Less, Summer 2009 – Spring 2010***

Just as all these activities hummed along, Joyce Lancaster, the VSD science curriculum coordinator, who led much of the partnership planning on the district's side, announced her resignation effective at the end of June, 2009, just after the summer camps. Happily, she was taking a position at a nearby university; however her loss at the district left a leadership void. Similar to school districts across the country at the time, VSD found itself managing "a loss of $13 million in state funds by eliminating or leaving unfilled nearly two hundred positions, and merging responsibilities into other employees' roles" due to the economic crisis (MWU-Vista campus report to MWU Dean's Council, February, 2010). Joyce's position would not be replaced, but rather her responsibilities would be distributed to other staff. Before she left, she helped oversee the Animal Sciences Summer Camp, consulted with MWU faculty before purchasing new lab supplies, and met with me to make arrangements for her departure. Yet due to the ongoing reorganization within the district, new liaisons remained unclear. In addition, it was still unclear who would be the teacher for the new Animal Sciences Twenty-First Century Program, which would be launched with a small group of sophomores that fall (2009).

Beatrice Price, VSD director of secondary programs who had been involved in the large partnership meetings from the start, would be the university's point person during the district's summer transition to new personnel and as the new Twenty-First Century Program started. She also asked for patience from MWU personnel as internal district restructuring continued due to budget cuts. Ironically, that same summer new construction commenced at all district high schools relating to the transition of the ninth graders moving from the junior highs to the high schools. The construction was funded by the bond passed the previous November and would continue throughout the entire next school year. An immense amount of reorganization, both internal and external, was occurring in the school district.

As school started in fall 2009, a teacher was secured to lead the new Twenty-First Century Program, Michael Dunlap. The new group of eleven students enrolling in the new program would all take a class he taught, and hence at least the first year of programming was secured for this pioneer cohort.

The new 2009-2010 school year started before the partnership groups met officially again. The district teachers and administrators had an enormous amount to do just to start the year rolling and were relieved once the school year was underway. In the meantime, Beatrice Price consulted with the MWU staff to move ahead without the use of the Vision Lead facilitators. Contracting with Vision Lead was an extra expenditure at this point, and everyone agreed that we had at this point developed our own working relationships and established our own channels of communication that did not depend on external facilitators. In September, a re-formed design team convened under the guidance of Beatrice Price. Janet Spencer became VSD science facilitator, which carried many of the same responsibilities as the former science coordinator, but with a lower rank. She and Linda Bradley, coordinator for career and technical education, joined the partnership team and would handle day-to-day district responsibilities for the partnership. I also picked up many of the responsibilities Joyce had managed. The teacher leading the new Twenty-First Century Program, Michael Dunlap, and another experienced teacher, Steve Graham, also sat in the meetings. And so we proceeded without a third party facilitator, which at that point seemed appropriate.

> So [having Vision Lead] was very helpful. But I also think that we saw in the evolution of the partnership that it was OK that faded out. We had identified our own communication streams, our own connections, our own way of keeping things going, and didn't really need a third party. … I think they could have continued, and we could have continued to use them. … But my sense anyway – this is just my personal feeling about this – we had established the connection. We had established really the bonds of a partnership. We were committed to it. And that was – to me – I don't know any other way to describe it other than to say it was just like an add-on, an extra … because we knew where we wanted to go. – *Beatrice Price, Director Secondary Programs at VSD*

Students were now enrolled in a three-year (soon to be four-year) Twenty-First Century Program that both institutions were publicly committed to, so there was immediacy in needing to create structure, activities and resources for them.

> You know, we're all deadline driven. And the real expectations and impact of participants [students] created deadlines that had to be met. And deliverables that had to be ready. And that's how things get done in general, you know. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

As the 2009-2010 school year progressed, the larger program needed elements for students in years beyond the sophomore one. In addition, teachers identified needs they would have in the upcoming year with a new grade of students joining the high school, the ninth graders. The district asked the university personnel to help meet these needs, and much of the year was spent coordinating and developing these elements. A new semester-long course, Lab Techniques (Lab Tech), would be co-developed by the district and MWU-Vista for all students entering one of the three science-oriented Twenty-First Century Programs at Vista North High School. New summer modules, a Field Research Camp and an online course, would be co-developed and led by MWU-Vista to give students experience in scientific research and higher education. The Lab Tech Course and one of the summer modules, the Field Research Camp, form two additional programs analyzed in this study as embedded units of analysis. A second summer module, an online course for high school students, was only just being developed during data collection for this study, and so will be referred to but is not in itself a unit of analysis.

A number of regularly scheduled meetings helped move the program planning forward. The full application for approval by the Board of Education of the new Animal Health Twenty-First Century Program progressed, and was handled by the two VSD administrators new to the partnership committees. Special meetings with them and me helped provide them the context and necessary history, and also helped us get to know one another and share the tasks ahead as we each saw them. Overall, there were different levels of working groups involved in developing programs, as Susan describes below.

> We had groups meeting at the strategic, the operational and the tactical levels, and all of those groups contained people from both the university and the school district. When we were talking about tactics, we really had groups that were dominated by the school district and you might have been the only person from the university side at those meetings. The strategic meetings were very very balanced. And the ops meetings were pretty balanced too. If the ops meeting was dealing with an issue that was more owned by one side than the other, there might be appropriate representation. So I think we actually had sort of a good structure for making things go forward. And again, we had a coordinator position whose job it was to make sure the ball never got dropped on either side. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista camp*

Several partnership events filled the fall of 2009. The Animal Health students toured the main flagship campus and the veterinary college two hours away, and a group of advanced biology students attended a national public health conference held at the campus. MWU faculty came to Vista to participate in the annual VSD career fair and Family Science Nights and hear student presentations.

MWU-Vista personnel moved into temporary offices, and I was given a small desk in the common room there. Plans for the start of construction of the first building on the new MWU-Vista campus culminated in an official groundbreaking in early November 2009. This was a large celebration with state and local dignitaries in attendance. The land grant by the City of Vista was reiterated, and the partnership with the school district was very visible by strong attendance by VSD administrators. Notably, Vista district high school students were the official videographers of the event.

A wave of personnel turnover was announced that fall and winter. Susan Rasmussen announced in December 2009 her resignation from MWU, effective the following June, after accepting a leadership position at another university. The VSD superintendent, Alice Hughes, announced her plans to retire the following summer, and shortly after that her successor, Richard Miller, was appointed. Like Hughes, he had much support throughout the district. Kelly Johnson, the VSD evaluation analyst, also resigned from the district, and her position would not be replaced in the climate of severe budget cuts. The district was in fact reeling from the governor's recent announcement that they would lose an additional $6 million, for a total loss of $19 million in the 2009-2010 fiscal year, with another $9 million cuts announced for the following year.

> I think we … lost a key person from the school district in terms of institutional data management and grants expertise. And I understand completely … but the person who Vista had in terms of Kelly Johnson – Kelly Johnson had deep visions and really understood how to work at many different levels. And that was an important piece of the project. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Rather than replacing Susan Rasmussen's unique position, a different position – associate dean – was created for internal reasons, yet the MWU-VSD partnership would still fall within this job description. A search committee formed to fill the new position. I worried that Susan's departure might mean a loss of resources that she was able to bring to the partnership, so many of my tasks that year involved stabilizing as many funding commitments as I could before she left. I did this primarily by documenting our current funding commitments to the collaborative efforts and communicating those to the district and to Susan for her reporting.

Planning proceeded throughout the spring on the new summer Field Research Camp module for students finishing their sophomore year. In addition, planning began for the new freshman Lab Tech Course. The development of these will be discussed below. Additional field trips were planned and classroom visits made. The partnership planning occurred more and more through the working groups, and large strategic planning meetings with members from both institutions were sparse by spring 2010.

The last meeting of the year was a farewell gathering the district held in Susan Rasmussen's behalf. At her own retirement celebration as superintendent, Alice Hughes spoke about how much was accomplished in such a short time. Susan reflects on this moment:

> At the time of [Alice's] retirement she talked about what we had done together over the course of really not much more than a year. And she said: we promised the community hands-on, real-world learning, and we were able to keep that promise – despite the economic strife – through partnerships and initiatives such as the one with MWU. And I felt really good when this was said in the sense that I think it speaks to the fact that we came together, administrators, teachers, scientists, and started out with the idea that we wanted something that would be a mutual learning experience, and that we would make it work because we would always be outward focused, that we would always recognize that the most important outcome was student learning, and our investment in those students as our future. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

***A New Page, Fall 2010 – Spring 2011***

The 2010-2011 school year saw the implementation of the middle school transition the district had been working toward, with the newly expanded high schools welcoming two new cohorts to their schools, both ninth and tenth graders. Administrators and teachers worked hard to ease the inevitable transition challenges. I worked closely with one teacher throughout the year to develop the new Lab Tech Course that all new freshmen at Vista North High School enrolling in science-based Twenty-First Century Science Programs would take. In addition, I worked closely with the facilitator of the Animal Health Twenty-First Century program to continue programming. Students took field trips to the main MWU campus, and MWU participated in the annual career fair.

An associate dean for the MWU-Vista campus was hired in August 2010, Mark Merino, whose responsibility among others was to oversee the partnership. I toured him through Vista classrooms introducing him to teachers, and I introduced him to administrators, including the new superintendent, in a formal meeting. He also had responsibilities, as did Susan Rasmussen before him, to work with other school districts in the county as mandated by the county tax revenue stream.

I learned early in the fall that the post-doctoral researcher who had been so involved in the Senior Biotechnology Project, in helping with field trips, and in advising program development had not been funded in the new school year by MWU-Vista as he had been in former years. Therefore, he was unavailable to help as a researcher on the main campus and in the College of Veterinary Medicine. I lobbied to have MWU-Vista fund him in a small amount so as to maintain our commitments to the partnership, and that minor funding was approved for that year but would not be continued.

Partnership activities for the 2010-2011 school year took place largely through my coordination with district teachers and administrators. The main focus of activities at the MWU-Vista campus was oriented to its grand opening, which would take place in April 2011 when the first building would be complete. As such, resources for the partnership were limited, yet commitments that were made to the district were fulfilled. In late fall, I began working with university departments on the main campus to design an on-line, non-credit course as a summer module. The online course would be, as agreed in partnership meetings earlier in the year, a hybrid course with some face-to-face class time to connect with students and help them learn the tools for success in online learning environments. It would also include animal health content so students could deepen their understanding of the field and continue to pursue their interests through course projects.

The MWU-Vista campus had a commitment to VSD due to the land grant, however the county tax revenue approved by voters in 2008 prescribed that MWU-Vista would work with all the school districts in the county. From the start, the programs being developed through the partnership with VSD were designed to serve as models of what could be implemented in other districts. In January 2011, I met with the new associate dean at MWU-Vista to discuss how the partnership with VSD could not only inform and serve as models for work with other districts in the county, but the Field Research Camp and the upcoming online course could be easily offered to other districts. However at least up to the point when data collection for this study ended, the programs and modules developed through the partnership with VSD had not been adopted by other districts.

The new associate dean was not as engaged in the partnership as Susan had been. He did not engage scientists from the main campus with the partnership, and he visited the schools and met with district personnel only twice during the year. While he helped maintain the university's budget line for the collaborative projects with the district, most of the expertise from the university that Susan engaged was lost to the partnership when she left. His communication with me was sparse, often not responding to e-mails or requests for meetings. This hampered general communication with the university about the partnership, because I had few alternative communication paths. I was not invited to MWU-Vista staff meetings because I was a graduate student. Although I was the coordinator of the partnership, I was funded as a graduate research assistant. This made communication and coordination a challenge. However, by this time, most of the collaborative program development with the district relied on my own scientific expertise, and I worked closely with the district administrators and teachers to continue developing the programs.

By now the partnership was in its third year, and it was recognized as an innovative and productive collaboration. Although Susan Rasmussen had been gone from MWU-Vista for a few months, she was asked by a national science educators association to present at a regional conference on the partnership. In consultation with me, she prepared and delivered an hour-long presentation in late October 2010. A few school and university personnel were present, and it was video-recorded and shared with those who could not attend.

Superintendent Richard Miller asked VSD senior administrators to prepare a presentation for the Board of Education on the partnership in February 2011, and I was asked to join the group to represent the university. Beatrice Price led the effort. Photos from my archives were used, most of which showed students actively engaged in hands-on activities, research projects, and field trips. The board enthusiastically received the report, with a prominent board member expressing the following during the meeting:

> I think it's really important for the Vista community to understanding what's going on here … we're on the cusp of something really fantastic. I think of a Silicon Valley and a Raleigh-Durham area of North Carolina. I think we've got the potential here to have something on a national scale like that. *– Board of Education member, VSD*

The Grand Opening of the new MWU-Vista campus was held on April 26, 2011, and state and local dignitaries joined university leaders in dedicating the first building on the new campus. County school districts participated, and many students came to sing, play music, and showcase their academic work. The day was a true community affair, and Vista School District students, teachers and administrators were especially well-represented. Community members who attended responded favorably, and a letter to the editor in the local newspaper specifically noted the work MWU-Vista was doing with district students as had been seen at the Grand Opening.

The rest of the 2010-2011 school year focused primarily on finishing development of the freshman Lab Tech Course, preparing for another offering of the Field Research Camp, and preparing the new online course.

Reflecting upon the progress of the partnership, the dean of the MWU-Vista campus said this to me during our interview:

> When I first started I really was very pedestrian about the thought of what was going to happen…. I saw it very early on as – it's going to be one at a time. One kid at a time type thing. Or one class at a time. It was going to take time. That's what probably surprised me more than anything is that … it happened so fast that – kudos to Dr. Rasmussen and yourself for – and the relationship – because it wouldn't have happened if we hadn't had somebody here devoted to it. *– Phillip Hendricks, Dean at MWU-Vista campus*

## *Development of Embedded Programs*

The overall partnership evolved in a way that spawned and nurtured several projects and programs – the tangible results of collaboration. Some partnership activities could not be considered particularly innovative, like field trips, family science nights, and career talks. Numerous universities participate in such science education activities. However, the programs highlighted in this case study represent innovative programming instead of typical outreach activities. Their innovative qualities stem from having developed through true collaboration to meet unique needs and circumstances, involving scientists, educators and students.

### *Overview*

The word "program" is an all-encompassing word used to describe these four programmatic outcomes, however these four "programs" differ considerably in scope and number of students affected, and they are all intertwined. The largest program developed was a new Twenty-First Century Program in Animal Health that had a four-year curriculum. At full capacity, this program would enroll twenty-five students in each grade, thus one hundred students overall per year. It consisted of coursework and other program elements throughout the four years of their high school career. During data collection for this study, the program's pioneer cohort was just finishing its junior year in high school, and the senior year coursework had been solidified. The new Animal Health Twenty-First Century Program was housed at Vista North High School, joining two other science-based Twenty-First Century Programs already operating at that high school: the Biotechnology Program, and the Geosciences Program. Figure 4.2 below shows these three Twenty-First Century Programs.

**The Four-Year Science-Based Twenty-First Century Programs at Vista North High School**

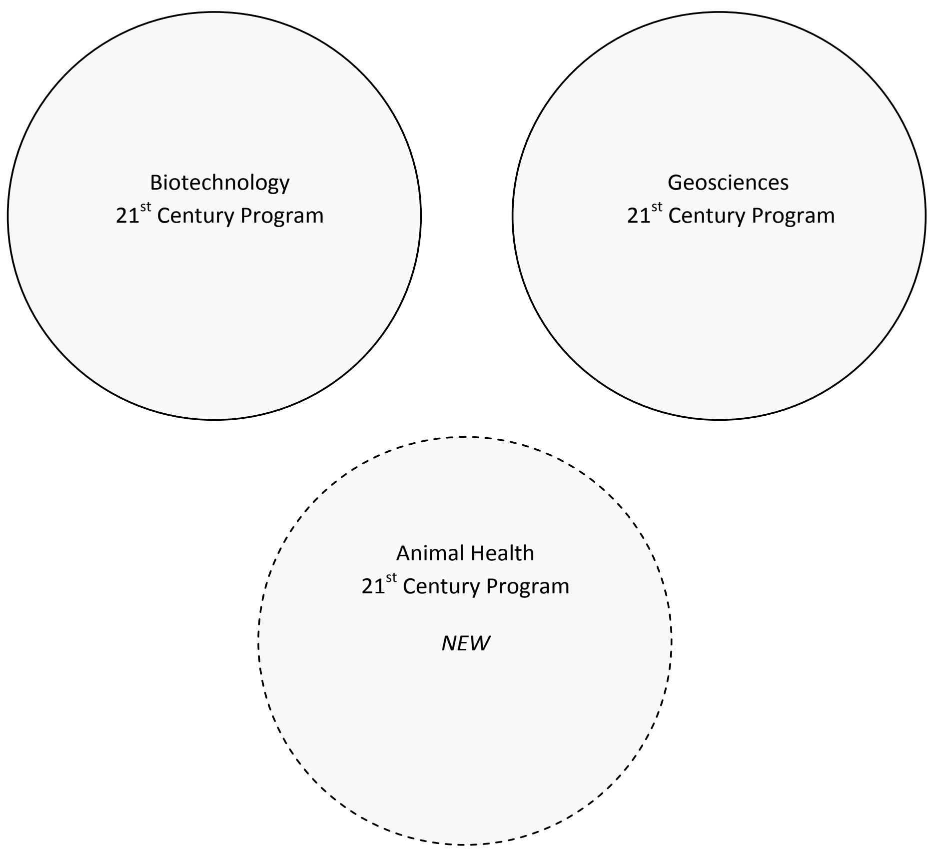


**Figure 4.2 The four-year science-based Twenty-First Century Programs at Vista North High School –** The programs existing at the start of the partnership have solid outlines: the Biotechnology Program and the Geosciences Program. The program developed through the partnership is outlined has a dashed line.

The three other programs embedded in this study consist of smaller projects and courses related to these large Twenty-First Century Programs. These other smaller programs that were designed collaboratively are the Senior Biotechnology Project, the Field Research Camp, and the Lab Tech Course. See Figure 4.3 below for an illustration of the small programs and how they relate to the Twenty-First Century Programs.

**Interrelationships of New Programs Developed Through the Partnership**

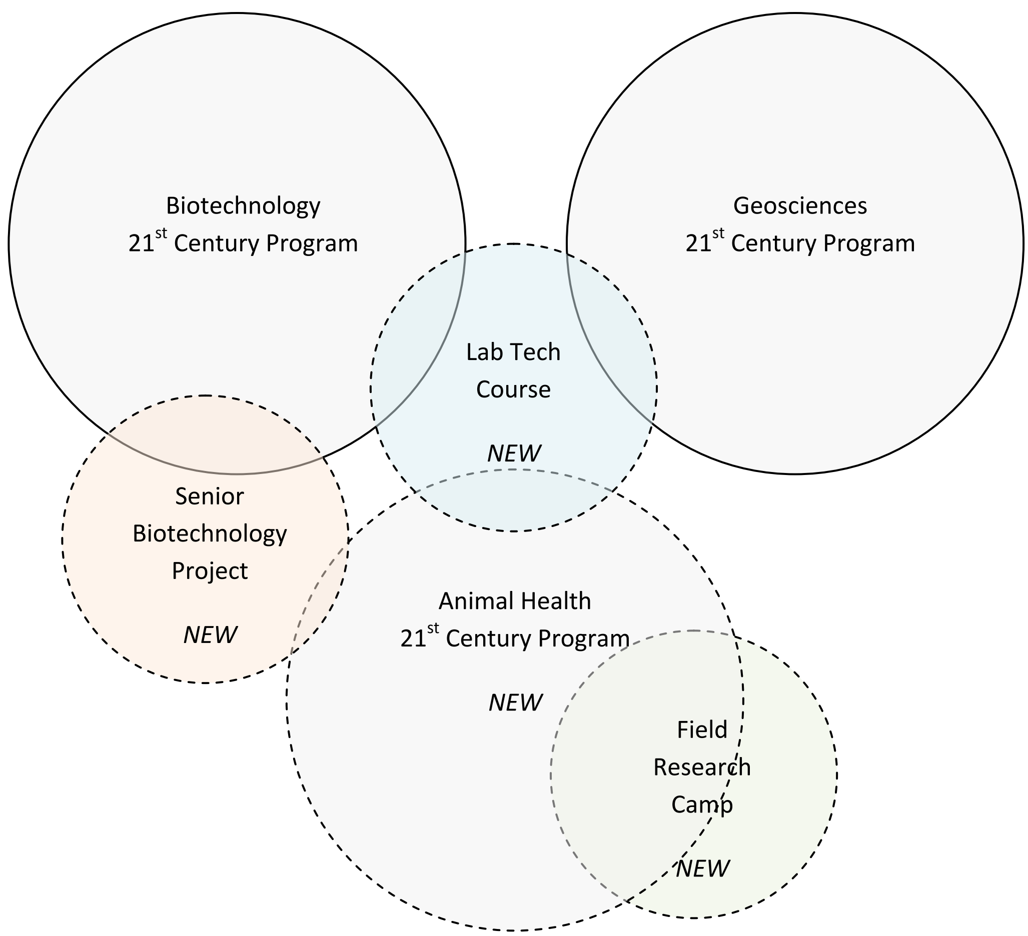


**Figure 4.3 Interrelationships of new programs developed through the partnership –** New programs have dashed outlines. Previously existing programs have solid lines. The new Animal Health Twenty-First Century Program was the largest new program, consisting of a four-year curriculum. The three smaller new programs, represented by small circles, engaged students from the three Twenty-First Programs as shown by overlapping circles. The nature of these programs and overlap is explained in the text.

The Senior Biotechnology Project consisted of engaging four senior high school students in the Biotechnology Twenty-First Century Program to conduct authentic research in the animal health field and mentored by a university scientist. It was developed to explore what it would take to create such a research mentorship program; however it was innovative in that the research took place in the high school classroom rather than the university lab. It was also initiated to explore the possibilities of developing animal health science content in the high school. It lasted just a year, though it was intended to be fully implemented as a mentoring option for senior student research projects in the future.

The Field Research Camp was designed to be a component required for students in the Animal Health Twenty-First Century Program, and as such would enroll up to twenty-five students each year. Course development and data collection for the pioneer cohort, however, involved eleven students in its initial implementation studied here. The Field Research Camp was also developed as a module that could be offered in or adapted to other contexts.

The Lab Tech Course was a new course required for ninth graders entering the Biotechnology, Geosciences and Animal Health Twenty-First Century Programs. It was collaboratively designed to introduce students to research and lab methods and skills, as well as to orient them to the nature of science. The facilitator of the Geosciences Program was the primary teacher, and it enrolled sixty-five students in the first year in two sections, with projected enrollment of ninety students in future years.

Below I discuss how each program developed. Although the development of the programs occurred to some degree concurrently, they are essentially presented in the order in which they started.

### *Senior Biotechnology Project, Spring 2008 – Spring 2009*

#### *Overview*

The Senior Biotechnology Project developed somewhat spontaneously, inspired by the question asked by high school student Chantal Morgan, eventually engaging four senior students in an authentic biotechnology research project with MWU animal health scientists. They would be mentored by scientist Tim Rollins, a postdoctoral researcher in Robert Tillman's lab, who would come to the high school classroom to guide students through the complex experiments.

Susan Rasmussen, scientist and leader at the nascent MWU-Vista campus responsible for the partnership with VSD, oversaw the project.

***A Spontaneous Beginning***

> I think this is a project that was built on the tug of heartstrings. You know, this is a project where you could really say it was done in response to a student request – Chantal Morgan raising her hand and saying, "Can I be a scientist and a veterinarian?" – you know, was something that was very intriguing as raw material for trying to do something.
> – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Even before the formal facilitated partnership meetings started, Susan Rasmussen launched a pilot project based on the student's question to "figure out how and if we can have this type of collaboration." She discussed the possibilities of a student research project with the teacher and facilitator of the Biotechnology Twenty-First Century Program, Steve Graham, who thought it would be better if other students were also involved. At the end of the students' junior year, Steve asked in class about interest in a MWU biology research project as their senior project the following school year. Four students, including Chantal Morgan, responded; all four were female, one was African American, one was Latina, and two were white. While all four would work on the senior project, two, including Chantal, were chosen to participate in a three-day tour of the MWU main campus and labs during the summer. Sophia Delgado and Chantal Morgan went to the MWU campus to explore senior research projects. Teacher Steve Graham describes his perspective of the project:

> I saw the goal as having the opportunity of authentic real research. I felt that my job as a high school teacher was to provide them with techniques and training and the tools that then could be applied for real research. And so my idea was well, this was kind of like an internship that I've had some students doing in labs. But the best part of this was that we were using my classroom and we had four students involved rather than just one student involved, so we had a larger number of student involvement. … So that was a plus. I think the other thing that really excited me was the fact that when I do internships with labs, it's always based on the availability of the researcher, availability of funds – many things that can change from year to year. Whereas with the MWU proposal, there – in

the piloting of this – was [the idea] to work up a system that could be done year after year whether I or anyone else is present, but it's just kind of a built-in mechanism." – *Steve Graham, VSD teacher*

***Finding a Research Focus***

Susan used the opportunity to pull high quality people into the project, some of whom would then work with the partnership in other capacities for years. She already had a number of projects and programs on the main campus operating – as an administrator, as a lab scientist, and through grant-funded interdisciplinary projects. Hence, she had a number of staff, colleagues and students working with her in a variety of capacities, and all served as resources she could draw on. A major challenge to overcome in the pilot project would be the two-hour distance between the main campus and the school district, though this would not be an issue once the satellite campus had operating labs. Susan asked a junior scientist working on one of her projects and me to organize the three-day visit for the two students during the summer of 2008. We drove them the two-hour trip and gave them tours of the main campus, the College of Veterinary Medicine, and a couple research labs. Susan and scientist Robert Tillman reflected on the students' visit to the campus labs:

> I knew we couldn't just let students make up a project. … But we could give them a choice of like – these are mentors whom I trust to get this on rail, who have projects that might have some appeal to students because of the nature of the projects…. And then the students seemed interested in at least one of the projects. I only let them look at projects with mentors whom I knew had labs and lab personnel that would be conducive to hanging with the students through this. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*
>
> The group of students visited – they saw everything…. And I think they went back and they said, "I really like this. I want to see if I can do that." – Robert Tillman, MWU faculty scientist

After looking at a couple possible research projects that Rasmussen presented them, the students chose to work on one in Robert Tillman's lab. His research in the College of Veterinary

Medicine involved questions about the effects of non-steroidal anti-inflammatory drugs (NSAIDs) on the gastrointestinal tract (GI) of horses. The research findings could also apply directly to humans. The specific project involved studying a group of proteins known as calpains that are responsible for maintaining and repairing tissues, functions that tend to be compromised under the influence of NSAIDs. The students investigated the expression of different calpains on a molecular level in horse GI tissue. A postdoctoral fellow in Robert Tillman's lab, Tim Rollins, served as the direct mentor to the students. Tim would come to the classroom, bringing materials, reagents and chemicals, underwritten by MWU, for the lab work.

> MWU was able to provide us with the lead mentorship, Dr. Rollins, to provide us with many of the materials and some of the equipment, expendables, and also the research samples, because a lot of times the big obstacle is getting valid materials – high school students are limited as to their obtaining the tissues. The tissues either have to be commercially provided, or obtained from a scientist based on his grant, and following the guidelines that the government sets forth for those kinds of research projects. – *Steve Graham, VSD teacher*

#### ***The Research and Mentoring Process***

In mid-September, a conference call between Graham, two of the students, MWU scientists and me allowed us to identify first steps to the project. An MWU online repository would help share important documents such as scientific literature and protocols for the project. A general timeline established that students would read background material to prepare conceptually for the project, and visits from Tim Rollins would guide them in lab procedures and experiments.

As the MWU-VSD partnership was still being formalized, all participants in this Senior Biotechnology Project were new in their roles, and planning was largely *ad hoc*. On September 23, a face-to-face meeting occurred with the students, teacher, faculty scientists and me at the high school. The classroom equipment was reviewed, procedures were discussed and next steps established. The teacher invited a journalist to the classroom meeting, and a story appeared in the local newspaper the following Saturday. A great deal of excitement was building for the partnership. Steve and Susan were quoted in the article:

> This is giving high school students a chance to see the research side of academia. What's making it more exciting is they are answering a real science question, not just doing a cookbook lab assignment where the teacher knows the answer. *– Steve Graham, teacher at VSD, from newspaper article*

> These experiments will reveal new information – this is contributing new understandings. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus, from newspaper article*

The university invested in distance-meeting technology to aid in communication, such as software and webcams. Using these tools, Tim Rollins – while at the main MWU campus – conducted an online tutorial of primer design and reverse transcriptase polymerase chain reaction (RT-PCR) set-up for the teacher and students in October. The students then designed relevant primers and sent them to Rollins, and he ordered them along with other supplies in early November. Rollins made several trips to the classroom to work with students after school conducting experiments, and I met with the teacher in the classroom to monitor progress, assess how things were working, and to help motivate the students.

The advanced equipment in the biotechnology high school classroom offered the students the ability to conduct the sophisticated protocols. Along with teacher Steve Graham, "Rollins directed the students to perform the RT-PCRs, protein electrophoresis and Western Blots to ascertain the effects of NSAIDs on the mRNA and protein expression of calpain3 and calpain 4 in different sections of equine GI tract treated with phenylbutazone (an NSAID) (MWU Press Release)."

We arranged for a full-day MWU campus visit during Thanksgiving break for the students to see the lab to which their research was contributing and other labs. They met the primary researcher for their project, Robert Tillman, who also gave them a tour of the Veterinary Hospital. He showed them a colt with a broken leg that had undergone surgery, and then its x-rays to show how the repair had been made, which made an impression on the students.

> I think our facility, technical skill, the mentorship with Dr. Rollins, the chance that they can walk through this hospital and get exposed, and when they walk through the downstairs and see an animal, [or] go see an exotic animal that nobody would ever see – I

think that's something a little special, something they might not see in a medical school, in their other medical research. – *Robert Tillman, MWU faculty scientist*

While the equipment in the high school classroom was relatively sophisticated, the team did reach a challenge with lack of equipment. Traditionally, the results of the electrophoresis would be analyzed using film to record the image of the fluorescent dye indicating bands of RNA or DNA fragments in a gel. Modern techniques, however, use sophisticated digital imaging equipment. Unfortunately, the high school did not have such equipment, and in order to record their results, an alternative had to be found. The teacher drew upon resources in the high school, and arranged with the photography teacher to have the students and Rollins use the school darkroom during class time to process film. I managed to purchase Polaroid film to use, and one of the students used her film developing skills. Although it was very uncertain if this method would work, in the end the students' films captured the image of bands: it was a concrete result from their experiments.

> Well, there were some technical limitations of facilities at Vista North High School. It was like – when we do a Western Blot here, we develop the film and take a digital photograph of it. At Vista North, we had to use the photography room and see if we could actually develop the film. That we ended up being able to do that, and we saw something on the film [laughter] – you know, it wasn't perfect but we did get a result.
> – *Tim Rollins, MWU post-doctoral scientist*

> And you know … the day that Tim and I thought, Oh gosh, they have bands! We can put it on the girls' poster! That was a real critical moment [laughter]. Yeah! – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The experiments typically occurred during late-afternoon class periods when Steve still had other students in his class, then extending into after-school hours. One or another student was often missing from these sessions, either ill, participating in band, or having had to catch the bus home. When a student was missing, the others covered for her, conducting the procedures with their own and the missing student's materials. Tim guided the students as the scientific mentor; Steve learned the biotechnology techniques, concepts and theory from Tim, as well as guiding the students in terms of classroom expectations; and I tended to focus on sense-making activities with the students. Susan Rasmussen, who had met with the students a number of times at the beginning, kept updated through reports from Tim and me.

> There were of course all kinds of little things. There was the one time when someone dropped a bunch of the samples on the floor, and everything all got mixed up and test tubes were flying everywhere, you know [laughter]. So it was like, oh my goodness, you know, type thing. Yeah, just little lab accidents. They're going to happen no matter what, but if you're just limited on time and resources, you don't like to see those happen. *– Steve Graham, VSD teacher*

***Concluding the Project***

In mid-February, the experiments were concluded and students then prepared their reports with Steve, Tim and I offering review, using distance technology for some of these meetings.

The scientific results of the experiments demonstrated that certain calpain proteins were expressed in the horse GI tract, but others were not. These were significant results that were unknown prior to these experiments, and they contributed to the ongoing research in Robert Tillman's lab. Two of the students presented their work at the large metro-based science fair, where they answered questions from judges and visitors. All four also presented to their fellow students and to a public audience at the school, which included their supervising researchers.

During the campus tours, we oriented the students to various programs that could serve as pathways and scholarships for studies at MWU. I introduced the two minority students to the director of a program for under-represented students in the sciences who wanted to work in research labs on campus. All four students earned scholarships for college, with three of them coming to MWU. One of them applied and earned early admittance to the Veterinary School based on her work and letters of recommendation from MWU researchers. Two applied to and were accepted in the research-based undergraduate program, and they both worked in labs in the College of Veterinary Medicine. One, Sophia Delgado, worked in Robert Tillman's lab as an undergraduate, continuing with the research she had been introduced to through this project. Upon interviewing her for this research study, I learned Sophia planned to graduate early, apply to graduate school and earn her doctorate so she could continue doing research.

> I thought it was great. I loved doing my senior project. The whole experience was great. It was something – because all through high school, you go through your math, your science, your English. This was a step up. The research part was more of a challenge, and that's really what turned me onto it…. It was a lot more difficult and a lot more challenging than I thought it was. I didn't expect to be as involved as they had us be. I thought they would just use what knowledge we had been learning in class and not teach us any new skills and things like that. But we were really a part of it. We were like undergraduate research students. That's how we were treated – we weren't treated like anything less. And that really made me feel like we were worth something to the program and not just there for their benefit, but for ours as well. *– Sophia Delgado, MWU college student, former VSD student*

Steve Graham, Tim Rollins and I presented a poster at a large national biology research conference. The presentation focused on the partnership between the school district and the university, highlighting the Senior Biotechnology Project.

> I was delighted that we were able to put together a poster that really had good information to take to [the national conference]. I mean, I think that was a very – an aspirational outcome that was realized, that we learned something worth sharing with other people, and I think that was really cool. And seeing you and Steve and Tim all go to [the conference] together was really – that was probably to me the best outcome of the project. Although, obviously seeing the girls succeed was a good outcome as well.
>
> *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

### *Animal Health Twenty-First Century Program, Summer 2008 – ongoing*

#### *Overview*

The large undertaking that the partnership group decided on was the development of a new Twenty-First Century Program. In the early strategic planning meetings with Vision Lead, a natural point of intersection between the two organizations was the university's expertise and focus on animal health, and the district's expertise in pedagogy and developing Twenty-First Century Programs. Located within the comprehensive high schools, the district's Twenty-First Century Programs focused on themes for career development, such as engineering, electronic communications, culinary arts, biotechnology, and geosciences. Students could choose to enroll in a program the district offered, and if they lived outside the boundaries of the high school that housed the program of their choice, they would be bused to that school. Students would be enrolled in the program throughout their high school years, with specific courses required in each year along with courses for their general high school diploma. The Twenty-First Century Programs were transfer programs that appealed to students all across the district.

Five years earlier, the district had launched several Twenty-First Century Programs focused on different themes. With the prospect of working with MWU, it seemed logical to create a Twenty-First Century Program with an animal health focus. And the university scientists were eager to help create opportunities for students to get turned on to STEM fields. The collaborative development of the four-year Animal Health Twenty-First Century Program would take three years to fully create. Slated originally to start in fall 2010, circumstances pushed the start date a year earlier to fall 2009. The program started when the high schools were still three-year high schools, and in the program's second year the high schools transitioned to be four-year high schools. In the end, the program could enroll one hundred students, twenty-five in each grade.

### *A Natural Intersection among the University, the District, and the Community*

> Animals are popular, so if you can use animals as a way to engage students in science and technology education and math, it's a good thing. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The Animal Health Twenty-First Century Program was conceived as a partnership venture in the earliest meetings in 2008 between individuals from both institutions. The former superintendent describes this process:

> I learned a lot about animal health sciences … and I'm seeing all sorts of connections – I mean it was just quick. And again, building on those assets we had in place, Twenty-First Century Programs, knowing what we could do. … And then … Susan and [Phillip] actually visited high school Twenty-First Century classrooms and saw what we were already doing, and the MWU staff could then see what the potential was. … You've got to have that understanding. –*Alice Hughes, former Superintendent at VSD*

The Animal Health Program represented the most collaboratively designed and executed program of the MWU – VSD Partnership in terms of number of individuals involved at multiple levels in each institution.  The strategic planning meetings facilitated by Vision Lead included discussions about creating an Animal Health Twenty-First Century Program, and these exchanges brought to light differences between how different individuals defined animal health. Not only were some MWU faculty veterinarians, but they were also research scientists and engaged with the thriving animal health commercial industry in the region.  District personnel were excited to learn of the many career opportunities in animal health and the potential for local work force development.  Career education was a top priority in their work with students, especially in the Twenty-First Century Programs.  They were dedicated to helping prepare students for this broadly-defined animal health workforce.  Some of the educators expressed caution in creating a "pipeline" for workforce development, since their focus was to educate the whole person and nurture the students' interests.  Yet they also recognized the importance of preparing students for their futures, and the natural intersection between students and their communities.

> When I was talking to the business community, I was using the term work force development, something that the private industry looks at.  It's developing the twenty-first century workforce.  That was a primary part of Twenty-First Century Programs. … Some people would say it's not your job to prepare what industry wants.  Well you know what?  If you're a parent or a kid, and you don't have a job, or your skills aren't right, what – why are we there?  I believe in liberal arts, and I want everybody to be well rounded, but we also have to have some sense.  *–Alice Hughes, former Superintendent at VSD*

At the time, three National Academies of Science studies documented the need for additional workers in animal health beyond traditional veterinarians such as in research, development, biotechnology, and public health.  The studies pointed to a dwindling workforce and yet a need for a multi-disciplinary workforce that could understand the intersection of animal health, human health and public health.  Susan Rasmussen stressed these factors in many meetings, and in addition noted that the animal health workforce at the time was not representative of the diverse national population, with the field being predominately white and female. She also reported the studies' findings that current K-12 activities did not embrace the breadth of animal health career opportunities, tending to be limited by relating to veterinarian careers only. By creating a VSD Animal Health Twenty-First Century Program, the partnership committee resolved:

- To educate students about animal health
- To engage students in the whole range of careers within animal health
- To create an endorsement that has meaning to both students and to the marketplace
- To achieve national recognition through publications and presentations for our work in broadening students' understanding and participation in the breadth of the field of animal science – *Vision Lead notes from August 26, 2008 meeting*

***Accelerating the Timetable and Gaining Approval***

To sow the seeds for the program and generate interest, we created a collaborative presence at the October 7, 2008 VSD Career Fair for ninth graders and their parents, and started planning a collaborative Animal Science summer camp for sixth, seventh and eighth graders in 2009.

> I think [the Career Fair] is one of the things we do to foster the success of the program, because we're getting kids interested. We're already showing them what's available to them. If we didn't do those things, our program wouldn't be successful because they wouldn't know about the program. – *Janet Spencer, Science Facilitator at VSD*

The target date for launching the new program was fall 2010, allowing a two-year lead time for planning, recruiting, and developing the infrastructure. However, after the 2008 elections in which local voters approved a VSD bond to expand the high schools and move ninth grade from the middle school to the high school level, the target date advanced to fall 2009, as described earlier. This decision occurred in a meeting called by the VSD associate superintendent on November 10, 2008, just a week after Election Day, and included a subset of the larger partnership committee with key individuals from both institutions.

The group that met on November 10 agreed to an accelerated timeline to launch the Animal Science Twenty-First Century program with sophomores in fall 2009, and full implementation in fall 2010. This meant the program would start a year earlier than originally planned. While this proved a challenge, and several participants described the subsequent process as “building the plane while we were flying it,” the quickened timeline had its advantages, as Susan describes below:

> We initially had a less ambitious timeline and it was pushed for a more aggressive timeline for political reasons really related to [district] building redistribution issues. And I think that was good, because I think with all the [staff] turnover we had, if we had had the original timeline, the project would have been more likely to fail. We got more done before we really had a lot of change going on, and I think that that was probably important. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista*

Vista North High School was deemed the appropriate location for the program. It not only had other complementary Twenty-first Century Programs there, but it was also the most economically and racially diverse high school in the district. A program design team was proposed with members from both institutions to develop the curriculum. As was customary with forming other Twenty-First Century Programs in the district, the group agreed that professionals and educators would be surveyed and queried in focus groups to inform the development of the Animal Science program. Susan would communicate these decisions to personnel at MWU and in the industry working groups, and VSD administrators would develop a district communication plan and propose this to the Board of Education in December.

It is worth noting that throughout the fall of 2008, district personnel started referring to the program increasingly as Animal Sciences rather than Animal Health, likely due to the fact that scientific rigor was stressed by university scientists. However, within the university context, this name change was significant and caused some political challenges. Within the year, the name would be officially changed to Animal Health.

While the district’s board of education showed enthusiasm with the proposal for the new program, it was measured against the economic downturn that was already causing drastic budget cuts. They approved the launch of the Animal Sciences Twenty-First Century Program with the provision that no new classes be added, no new teachers, and no new budget lines.

> Part of the proposal when we first kind of took that leap forward and called it Animal Science at that point was – the school board said OK, we’ve got another Twenty-First

Century Program if you don't spend any new money, if you don't create any new classes, because creating any class creates a new teacher. *– Steve Graham, VSD teacher*

***Developing the Program of Study***

The design team consisted of district administrators and teachers, and university senior and junior scientists including me. We met throughout spring 2009 under the leadership of Joyce Lancaster, VSD science coordinator. She prepared proposals to be discussed at the meetings throughout spring 2009 as program coursework and an overall vision were created. It was important that students in each Twenty-First Century Program, some of whom transferred to a new school to participate, could form a group identity. They needed to have a relevant class they all took together so they could bond and share program experiences. Joyce suggested that an existing class, Student Naturalists, could serve as that home-base class. Normally, the class was a junior-level class that covered general environmental science, with the classroom housing a collection of animals, most small exotics. In this case, Animal Science sophomore students would enroll in the class and be scheduled in the same section, would be responsible for caring for the animals, and would be able to get to know one another. Susan Rasmussen was enthusiastic about this idea, stressing the importance of an interdisciplinary focus to animal health. Including environmental science as a fundamental course reinforced the idea of integrating animal health, human health and environmental health, a concept referred to as One Health among professionals. The Student Naturalist teacher began attending meetings.

District personnel wrestled with the question of who should lead the new program. The Student Naturalist teacher was an obvious choice, however this was his first year in that school district and he was still settling into that school. To complicate matters, Twenty-First Century Program facilitators – teachers who also had responsibilities of leading and coordinating the program – were paid an additional stipend. Given the economic conditions, the district could not create a new budget line. The facilitator of the Biotechnology Twenty-First Century Program, Steve Graham, attended the Animal Science Design Team meetings, and the new program captured his imagination. He was well-respected by the university scientists, as they had engaged with him on the Senior Biotechnology Project. The scientists also wanted biotechnology to be incorporated into the Animal Science program. So for a while, it seemed Steve might lead the program, and he certainly contributed to the vision and planning of it.

However, he was already over-committed in his existing responsibilities. While Michael Dunlap, the Student Naturalist teacher agreed to teach the special course section for the Animal Science, he did not commit to being program facilitator until the following year. So Joyce Lancaster served as the temporary district leader of the program.

> I think one of the challenges was that while we had a very academically oriented person in Steve Graham for implementing the program, he was already pretty busy with the biotech program…. We have to protect personnel. [The animal health program] was not built by the person who would lead it, and envisioned by the person who would open the program. *– Joyce Lancaster, former Science Coordinator at VSD*

Programs of study were discussed, with most in the design team emphasizing the importance of a rigorous math and science curriculum. The group debated the benefits of different subjects, Advanced Placement (AP) courses versus standard courses, the importance of electives, the requirements and definitions for endorsements, and recruitment of a diversity of students. Susan Rasmussen announced that some online courses being developed in a university public health program she was involved with could be available for students in the program. Meetings were attended by senior and junior scientists at the university in animal health, biology and education, as well as teachers and administrators at the district. Teleconferencing was the norm, with technology occasionally failing in one way or another. Often, the video worked but not the audio, and individuals from each location would use cellphones to patch in the audio. Throughout spring 2009, discussions helped set priorities, though a concrete multi-year curriculum was not set.

### *Recruiting Students to the Program's First Year*

While the program of study was discussed in design team meetings, practical details for launching the program on the accelerated timeline were also tended to. With the Student Naturalist course identified as the common course for incoming sophomores, students needed to be recruited and excitement generated. Joyce Lancaster circulated an announcement of the program to middle school counselors in February 2009 to recruit students who would be sophomores the following year into the program. In addition, dates were set for the Animal Science Summer Camp and flyers for it were distributed to administrators, parents and teachers.

The camp was initially offered to middle school students to generate interest in the high school program. In March 2009, press releases at both institutions were distributed about the new Animal Sciences Twenty-First Century Program, resulting in local newspaper articles. Teachers were secured to teach the summer camp, and I attended the four-day camp as an assistant and to coordinate university offerings. Fifteen students finishing grades six through eight enrolled in the first Animal Sciences Summer Camp.

During April and May, Joyce Lancaster and I interviewed ninth grade applicants for the Animal Sciences Twenty-First Century Program and their parents. While no student was turned away from Twenty-First Century Programs based on academic performance, some self-selection could occur when expectations for the program were made clear. All the students interviewed for this new program were motivated to work with animals, and many claimed they had wanted to be veterinarians since they were very young. They were invited to join the Animal Sciences Summer Camp, which was primarily for younger middle school students, as junior counselors and most did. Joyce's logic behind this was that it would be beneficial for them to bond as the initial cohort during the summer, and to experience animal-related activities that they might not have offered again in later grades.

All together, the Animal Sciences Summer Camp in June 2009 attracted twenty-four participants, nine incoming sophomores and the rest younger students. The camp's teachers brought live animals such as millipedes, ferrets, birds and tortoises for the students to observe and handle. Field trips to a veterinary clinic, a historic working animal farm, and a nature preserve punctuated the days. The university arranged for a talk by a service dog trainer, who brought his current puppy trainee, and for university veterinarians to direct a hands-on activity demonstrating the kind of bone repair an orthopedic surgeon does. Joyce included me in the design of t-shirts for the students in the summer camp, and they all received one prior to the start of the new school year in fall 2009. The students indeed bonded that summer, including across grades. Having announced her resignation earlier in the spring, Joyce Lancaster left the district at the end of June to accept a position at a university. Susan describes the importance of the type of educator expertise Joyce brought to the collaboration:

> We had the incredible base of knowledge the school district had from developing other Twenty-First Century Programs and what it took to make a cohesive learning community. And we all trusted them to say, we need t-shirts, we need a logo, we need to have a

> [course] section. And we were, like, go! You know, we trust you, we need this. And so there were things that were built into the structure that were based not just on the literature but on the school district's very real-time experience in that environment in how you recruit students, how you build a group, and we went with that. So that was great. We never could have done this, you know, we would have done it very poorly – meaning the partnership – without all of that resident knowledge and experience.
> *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

### *A Program Leader and Continued Planning*

Just before Joyce left, she and I met with Janet Spencer, the soon-to-be science facilitator to review the status of the partnership and especially the Animal Science Twenty-First Century program. Janet, on a ten-month contract, would not be available the rest of the summer, and Beatrice Price, director of secondary programs, led the transition of the partnership program into the new school year. District administrators worked hard over the summer tending to the details of initiating construction to expand all high schools and many elementary schools, as well as internal reorganization due to the massive budget cuts.

When Beatrice, Susan and I met together at the end of August 2009, Susan officially requested changing the program name officially to Animal Health instead of Animal Science to align with university interests and the intent of the program. Unbeknownst to the district, there was a distinct difference on the MWU campus between the two fields, Animal Health relating more to veterinary practice, and Animal Science relating more to agricultural practice. For diplomatic relations on the university campus, the change in title would reflect the proper affiliation of the program.

At that meeting, Beatrice also reported that teacher Michael Dunlap would be the facilitator for the program. He already had all the new program students in his Student Naturalist course, and he was working closely with them, getting to know them and their interests. Most of them indicated they wanted to be veterinarians, and one wanted to be a wildlife biologist. Michael was fully on board with the idea of expanding their horizons over time to many other animal health career options in addition to veterinary practice. He listened carefully to their interests and passions, gained experience with them revealing their natural talents, and noted how well they did in their math and science courses. He reported planning field trips that might appeal to particular interests of the students.

Susan reported that "online courses in public health will be available to high school students in summer 2010 … and students would be able to enroll using MWU scholarships earmarked" for local county students (notes from August 21, 2009 meeting). Beatrice embraced the idea, suggesting that doing college-level online courses while students are still in high school with the support of teachers was an ideal situation to introduce students to online learning.

The 2009-2010 school year commenced with eleven students in the new Animal Health Program. They were given special responsibilities to care for the animals in Michael Dunlap's classroom, which they did during and outside of class hours. Michael and I arranged for the students to visit the MWU campus and veterinary hospital that October, with costs shared by the district and MWU-Vista. Michael also arranged field trips for the students at a large animal health pharmaceutical company, and at a large animal wildlife sanctuary.

The Animal Health design team met for the first time in the new school year in September, with a smaller working group designated to carry out the final design and implementation of the program. The working group consisted of Janet Spencer, new VSD science facilitator, Linda Bradley, director of career and technical training, teachers Steve Graham and Michael Dunlap, and me representing the university. We met monthly throughout the rest of the year.

> So you know, we had lots of meetings there. Oh gosh, we're still having lots of meetings [laughter]. We went from large – there's a hierarchy. I'm not even sure I know the terminology. We had a district level steering committee. We had some sort of animal health committee that would meet composed of people from MWU and Vista that would meet on those [tele-]conferences. Now we're down to … just a few individuals – Michael, myself, you, Janet and Linda – that are kind of working together. So we got a little bit of district level, a little bit of MWU, and a couple there at the high school. So the working group is actually doing that [the design and implementation] rather than the design and the steering committee. – *Steve Graham, VSD teacher*

Although eleven sophomores were enrolled in the program, the program of study for the students' subsequent years was unclear. Michael Dunlap, facilitator and teacher for the Animal

Health Program, pressed the working group to clarify the details of it, since he was advising the students of what courses they needed. He felt the frustration and ambiguity of not knowing what to tell them. He and Steve Graham spent extra time working on it. They devised a set of required courses and electives, along with other requirements that would constitute earned “endorsement hours,” or e-hours. These e-hours were part of every Twenty-First Century Program in the district, and consisted of out-of-class hours students worked to gain experience in the field of study, such as internship, volunteer, training or research hours. Steve and Michael also proposed different levels of endorsements: Proficient, Highly Proficient, and Highly Proficient with Honors. All district Twenty-First Century Programs offered students opportunities to earn endorsements – official recognition of students’ accomplishments in the professional learning track. The different levels would reflect amount of e-hours earned, as well as the student grade point average (GPA). A senior project in the student’s area of interest was necessary for any level of endorsement.

> Students can earn an Animal Health endorsement on their high school transcript to show their education went beyond basic high school graduation requirements. *– Plan of Study presented to Board of Education, January 2010*

> Endorsement is: you have to take certain classes throughout the year, keep up your math and science GPA to a 3.0 or above, and have two to three hundred hours of extra community service with animals to get that certificate.… [It gives you] experience in the field, and experience working with many different job fields, and working with the MWU people. *– Zoey, 11th grader in the VSD Animal Health Program*

When Michael and Steve presented the program of study, with its emphasis on rigorous math and science courses, to the Working Group, they also noted a dilemma: the Animal Health Program looked nearly identical to the Biotechnology Program. The group felt that was reasonable, since both organizations wanted to emphasize the rigorous curriculum, college preparation, and the integration of different sciences. Yet, how could we distinguish them? They turned to me as the MWU representative and suggested that the partnership offerings with MWU could be the distinction, since the Animal Health Program specifically grew out of the partnership. What about those online courses Susan Rasmussen mentioned? What about turning the middle school summer camp into an introductory animal health camp for freshmen? What about a field research experience taught by an MWU scientist? What about continuing field trips to MWU, but also to the local animal health industries MWU worked with?

> We followed the model of other programs, like Steve's [biotechnology], and so it's very closely aligned. But that's also where this program came from. It came out of that. So trying to differ – I think that was one of the conversations Steve and I had, trying to differ it too much didn't make a lot of sense, since that's really where it came from. *– Michael Dunlap, VSD teacher*

***Formulating Unique Program Components***

Based on the positive bonding experiences the incoming sophomores had in the summer camp, we agreed that an Introduction to Animal Health Summer Camp for new incoming students made sense. Michael had also built a relationship with the historic working animal farm the previous summer, and made arrangements to have the camp located there in subsequent years. Students were able to work with the large animals and it was a very positive relationship, and Michael took responsibility for leading this introductory summer camp.

Based on his assessment of student interests and needs, Michael thought a field research course would be a good summer experience for students between their sophomore and junior years. With my experience as a field biologist, I offered to teach one. We proposed it be launched that summer (2010). This course is described in this study as an additional embedded unit of analysis, since it was also developed as a model for MWU to use in other districts.

The online course option needed further exploration with Susan Rasmussen, but the district personnel liked the idea for several reasons. Integrating online learning into high school students' learning experiences would help prepare them for what they would likely encounter in college. Online learning involves self-motivation and good time management. These qualities and skills are easier to develop when students have some teacher support at the high school. Finally, taking an online college course for credit would help secondary students earn precious college credits early. The teachers thought an online course with animal health content would be well-placed in the students' senior year.

> When we were developing the Animal Health Program, we thought [about] having an online class because we thought that's what their generation is more likely to do. And it

was a way we could deliver animal health specific content. – *Michael Dunlap, VSD teacher*

We discussed tuition costs for an online course, and district administrators noted that nothing could be required of students that cost too much. They did use community college courses at times, and those tuition rates were reasonable enough that if a student's family could not pay, the district covered the costs. So I discussed with Susan the logistics of using one of the public health online courses she proposed for the animal health students using the scholarship money she had previously mentioned in our August meeting with Beatrice Price. She explained that while the scholarship money may have been able to support a few students, it could not support all program students for multiple years. She had also learned through work on other projects that tuition for online courses cannot be reduced within the university structure. We would need to work with the district teachers and administrators to find another solution.

I scheduled a February 2010 design team meeting to review all the proposals for the whole Animal Health Program plan of study, including MWU contributions, to formalize the partnership program and to secure commitments for sustainability. Several MWU scientists were present, as well as district administrators and teachers. We reviewed recent accomplishments, and teachers reported on the very high number of students enrolling in the program the following year. The proposed plan of study, including elements MWU would contribute, were discussed. The summer camps were approved as they would be run on minimal expenses. I would lead the Field Research Camp. Michael would lead the introductory camp at the animal farm, with MWU sharing costs of instructors.

The situation with the proposed online course was more complicated, as both the university and the district had non-negotiable constraints. Full university tuition would be required ($300-400 per credit) for students to enroll, and even tuition for one credit was too high for the district to require students to pay. Both the district and the university agreed that neither organization could likely support the large number of scholarships needed for all students to enroll in the course. Further, it would not be possible for students to audit such a course due to its online nature.

In the midst of this quandary, I suggested creating a non-credit online course that would obviate the need for tuition. District administrators liked the idea of an introductory "how to take an online course" summer offering through MWU, and then they could try to find an appropriate community college online course for credit with a lower tuition rate for students to enroll in during their senior year. For this purpose, a local community college with a veterinary technician program was suggested – both the district and university had good relations with the college. So we agreed in the end that MWU would offer a three-week non-credit online course with content related to animal and public health, and that would also introduce students to the skills and technology of online learning. I would design and teach it. And the district would pursue the possibility of having an online course for credit through the community college.

> We felt that it was certainly a twenty-first century skill for anybody to be technologically literate, but also to have the self-discipline necessary for online learning, and to try to teach students the skills for online learning in their high school setting with the support of the teachers … but doing it in the context of animal health content.
>
> *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

In addition to the summer camps and the online course, ninth grade students – joining the high schools the following year – would also need a course to serve as an introduction to the program in the same way the Student Naturalist course had, allowing students to bond and orient to their twenty-first century program. Steve Graham proposed creating a new course to serve as an introduction to scientific research and lab techniques. The course would be for the freshmen in the Animal Health Program as well as two other twenty-first century programs at Vista North High School: the Biotechnology and Geosciences programs. All these students who had chosen to study science would be required to take this introductory course. However, as the district was constrained by the Board of Education to not add a new course, Steve took an existing course for juniors, Introduction to Laboratory Techniques, and suggested it be transformed into a freshman course. He proposed that MWU co-develop it and even help teach it with him, and this was agreed upon. The team who had worked on the Senior Biotechnology Project, Steve, Tim Rollins and I, were designated to work on this. Since this course extended beyond the Animal Health Program and included other Twenty-First Century Programs, it is presented in this study as a separate embedded unit of analysis.

The full program of study was set and approved by administrators and by the Board of Education (see Table 4.1, p. 164). Janet Spencer, Michael and I then set to work planning and preparing for the summer camps. Steve, Tim and I met to design the new course. Commitments, both financial and staff-wise, that MWU was making to the Vista Animal Health Twenty-First Century Program were documented so that they would be transparent to everyone after Susan left MWU.

The program proved extremely popular, with over twenty-five applications for each new grade ($9^{th}$ and $10^{th}$) for fall 2010, necessitating a need to cap program enrollment. Michael and Steve interviewed students and their parents during spring. With two new grades moving to the high school the following fall and with the new program generating much interest, the job was enormous. They received fifty-seven Animal Health Program applications for the following year – roughly evenly split between eighth and ninth graders. Most were white females, so strategies of trying to recruit for greater diversity were discussed in meetings.

With two large classes of students joining the Animal Health Program, Michael doubled up on summer programming. He and I planned the Field Research Camp – in the form of a summer camp – for the finishing sophomores. And Steve, Tim and I began meeting to plan the introductory science course for freshmen, the Lab Techniques Course, for the following fall. However, late in spring 2010, Steve announced he would not be teaching that course, as he was needed to teach other courses. Instead, Christine Finley, teacher and facilitator for the Geosciences program, would teach it, and I met with her to develop that course, as will be detailed later.

> I think things were in a reasonable place that we had managed to get through the first year, we had managed to recruit students for the second year, we had expanded the contribution of the university in the school district to be something innovative and important that gave more identity to the program. You know, I think both sides were feeling resource pains by the end, but still moving forward…. I think there was more realism and less optimism by the end, but I think that was really economically driven. In all of us could have used more resources. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista*

> The resources each institution contributed were definitely the people for the thinking and the funding. It was very impressive how, when we had some funding challenges to make that animal science camp happen, that MWU would say, we'll take care of this part of it.

> And so that shared funding – like I said, this wasn't a partnership that started with a pile of money on the table saying, how should we spend it? But I think it was very targeted.
> *– Joyce Lancaster, former Science Coordinator at VSD*

***Students in Grades Nine Through Eleven, Planning for Grade Twelve***

The 2010-2011 school year started with four high school grades, including now new ninth and tenth graders. Some teachers who had previously been in the middle schools moved to the high schools to accommodate all the students and their levels, so there were adjustments on everyone's part in making the transition. Michael had the new Animal Health Program sophomores in one section of the Student Naturalist course, and they cared for the resident animals under the guidance of one of the junior students in the program. The new Animal Health Program freshmen enrolled in the semester-long Lab Techniques Course – either in the fall or the spring term. T-shirts were designed and distributed to all the Animal Health students, and Michael arranged for a number of field trips for students in the program. In the 2010-2011 school year, the Animal Health Program had ninth, tenth and eleventh grade students enrolled, and Michael was actively recruiting the following year's freshman students. As funds were limited, Michael also took the initiative to successfully raise funds from local animal health businesses to support activities such as field trips and camps.

Most of the planning occurred spontaneously at this point, with obvious deadlines looming to implement programming. Susan had left MWU, and Tim Rollins was available only to help arrange university lab tours. The new associate dean at MWU-Vista, Mark Merino, started his position in mid-August 2010. While I was able to ensure our financial commitments were in place for the partnership through him, he did not engage with the Animal Health Program. The working group continued to meet as needed, however the design team dissolved with the departure of Susan, since all other MWU scientists serving on that committee did so through relationships with her. However, the Animal Health Twenty-First Century Program was relatively established by this point, and I was essentially able to meet MWU commitments through my own work, and through the well-established channels of communication established with the district. During 2010-2011, I arranged field trips and career talks for students in the program, and the working group met a few times that year as needed to make decisions regarding development and implementation of the online course.

Starting in late fall 2010, I worked with the Division of Continuing Education at the university to develop the three-week non-credit online course so it would be available to teach the Animal Health students in the summer. With the new MWU-Vista building opening, teachers requested that the students come to the new campus for the two face-to-face meetings, and with input from the working group, I designed and taught the 3-week non-credit summer hybrid online course. The course prepared the pioneer cohort of Animal Health Twenty-First Century Program students for their senior year in 2011-2012, when the four-year program would be fully implemented.

> I think that we have created in the school system, building upon the excellent foundation of the Twenty-First Century Programs and the way they were laid out, activities that give students an opportunity to see where the boundaries are blurred between biotechnology and life sciences and animal health, giving students a broader understanding of what animal health and One Health concepts mean in terms of career options, contributions to society, and I think that's a real positive…. I think it was really more an important goal for us than it was for the school district going in. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista*

> We initially started off with the idea of trying to show students what veterinary science would have to offer. [For many], the only perspective they had was the idea of being a small animal veterinarian, and none of the other research components or laboratory or health components were even brought to mind for them. So we developed this program, and we're getting a lot of kids in there that were coming in just because of the soft, warm and fuzzy animal effect. And so one of the things that we did feel like was important was that not only did they have to have strong science and math skills to go into veterinary medicine, but they also had to understand the significance of the research. So that's why we added [the requirement that] at least a portion of their classes needs to be in the cellular and molecular area. – *Steve Graham, VSD teacher*

> [One student] may even still want to be a vet, but clearly [she] has an interest in this research component, and that may be a good fit for her. And she would not have had that [cellular and molecular] class – it wouldn't have even been available to her – if she

wasn't in the program.  So there are going to be students like that that are a little more introverted but want to make a difference, and just had never had that experience to do that.  I think that class is really important to our [animal health] program as well.
*– Michael Dunlap, VSD teacher.*

At first it was kind of like, ooh, puppies.  But then you realize it's not just about the animals.  It's about many other things and learning about the environment, like we did in Student Naturalists.  It gives you a different perspective on what animal health is.  And being able to go to [the veterinary conference] and look at all the vet products they use. It's very very cool.    *– Zoey, 11th grader in the VSD Animal Health Program*

**Table 4.1 Program of Study for Animal Health Twenty-First Century Program**

| Requirements | | Proficient | Highly Proficient | Highly Proficient with Honors |
|---|---|---|---|---|
| **Science Coursework** | Biology or Honors Biology | X | X | X |
| | Chemistry or Honors Chemistry | X | X | X |
| | Lab Tech Course (9th) | X | X | X |
| | Student Naturalist (10th) | X | X | X |
| | Adv. Biotech: Cellular-Molecular (11th) | X | X | X |
| | Senior Project (12th) | X | X | X |
| | AP or College Biology | | | X |
| | Science Electives (9th, 10th, 11th, 12th) | 1.0 | 2.0 | 2.0 |
| | | | | |
| **Math** | Continuous Enrollment in Math at your Progressing Level | X | X | X |
| | | | | |
| **Endorsement Hours** | Average Hours per Year | 50 | 63 | 75 |
| | Total Hours for Endorsement (at graduation) | 200 | 250 | 300 |
| | | | | |
| | Resume | X | X | X |
| | Post-Secondary Ed Search | X | X | X |
| | ACT/SAT (or Compass) | X | X | X |
| | | | | |
| | *Summer Work (see below)* | 3 of 4 required | 3 of 4 required | 3 of 4 required |
| | Animal Camp (9th/10th) | X | X | X |
| | Animal Camp Mentor (10th) | X | X | X |
| | Field Study (11th) | X | X | X |
| | MWU On-line Course (12th) *required* | X | X | X |
| | | | | |
| **GPA** | Program GPA (ALL Math and Science Courses) | 3.0 | 3.5 | 4.0 |
| | | | | |
| **Senior Project** | Completed in “Senior Project” | Mid or End year public presentation | Mid or End year public presentation | Mid or End year public presentation |
| | | | | |

***Field Research Camp, Summer 2010 – ongoing***

***Overview***

One of the unique components that would be included in the Animal Health Twenty-First Century Program would be a summer Field Research Camp focused on insect-plant interactions. While it was originally designed in the context of the Animal Health Program, it was clear it could also be offered to other programs or adapted to other contexts. The Field Research Camp would consist of four consecutive half days, with students in a natural setting conducting basic investigations in which data were pooled within the class to look at patterns and trends of insect behavior.

***Collaboratively Conceiving the Camp and Its Goals***

As we designed the Animal Health Twenty-First Century Program, district teachers and administrators suggested developing a field research experience with MWU scientists that would be required for students, and that would help distinguish the program as unique. My own scientific research included field-based investigations of insect pollinators. I offered to lead the course myself based on my own experience as both a biologist and an educator. The design team approved, noting that it was nice to have the "right person at the right time," and VSD teacher Michael Dunlap and I met together to develop a plan.

> We were lucky in that you were working on the development team, because you happen to have that experience. If you didn't have that experience and hadn't offered that up, I'm not sure if we would have thought to do that, or done it…. So it was having the right players at the table at the right time. *– Michael Dunlap, VSD teacher*

Our goals for the program were to develop a low-cost research experience that would be different than what they had likely already encountered. Michael valued the outdoor field research experience for his students, recognizing that in the animal health field, both indoor and outdoor research were important.

> There's no reason for high school students to have any concept of what a field study is. They're not exposed to it in high school. It's not a requirement. If they happen to have a teacher who does that for fun or is familiar with it, then they might have some very limited exposure, even less than what we're providing. And the field study component is

> something that I think more students have an interest in than they know. Because it's a different kind of research, and they're not just sitting in a lab – well they are in a lab – it's just not a traditional lab. It's an outdoor lab. And collecting the data and getting outside and doing those things are things that students like to do. It's more hands-on, it's outside, even if it's somewhat miserable at times, because it can be hot. And since they don't have any exposure, they wouldn't know whether they would want to. If they went to college and the opportunity popped up, they'd have no idea what that meant. Absolutely no idea what that meant. – *Michael Dunlap, VSD teacher*

From the perspective of MWU scientists, a field experience was valuable experience in research, and underscored the perspective of the interdisciplinary nature of animal health.

> Direct, hands-on experience conducting natural science research in an outdoor setting was attractive because it required no special equipment, focused on insect observations and plant-insect interactions, driving home that animal health and environment theme. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The primary purposes of the camp, according to the module documentation, were to:

- Offer students a simple direct experience of conducting science research in an outdoor natural setting requiring no special equipment;
- Offer students a hands-on immersion experience demonstrating how science research is *curiosity-driven* and *evidence-based*

*– Field Research Camp document, MWU-Vista*

***Implementation of the Camp***

Although the camp would be outdoor-based, we recognized the value of also having at least a shelter and some picnic tables for instruction. We could not hold the camp at the high school, due to the construction activity during the summer. So I procured permission from a local nature center to hold the class there and even for students to carefully go off the designated trails. Michael and I agreed on an early June four-day schedule to conduct the camp, all half days in the morning to avoid the Midwestern afternoon heat.

Michael communicated the logistical details to students and parents, we both secured consent forms, and I prepared a checklist of things for students to bring – and not to bring. Michael and Janet, the district science facilitator, secured field journals for students from the district, and I purchased such things as guide books, magnifying glasses and dissecting knives through the university. While the module was "designed for students to conduct hands-on research in basic insect-plant interactions," it could also be adapted to focus on other observable phenomena, such as other animal behavior, in a natural setting (documentation of Field Research Camp, MWU-Vista).

I prepared lesson plans and led the course, while Michael assisted and offered insights into the students. I brought posters of my own research while introducing the themes, and guided them to develop their own research questions while exploring plants and insects in the field. We dissected flowers to understand what insect pollinators were doing. They found their own flowers to observe and developed hypotheses that data from the whole class could address. We agreed on protocols for collecting data, they spent hours patiently observing for three days, and each day we analyzed the data in progressively complex ways. On the final day they reported their findings for the group, and we pooled data to answer additional questions.

> Within the framework of a pollinator observation project, students developed their own questions. Some worked in groups while others worked individually, and each chose a plant species to observe. One of their questions was to compare which species had the most insect pollinators, but then they also went further and asked if pollinators would come to the same species more often in the sun or in the shade, and so they collected additional data and conducted that analysis as well. – *MWU-Vista media article*

The camp was launched in summer 2010 with the initial cohort of animal health students. The following summer it was taught again for the following cohort of animal health students finishing their sophomore year. It would also serve as a model for programs that could be implemented in other districts. Reflecting on the development of the Field Research Camp, Michael told me:

> Unlike the development of the [animal health] program, which we made much harder than it needed to be [laughter], I think the field study was just a matter of combining what you already knew. – *Michael Dunlap, VSD teacher*

[I learned that] under our world, there's a whole other world in animals and insects, and how they communicate and feed themselves, and how one thing affects another thing and the bees take the pollen and that feeds the bees. And how they do all that, and then the flower – it needs to be pollinated to make more flowers, and everything's just a chain reaction. And I thought that was really cool. *– Brooke, 11th grader in the VSD Animal Health Program*

***Lab Techniques Course, Fall 2010 – ongoing***

***Overview***

The Lab Techniques (Lab Tech) Course was a new course designed collaboratively between the district and the university for high school ninth graders entering either the Biotechnology, the Geosciences, or the new Animal Health Twenty-First Century Program at Vista North High School. It was to give these students an introduction to science research and lab skills, as well as to help students bond among themselves. The course would be a one-semester course. During the 2010-2011 school year, the first year this course was taught, there were two sections of it, one in the fall and one in spring. In future years, all sections would be taught in the fall.

***Circumstances Related to the Course Formation***

Anticipating the new freshmen that would be housed in the high schools starting in 2010-2011, the three teachers at Vista North High School who facilitated the science Twenty-First Century Programs realized they needed to create a new course for their programs. One of the important qualities of the Twenty-First Century Programs was that students in the same program had at least one common course section together so they could bond with each other and their program teachers and facilitators. This now meant a new class in the ninth grade year. The three teachers decided to streamline their efforts and create a common course that students from all three science-based programs would be required to take as freshmen, and it would be an introduction to science methods.

We needed a special course for them to take. … The importance of the course was to develop good science laboratory skills, to understand some research methods, scientific

> methods, you know, looking at a project or something of that sort. We talked about poster presentations and research. And then a career component. So those were the three things that we thought were really important for these students. We were going to make it a semester long class, and we could do that. *– Steve Graham, VSD teacher*

Under restrictions from the board of education during the dire financial crisis at the time, they could not actually create a new course. Steve suggested transforming an already-existing course from his Biotechnology Program into the new freshman course. The course he would sacrifice was called Lab Techniques, a small class for juniors who helped Steve prepare the biotechnology labs.

> The Lab Tech – prior to its current status – was a class that students would learn behind-the-scenes research, or preparation of materials and equipment maintenance. I would technically have four or five kids or so that would be in that class, and we would get everything ready for the biotech class, and we would actually set up things. We'd autoclave, we'd prepare, we'd set up. *– Steve Graham, VSD teacher*

It was this existing course for a small number of juniors that was transformed into the freshman introductory course for over sixty freshmen. When Steve lost the preparation class for his biotechnology class, he worked alone in the school lab on weekends to prepare the complex labs. I interviewed Steve on one of those working Saturdays:

> That's one of the reasons my Saturdays are kind of like this – I don't have the Lab Tech prep students doing this for me. *– Steve Graham, VSD teacher*

#### ***Initial Planning Efforts***

In spite of the sacrifice, Steve enthusiastically embarked on planning the new course. As had been agreed by the Animal Health Program design team, the course would be developed with VSD and MWU personnel collaborating. The team was comprised of VSD teacher Steve, MWU scientist Tim Rollins, and me. We had all previously worked together on the Senior Biotechnology Project.

> It's an introduction to research and lab techniques course. It introduces basic research and laboratory methods as well as addresses the nature of science, exposes students to

> different career options. It's non-textbook based, and the thing that I love about this is the Vista School District teacher, the post-doctoral scientist from MWU, and the science partnership coordinator from MWU who worked together so closely on the biotechnology project, and had a real feel for where some of the deficits were in that experience, were putting this course together as a team without a textbook, hoping that having this as a building block early in the high school education will allow some of these more authentic experiences to have higher value to students later in their high school education. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

We first met to develop an outline of the course on February 24, 2010. The course would be a textbook-free, laboratory-based course. The four organizing ideas for the course that we identified in that meeting were:

> - Understand Nature of Science
> - Develop set of skills
> - Read peer-reviewed papers
> - Exposure to careers and role models
>
> *– Meeting Notes, February 24, 2010*

We discussed specific activities that would show students the different ways of doing science, including descriptive, experimental and modeling activities. We thought lab notebooks were important, as well as the process of communicating about science such as in a poster session. We wanted to include the development of lab skills such as measurement, equipment use, data recording and data analysis. Steve especially wanted students to read primary, peer-reviewed literature, and then present on what they learned from the literature. Finally, career exploration and exposure was important to include in the course, and we brainstormed on various individuals to present to students. We thought to access archives of short videos on careers, and also decided to develop a collection of short video interviews with MWU scientists.

One of the challenging ideas was having ninth graders read primary literature. We could look for science articles for the general public that described active research areas. It was clear from the Senior Biotechnology Project that high school seniors had difficulty making sense of scientific articles.  Ninth graders had significantly less exposure to science than twelfth graders, and the sophisticated concepts in peer-reviewed journal articles seemed out of reach for freshmen students.  In my investigations for a solution, I discovered publications from a small group of science educators working with the idea of Adapted Primary Literature, that is, primary scientific literature adapted to be understood by high school students.  Working with this approach seemed exciting to the team, and was strongly supported by Susan Rasmussen.  She, Tim Rollins, and I met with an MWU animal health researcher to try to adapt a research paper of hers using the innovative approach.  Funding such a project, however, would be problematic, though Susan had some small funds from another grant program to help support it.  She described the situation in our interview:

> OK, we want to do Adapted Primary Literature.  The school district can't really fund something of that magnitude.  MWU-Vista is already funding you and they were really unable to – or unwilling to – fund much more.  And so again, it's like, OK, who on [the main] campus might be interested in doing this?  *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista*

However, pursuing this approach became untenable for several reasons.  First, with Susan's departure from MWU, institutional support for pursuing the project was lost.  Part of that support included the funding to have Tim Rollins, MWU post-doctoral researcher, work on the project.  Finally, Steve's responsibilities for the Lab Tech Course changed so that he would no longer be teaching it.  He strongly advocated for the primary literature aspect of the course, yet the teacher newly assigned to the course had other priorities.

Susan reflected about working sometime in the future with the Adapted Primary Literature approach:

> I hope that really works.  I think it has the opportunity to transform classrooms.  I think when you hear the word 'innovative' … and school districts and universities working together to really innovate – that's something that could really change pre-college science education.  And you know, it's not an original idea, but the more it's done, the more knowledge there is, the more research-based evidence can be used to inform teaching practice.  *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

### ***Collaboration and Course Implementation***

Steve's teaching responsibilities changed when the science teachers at Vista North High School strategized about how to meet the needs of all the ninth graders who would be coming to the comprehensive high school the following school year. Both ninth and tenth graders would be taking biology as the district worked with shifting biology courses from the tenth to the ninth grade. Steve would be needed to teach biology. So in late spring, Christine Finley, earth science teacher and facilitator of the Geoscience Twenty-First Century Program, agreed to teach the new freshman Lab Tech Course. She agreed to the collaborative approach with MWU, and she started joining our planning meetings as Steve phased out.

In early summer, Christine and I developed a week-by-week schedule with potential activities, things we could each work on during the summer. However I found it difficult after Susan's departure to receive approval to purchase supplies for our activities. When Tim's involvement was curtailed due to funding, it remained Christine and I who worked closely together using minimal resources to develop the course that would start the following fall. We started meeting again in early August. Christine remembered the start of our collaboration during our interview:

> When this [course] was getting started and I was trying to gather information from the rest of the department, they would give me ideas and thoughts. But I was getting frustrated to the point of almost tears at one point where I was [thinking], what am I going to do? Because they don't have time to help me. They want to help me. They don't have time. And then when we connected, and you know, we kind of really jived in the classroom and that was just a relief. And I know that if I'm ever needing ideas I can just e-mail you and say, what are your thoughts? … I can teach something, but with this class, it's not my background…. So you're my idea generator, and then I can implement it. *– Christine Finley, teacher at VSD*

The school year started in fall 2010, and Christine had thirty-four students in the fall semester Lab Tech class. As in former years, her students needed to collect the paper for recycling throughout the school building. She decided to assign this task to the Lab Tech students, and we thought this would be a great context for a semester-long class research project. She oriented students to the logistics of paper collecting, and I led the class in generating research questions and choosing one or two for investigation. Christine used the project to review volume and mass measurements, and students collected measurement data on paper collected throughout the semester. I led the students in the use of spreadsheet software for data analysis and graph making, and we spent time making sense of the results.

Week by week, Christine and I developed lab activities for students to explore chemistry, biology and earth science themes. Although we had a general outline of the course, we developed the details on a day-by-day basis.

> It's just a day to day – here we go! And if something comes up, I go, oh my gosh. And then I e-mail you or I find somebody that I need to help answer the question or whatever the challenge is. And I mean really, it always goes back to that collaboration piece. And if there's a challenge, we talk, we figure it out, we solve the problem. And if I didn't have you to collaborate with and work out those challenges with, it would be much more difficult if not nearly impossible to do it well. *– Christine Finley, teacher at VSD*

The fact that this course was a "singleton," a stand-alone course, allowed great flexibility in designing it. Christine describes the significance of that:

> [Development] was more just discussions between us. The nice thing about having this one class is there isn't anybody else necessarily that we have to deal with and get approval on because we're still experimenting ourselves, kind of formulating the class. And the science department in our building is pretty flexible, and they're just happy that I'm teaching the course …. So it's more about me communicating with you…. We have our goals that we're trying to reach. But we have some flexibility, where in other courses teachers don't. That's one of the unique things about the Twenty-First Century Programs is all of these singleton classes. The teachers have a little bit more freedom with what we're doing in those classes because we're not trying to keep up with eight or nine other sections. You know, there's one section of Lab Tech, where there are twenty sections of Biology. So those Biology teachers really have to stay together in their teaching, in their professional learning communities. *– Christine Finley, VSD teacher*

One way we chose to incorporate the Nature of Science elements was through the use of students' lab notebooks. We developed a flexible approach for student notebook elements that took into account different emphases on observations, experiments, analysis or communication. However, students became confused because these instructions contradicted instructions other teachers used for their lab notebooks. Other science teachers in the school emphasized experiments as reflecting the scientific method, and expectations for every lab entry required an experimental format (hypothesis, independent and dependent variables, control conditions, etc.). In an effort to not confuse students, Christine decided it was important that she conform to the other teachers' expectations for keeping lab notebooks.

While Christine supported the idea of requiring students to communicate about science, she was wary of requiring them to understand peer-reviewed scientific literature. Instead, she suggested the theme for student presentations be focused on career investigations. We scheduled speakers who presented to the class on different careers, and students conducted independent projects investigating a career they were interested in. We introduced students to professionals whom they could interview and learn about careers, and we guided them to key websites and other resources. Christine required them to create a poster presentation that was delivered during an evening public showcase of student work.

> When I look back on that first semester and its successes, I really felt like that career poster session was kind of a culminating capstone type project for them, and being able to stand out in the hallways next to their presentations in front of people. Whether their presentations were fabulous or not so fabulous, I still think that that was a huge success to get them out there in that presentation mode. – *Christine Finley, VSD teacher*

***Reflection and Adjustments***

With the first semester completed, Christine and I prepared for the spring semester when a second section of students would take the same course. This gave us the opportunity to review, revise and adjust elements of the course. We added some things, combined some things, and refined everything. Not knowing the longevity of my position, which was still as a graduate research assistant with MWU, we made a point of having Christine try to lead the labs and activities that I originally took the lead on.

> Just being able to get through it, through the first semester and have multiple labs developed. A lot of the things we've done have been major, either create from scratch or – you know – major tweaking of existing labs, and modifying it and adapting it to the

needs of the program.  And you know being able to work with you on that to come up with a good product.  – *Christine Finley, VSD teacher*

The science department in the school reviewed the coursework, and recommended that in subsequent years all the sections of the Lab Tech Course be placed in the fall semester, so students in the twenty-first century programs all had an initial course in their first semester in the high school to connect to their program.  Upon reflection, teachers appreciated the head start that the Lab Tech Course was giving students in their programs.  The teachers described in our interviews why it was important to their programs:

> My [biotechnology] program is set up for the juniors to learn the techniques … and if they wait to start [research] in their senior year, they kind of lost any head start and they're kind of behind.  I'd really like to see the research taking place at an earlier date.  We've actually found that by doing the ninth grade Lab Tech class, that's going to probably give us that little edge I've been looking for where students start off with thinking about research…. So there we have fresh groomed sophomore level independence, so that to me means that they're much more prepared for my presentation of all these different techniques and tools.   – *Steve Graham, VSD teacher*

> Adding resources in the classroom for students starting out in the program and being able to excel there and get the exposure to science in a different way – I'm talking about Lab Tech.  Where you know, that class and what's going on there is so different than the regimented state assessment type stuff that I think it inspires students to want to be more curious about what's going on, and it gives them another avenue.  And I think that'll carry over into state assessment type stuff, because they want to excel so they get more of those opportunities.  – *Michael Dunlap, VSD teacher*

> I like the foundation of teaching.  This is a foundation class – they're getting their basics…. I just feel like I'm really good at getting kids a good foundation, base knowledge, where they can have that solid footing to move up and move forward.  I know it's one of my skills.  And so that's why I like this class, because that's what it is – it is a foundation class.  – *Christine Finley, VSD teacher*

### *Summary of Embedded Programs*

The science education program and curriculum development formed the heart of implementing the goals of the MWU-VSD partnership. They were developed in teams that ranged in size from small groups of two or three, to over a dozen for the Animal Health Twenty-First Century Program. Students influenced the program development as educators and scientists tried to meet their needs while also challenging them and expanding their horizons. Through the collaborations, programming was created that fit into the context of the district's Twenty-First Century Programs, and they were designed to be implemented within the school classrooms. They also focused on animal health content, interfacing university animal health scientists, students and educators. In these ways, the programs were innovative.

## *Concluding Thoughts on Partnership Development: Evolving Focus and Involvement of Members*

A number of participants commented on the different types of meetings: strategic, tactical, and operational. One person described the progression from a more strategic focus at the inception of the partnership to a more operational, or "boots on the ground," focus as the partnership matured:

> As implementation has proceeded, the people who had a more peripheral role such as myself have been less involved on a regular basis. And so it's proceeded the way many projects do that once you've done sort of the high level planning then the people who are delegated to be the boots on the ground have gone out and gotten the work done.
>
> *–Barbara Shepard, MWU faculty scientist*

In order to examine how true this was, I plotted the number of different types of partnership meetings over time, as shown in Figure 4.4 below. Strategic meetings are considered to be those involving top institutional leaders who can make decisions on behalf of the institution, such as the district superintendent or associate superintendent, and the university chief academic officer or dean. Tactical meetings involve middle managers, and operational meetings involve those implementing aspects of the partnership, such as programs or events.

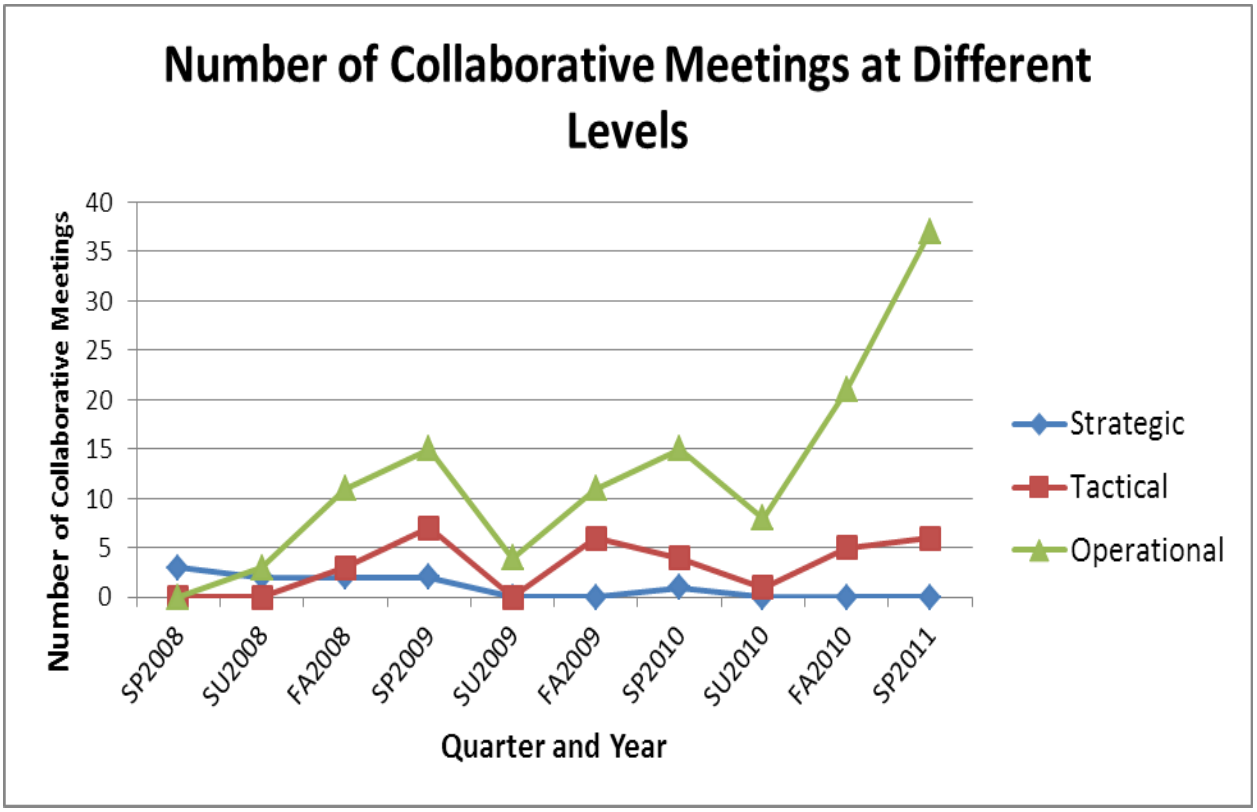


**Figure 4.4 Number of collaborative meetings at different levels over time –** The numbers of three different types of meetings, strategic, tactical, and operational, were plotted over time per quarter. These meetings were counted only if they involved staff from both institutions, not internal meetings within an organization, even if it was in regard to the partnership.

The graph shows that the first quarter was the only one in which there were more strategic meetings than either tactical or operational, while the tactical meetings increased though remained relatively stable over time. The number of operational meetings increased significantly. The number of all types of meetings hit low points in the summer, largely due to the fact that schools are not in session in summer, and teachers and many administrative staff are not on contract then.

The fact that the number of operational meetings increased over time is not surprising since program development required multiple meetings from those who had "boots on the ground." The guidance of operational development largely came from decisions made in the tactical meetings, and there was enormous overlap of personnel sitting in the operational and tactical meetings. For instance, the teachers, science facilitator, and I as program coordinator largely represented the operational development, and we were also involved in the tactical meetings. In fact, the inclusion of teachers in the tactical meetings was important to informing decisions made in the tactical meetings. They contributed a deep understanding of the challenges in the classroom, the pedagogical goals in working with students, and solutions to meeting the needs.

Only one strategic meeting occurred in the second year studied in this case, and none in the final year, in contrast to the two to three meetings per quarter in the partnership's first year. While the decline of strategic meetings between institutions would be expected to decrease as implementation increased, the complete lack of such meetings in the third year concerned at least two interviewees from the school district, who recommended a strategic meeting in order for the collaboration to be reviewed, reflected upon, and commitments revitalized or adjusted for the future.

## Emerging Issues (Research Question Two)

*What are the emerging issues, such as outcomes, successes, and challenges, of the partnership?*

The partnership between MWU and VSD was shown to consist of a number of important elements and dynamics during its first three years contributing to its successes and outcomes. It also faced a number of challenges. The themes I will discuss in this section will include:

- Drivers of the partnership
- Equitable assets dedicated to the partnership
- Processes and dynamics creating a positive and productive climate
- Roles of the scientist-educator coordinator
- Productive teamwork of educators and scientists
- Challenges faced by the partnership and how they were met
- Benefits of the partnership
- Outcomes of the partnership

### *Drivers of the Partnership: Political Drivers and Key Leaders*

The start of the partnership was unique in its external political drivers – first with the city investment of the land grant and then the county investment of the sales tax. While many science education partnerships between universities and school districts originate through one or the other institution reaching out to the other, the MWU – VSD Partnership originated through the vision of city leaders. The fact that this partnership was mandated in the memorandum of understanding drawn up between the City of Vista and Middle Western University upon the land grant for the new satellite campus secured an equal standing for the school district. From the beginning this partnership held the character of a collaboration of equals. The city gave a gift of land for the university to gain a very valuable physical presence in the metropolitan area for purposes far beyond recruiting students from the Vista School District. The university wanted a campus in the metropolitan area to create a conduit not only between prospective students and the main campus, but also between industry, research and development resources in the metro region and the main campus. The City of Vista leaders, however, wanted to ensure that this land grant would benefit its own community, a suburb within the larger metro region, and as a condition of the land grant, stipulated that the university partner with local schools. Phillip Hendricks describes the agreement:

> It's a legal document. It was actually put together contingent upon getting the land. In other words, this is what you have to do, or [the land will] revert back…. We were committed to – in that very first written agreement – in order to get the land we had to have those relationships established with no real guidelines. It was so nebulous that you could lose it if you – you know. *– Phillip Hendricks, Dean of MWU-Vista campus*

The "nebulous" nature of the partnership as stipulated left room for interpretation and might have been implemented to as little or great a degree as those involved wished. Yet the fact that specifics were not spelled out also activated something of a conscience, as can be seen in Phillip's comment above on the possibility of losing the land if "those relationships" were not established. Thus, a foundation of external accountability was created at the beginning.

These political drivers for the MWU – VSD partnership were vital to the interests of the MWU satellite campus, and to the university itself. Seventy-five percent of the adult participants interviewed for this study ($n$ = 12) stressed that the land grant especially was "a very important driver for our partnership." Further, the MWU-Vista Campus, in conjunction with other institutes of higher education in the county, was invested in raising funds from the community through a tax levy, promising to engage with all the school districts in the county. So its credibility in working with local education was at stake.

As important as the political drivers were, the partnership mandate could have resulted in standard outreach activities were it not for the foresight and active engagement of key individuals. Susan Rasmussen describes these drivers:

> I think this is a partnership that really started out of a political expectation related to the land grant for the MWU-Vista campus and the politics of wanting to pass the sales tax ballot measure so that there would be funding for the campus. And so in that sense I think there were very much external drivers for this partnership that led to the first meeting. I think that another major … driver for the partnership was the will of Alice Hughes who was then superintendent of the Vista School District, because she could have let the language in the land grant and the ballot measure lay fallow, but she chose to push

> the envelope. She chose to invite MWU-Vista to be part of the school district's strategic planning process so that the partnership was on the table and delineated early in the advent of the MWU-Vista campus history, and I think that was very important for launching the partnership. *–Susan Rasmussen, former Chief Academic Officer at MWU-Vista Campus*

Not only the external political drivers, but also key leaders who had the imagination and will to be bold and creative were important to how the partnership began. Former superintendent Alice Hughes's retrospective description below sheds light on her efforts to leverage political interests for the mutual benefit of both partners:

> When it began, the city in its work with MWU had indicated that one of the things they wanted was to have a close partnership with the K-12 school district, with Vista. And so that was publically stated in a variety of venues. And as superintendent, I was given the opportunity to make sure what was said publically happened. And the leadership from MWU was also committed to that publically, and I think the citizens in this area in particular were paying attention and expected that to happen. So that's a very important piece, because sometimes things get said that they're going to happen, and unless somebody starts right away – . It really came from MWU that we needed to start right away, even though there wasn't a building and there was not a funding stream for sustainability of the MWU campus yet, because the sales tax obviously had not been promoted and passed yet. So MWU wanted something concrete to solidify this, and so it landed on the partnership with the school district as something to begin working on immediately. *–Alice Hughes, former Superintendent at VSD*

The nature of the external drivers, and Alice Hughes' initiative to keep it in the public eye helped create a spirit of equality, accountability, and enthusiasm. Both partners could leverage their interests, and Alice seized the opportunity to assert the district's standing. In turn, the partnership would be a concrete outcome that MWU could show the community. It would lend credibility to the appeal for the sales tax ballot measure. It would genuinely benefit the citizens of Vista, the district, and the university. Both partners prioritized it.

> We had no physical notice, so to speak. We had a lot of people doing some good things, but I think that the partnership with Vista led to the credibility [of the MWU Vista campus]. – *Phillip Hendricks, Dean of MWU-Vista campus*

So the initial foundation of the partnership really consisted not only of the mandate from the land grant, but also very skillful strategic planning by the leaders of both institutions, especially Susan Rasmussen and Phillips Hendricks from MWU and Alice Hughes from VSD. They each talked about the importance of building respect, support and consensus for the partnership, which meant keeping it in the spotlight at key moments through reports, presentations and press releases, highlighting accomplishments, and recognizing those involved in the partnership. While MWU's Phillip Hendricks thought in a more "pedestrian" way about what a partnership might mean – such as general outreach activities like guest talks – Superintendent Alice Hughes "pushed the envelope" and engaged the university in serious strategic planning for complex program development. She kept it in public view to hold the university accountable to its commitment and engender enthusiasm and momentum. She saw great potential in providing students in the district extraordinary opportunities through a partnership.

Phillip was pleased that the partnership evolved in a more dynamic way than he initially imagined, and he too leveraged its successes to build support for MWU throughout the metro region. The partnership helped established credibility for MWU building a satellite campus in the county, since it showed even before a building was constructed that the university would contribute to the local community and add value. This credibility helped him successfully campaign for the passage of a county tax that would provide a reliable stream of income to the new campus in Vista. Likewise, Susan Rasmussen, who oversaw the MWU side of the partnership, had experience developing programming for undergraduate and graduate students, as well as with K-12 outreach. She had been associate dean in the college of veterinary medicine, and strategically engaged many colleagues across the campus and funding sources to help support the partnership. In short, she had "a Rolodex that was important to have … bringing resident knowledge of the people, the capabilities, the structures, the centers at the university to the school district, and being able to represent them to the school district in a constructive fashion." She also hired key people to carry out important tasks for the partnership.

> It was part of my job to keep abreast of what was happening at the 20,000 foot level and make sure that the superintendent and the [dean] of MWU-Vista who might have to advocate for the program to the general public were aware of what was going on. And also to be able to invoke them when I felt that it was important for the partnership to realize its goals…. I made sure that people who were very publicly identified with both the university and the school district – and when I say the university I don't just mean MWU-Vista but I also mean people from the main campus – that they were kept looped. You know, I think that we put together a working group of people whom I knew would put things together. I was very clearly hand-picking people from the [main] campus because I knew that they had a strong history of not only productivity but excellent collaboration. They were people I'd worked with previously who I knew would deliver.
>
> *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista*

### *Equitable Resources Dedicated to the Partnership*

When interview participants were asked what resources each institution brought to the partnership, a very balanced picture emerged (see Table 4.2 below). Funding was dedicated to the partnership, with both organizations contributing to supplies, materials, and technology. Both institutions opened their doors to each other, allowing them access to their facilities, technology, and labs. The district's generosity in terms of offering office and meeting space as well as distance communication technology was especially important in the early days when the MWU-Vista campus had no building yet. The university's main campus labs and animal hospital also proved valuable to the partnership, especially for students to be able to experience the world of science research and clinical practice. Table 4.2 below lists the assets that were contributed by each institution identified by interview participants as important.

**Table 4.2 Resources for the partnership –** Assets identified by interview participants are listed in two columns according to institution, and the number of participants discussing each is noted in parentheses.

| Assets from School District | Assets from University |
|---|---|
| People (12)<br>Time (5)<br>Expertise (12)<br>Pedagogical (11)<br>21st C. Programs (9)<br>Partnerships (4)<br>Evaluation (1)<br>Vision Lead Facilitators (5)<br>Students (10) | People (12)<br>Time (4)<br>Expertise (12)<br>Coordinator / Liaison (12)<br>Scientists (11)<br>STEM Outreach (3)<br>College Recruitment (2)<br>Evaluation (1)<br>Industry Connections (4) |
| Facilities (6) | Campus (9) |
| Well Equipped Classrooms (6) | Science Laboratories (8) |
| Access to Technology (4) | Animal Hospital (4) |
| Office Space for Liaison (1) | |
| Supplies and Materials (3) | Supplies and Materials (8) |
| Financial Resources (6) | Financial Resources (10) |

***People were the Primary Resource***

While participants recognized assets that each institution contributed such as facilities, materials, and financial resources, all of them noted that people were a primary resource. Both institutions dedicated staff to the task. The university created a position specifically to coordinate the partnership. The school district reassigned responsibilities of existing staff to work with the partnership. As Beatrice Price illustrates below, those who recognized people as resources also noted the particular talents, skills and commitment of the people.

> When you talk about staff, OK, it's a person, and it's a person supervising kids. But it's also expertise. It's passion. And put those two together -- when you put passion and expertise together, then the benefits to the kids are the fact that they're learning. And I don't think this is quantitative. Their learning is enhanced beyond reading a textbook, beyond looking at a PowerPoint, beyond going to a website. They have had all of these authentic experiences that are not quantifiable as far as I'm concerned…. And it's the right individuals around the table. If we're going to talk just cost, we [can say], OK, that

body costs us this amount of money. Well, the benefit, though is that it's that body, and it's the right body, because that body has a head on it that's committed and dedicated to making this happen. And that is priceless. *– Beatrice Price, Director of Secondary Programs at VSD*

When participants were asked during interviews what resources each institution contributed to the partnership, all adult interviewees responded that people were the most important resource. Different aspects of the human resource were discussed; they are listed in Table 4.2 (p. 184), and I will discuss them below according to institutional contributions.

***Human Assets Contributed by the School District***

When people are involved, *time* is involved. Interview participants recognized that staff gave time both within their official duties and outside the normal work day to tend to the partnership.

And the teachers have given up their time beyond the traditional professional day because they believe in it. So there have been individual contributions of resources. And there have been financial resources from the district as well as the commitment of the leadership in teaching and learning to say, 'We want to tend to this.' You know, this is intentional. And that takes time and commitment and nurturing. *– Alice Hughes, former Superintendent at VSD*

The *expertise* individuals contributed to the partnership was well recognized by interviewees. The school district brought considerable pedagogical expertise, both in relation to the *Twenty-First Century Programs*, in general educational skills such as classroom management and learning strategies, and in pedagogically-informed administrative support for students. When asked about the resources each institution contributed, Steve Graham responded:

The way the school district has been helpful in coordinating the direction of these students into classes, because the Twenty-First Century Program does provide good support with the scheduling of students, and getting them into the classes they need to be into and helping monitor their progress, and making them feel like they're part of a bigger program. *– Steve Graham, VSD teacher*

Additionally, the experience school district personnel had with other *partnerships* in higher education and business was recognized. The district offered templates and guidance in such collaborations. In this vein, interview participants also noted that the school district underwrote the *Vision Lead facilitators* who helped facilitate the initial steps of the partnership.

A talented human resource originally dedicated to the partnership was the district *evaluation specialist* who helped design and write grants for the partnership in collaboration with the university, and who inspired leaders with her vision. Unfortunately, her position was a casualty of the severe budget cuts during the Great Recession, and this was a loss for the partnership.

Employees were not the only people reported to be resources: *students* were also overwhelmingly noted by interview participants as an important resource. Students helped inform the development of the programs since teachers and scientists who interacted with them reported making decisions to meet their needs and interests. The university was seen as gaining resources when it could recruit high school students, especially talented well-prepared ones, to attend MWU. In addition, high school students were seen as a source of inspiration to university scientists, contributing ideas and enthusiasm. The district students were also considered a source from which university staff could learn about incoming college students.

> And so [considering] the perspective of the scientist or the researcher or the professor, it's probably getting that story out: Here are the profiles of kids that are coming to you.
>
> *– Alice Hughes, former Superintendent at VSD*

### ***Human Assets Contributed by the University***

Participants also recognized the university's most valuable contribution were the people dedicated to the partnership. And similarly, the extra *time* that university personnel put into the project was noted.

> I think MWU faculty were very very generous in contributing time to a project for which they were not rewarded, but for which they had a vision of how to go forward. … I think these are people who went above and beyond what their job descriptions would have required – for their own professional development but also for their own investment in

> the future of STEM education. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

*Expertise* from the university was also seen as a very important resource for the partnership. Such expertise encompassed areas of science, recruitment, administration and evaluation. The most frequently reported expertise was that of the *scientist-educator coordinator*, which may not be surprising in that this role was almost solely dedicated to attending to the varied and complex details of the partnership, while all other participants had numerous other responsibilities to attend to. So it was the coordinator who interacted with all participants and tended to the many tasks of the partnership. While the university supported the salary of this position, the district provided office space for this position for the first year.

The expertise of *scientists* was also noted by nearly all interview participants as an important human resource that the university contributed. Scientists were involved in all aspects of program design and development, and they offered important skills and specialist knowledge to the partnership.

> I think MWU has the expertise in animal health, the veterinary science. The veterinary college has been very helpful, everything from providing tours to providing some leadership on the summer field studies and summer camps. – *Steve Graham, VSD teacher*

A number of the scientists involved in the partnership were experienced in other *STEM outreach* programming at the university, especially in regard to creating opportunities for under-represented groups in the STEM fields. Related to this was the expertise of university personnel in *recruiting students* to the university. University individuals were also seen by district educators as a resource because of their *connections to the regional life science industries*. This was important because the Twenty-First Century Programs strove to connect their curricula to real-world applications in the work-force, and they tried to partner with businesses and other institutions to help provide students opportunities for shadowing and internships.

> MWU, I believe, brought to us an awareness of resources in this area. MWU and the animal health business cluster – when I think of Susan walking into the room, both of those things walked in with her. – *Joyce Lancaster, former Science Coordinator at VSD*

### *Processes and Dynamics Foster a Supportive Climate and Common Vision*

> Did we sign something, like sign on a dotted line? I don't even remember signing anything. This comes back to just moving the planning and the processing forward. It was built on relationships. *– Alice Hughes, former Superintendent at VSD*

Since people were recognized as the most important resource involved in the partnership, it is not surprising then that the success of the partnership could be attributed to relationships. Ironically, when the partnership first formed, the intention was actually to *not* base the partnership on particular people, but to create infrastructure that would be sustainable beyond the transience of individual people, as illustrated in Susan Rasmussen's discussion below (and confirmed by minutes from meetings).

> As the people who came to the table at the first meeting started to develop the strategy with the help of the facilitators from Vision Lead from day one, people were tuned to the fact that we had excellent people at the table to plan this partnership. But we couldn't plan a partnership that depended on the individuals. We had to plan a partnership that would be sustainable because of the nature of the infrastructure and the planning and the details. I mean, that was echoed by everyone sitting around the table that day. And I think that was very important because we were prescient in that very few of the people who were at that table are still in the roles that they were at the initiation of the partnership. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

So how do we reconcile this paradox that the success of the partnership was actually based on the relationships of the people involved, and yet designed to *not* rely on specific people? Interview participants repeatedly attributed the processes and dynamics among people that contributed to its success. These included collaborative decisions, strategic planning, accountability, face-to-face interactions, and communication woven together into a supportive climate of respect, equity, trust, understanding, dedication, inspiration and synergy, and flexibility. These helped shape a shared and evolving vision of the partnership. While specific individuals may have been critically important to the partnership, it appears it was because they could form strong relationships according to the dynamics and processes interview participants described. The interrelationships of these are shown in Table 4.3 below.

**Table 4.3 Processes and Supportive Climate Foster Common Vision –** The processes and dynamics listed on the left foster the supportive climate listed on the right, which also mutually foster the processes and dynamics. Together they help form an evolving common vision, which in turn supports the processes and climate. The number of interview respondents indicating each element are noted in parenthesis.

| **Processes and Dynamics** | **Supportive Climate** |
|---|---|
| Collaborative decisions (10) | Respect (10) |
| Strategic planning (11) | Equity (12) |
| Accountability (9) | Trust (7) |
| Face-to-face interactions (12) | Understanding (9) |
| Communication (9) | Dedication (11) |
| | Positive Attitudes (3) |
| | Flexibility (7) |
| | Inspiration and Synergy (11) |

**Common Vision**

The initial planning involved getting the right people involved. Not only did leaders choose high quality people from their respective institutions to participate, but Alice Hughes also invested in the experienced Vision Lead facilitators to guide and provide external oversight of the initial planning process. This helped establish processes early in the partnership of identifying goals together, making collaborative decisions, and providing accountability. Alice knew the importance of building the partnership on face-to-face relationships, and she invested in it. Yet it was also important to establish healthy processes that were not dependent upon any single individual.

> We understood that we needed a system and structures that would be both flexible and sustainable. It couldn't be about individuals – it had to be about infrastructure, about personnel's roles and responsibilities rather than about their personalities or specific

> individual skill sets. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

***Collaborative Decisions***

The Vision Lead facilitators guided individuals through deliberate processes of making *collaborative decisions*. Ten of the twelve adult interviewees stressed the importance of collaborative decision-making, and Beatrice Price perhaps describes it best:

> I think the point about the decisions being made is that they were made collaboratively. I think that we worked very very hard at keeping this a partnership, which meant we came to the table as equals. And I think that is something that [in] my personal experience with partnerships is not easy to sustain…. I think we just worked real hard to be very appreciative … [and] respectful to both organizations and to both the perspective that the people from both organizations brought to the table. And I didn't see people assuming the "my way or the highway" attitude, because MWU knew how to do it and we were going to do it that way, or VSD knew how to do it and we were going to do it that way. When you think back to that first year there was a lot of give and take and testing the waters: "How's this feel?" "Does this work for you?" "Well, what about if we do it this way?" I mean there was just a lot of that kind of dialogue…. But I also think there were things where we had to come to consensus on: "Is this going to be an activity that we support through this partnership?" And that was a consensus. That wasn't a "How's this feel?" kind of conversation. – *Beatrice Price, Director of Secondary Programs at VSD*

Repeatedly, participants described that decisions were made collaboratively, and almost always by consensus, from the large strategic planning meetings to the small teams that worked for program development. Participants acknowledged the skillfulness of partnership members at working together and forming collaborative decisions. They showed respect and strove to understand one another to come to agreements that everyone could support. When problems arose, their strong and trusting relationships allowed them to solve even thorny issues without threatening their good will.

### ***Strategic Planning and Management***

The amount of skillful *strategic planning and management* involved in the partnership and in programs engaged with the partnership were discussed by nearly all participants. The first year of strategic planning was guided by the Vision Lead team whose involvement was underwritten by the school district. Four of the five participants interviewed for this study who had been in those meetings stressed the importance of these external facilitators at the beginning of the partnership, noting that it freed the partnership members up to build relationships and strategize.

> The facilitation helped do two things. It created focus with some basic initial steps to implement, and it built relationships. And that's very important in a partnership that you have those relationships, that face-to-face of the people that are working, and again, the sustainability of leadership. *–Alice Hughes, former Superintendent at VSD*

> I think actually sitting down with the facilitators, being forced to task, to stay on schedule, having them reflect on what was said back to us, and having that kind of intense interaction allowed people to trust each other early, and that was very helpful in the long-term survival of what happened. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

By examining who discussed strategic planning the most, we can infer who may have directly engaged in those activities the most or at least been aware of them, either in the development of the partnership at large, or in the development of specific programs (see Table 4.4 below).

**Table 4.4 Strategic Planning and Management –** The table identifies individuals who spoke about strategic planning and management in the context of the partnership, their role, affiliation, the number of references they made to the topic.

| Name | Role | Institution | # of References |
|---|---|---|---|
| Susan Rasmussen | Faculty Scientist | University | 25 |
| Steve Graham | Teacher | School District | 13 |
| Michael Dunlap | Teacher | School District | 10 |
| Alice Hughes | Administrator | School District | 11 |
| Janet Spencer | Administrator | School District | 3 |
| Barbara Shepard | Faculty Scientist | University | 4 |
| Phillip Hendricks | Faculty Scientist | University | 5 |
| Beatrice Price | Administrator | School District | 4 |
| Tim Rollins | Junior Scientist | University | 2 |
| Joyce Lancaster | Administrator | School District | 1 |
| Robert Tillman | Faculty Scientist | University | 2 |

The top four individuals contributing most to this topic were two institution leaders and two teachers. The two leaders, Susan Rasmussen at MWU and Alice Hughes at VSD, were responsible for garnering support for the partnership from their home institutions. They both spoke at length about leveraging the partnership mandate written into the original land grant from the City of Vista to MWU for its Vista campus, and of their efforts to keep stakeholders of their respective institutions informed and supportive. Stakeholders in the district included board of education members, parents, teachers, and the local community. Stakeholders in the university included the MWU-Vista campus board of director members, the provost and other vice-presidents, respective deans, and faculty. Three people specifically noted the importance of the support of MWU's provost's office.

Strategic planning and management also occurred at the programmatic level, especially with the teacher facilitators of the Biotechnology and Animal Health Twenty-First Century Programs, since these were the programs most closely interfaced with the partnership. They needed to answer questions from students and parents about planning their schedules and programs. The teachers were involved in planning the programs implemented in the partnership, including in design meetings. They communicated to others in planning meetings a sense of what would and would not work in the classrooms, and were very involved in the strategic planning of the specific programs and projects. They created proposals of required coursework for the new Animal Health Program, found solutions to problems of needed coursework without adding to the budget, created lessons and projects for students, developed recruiting strategies, and networked with business leaders to bring students field trip opportunities and to raise funds. The teachers thought seriously about their individual students and what opportunities they could offer them based on their interests, aptitudes and career goals. They were dedicated to presenting career goals that the students had not necessarily thought about yet but that the teachers felt would be a good fit. In so doing, the teachers researched careers and learned new skills themselves. For instance, Michael Dunlap's discussion about the ongoing development of the Animal Health Program reveals the elements of planning, both short-term and long-term:

> This particular program in my mind is one that's really going to be dependent upon the relationships in the community, because a lot of these students want to have jobs where they're working with the public. They want to be vets; they want to work with the animals. They have to have a lot of interaction…. And so we have to open those doors so students can experience that…. In order to knock down some of those doors, [we] kind of have to have the best foot forward all the time and have our name out there and doing things…. Then I think some of the other things that can come along in the program will be a lot easier to gain and do and have those opportunities….
>
> The interest in the program has increased every year. We had fifty total applicants between two grade levels last year. This year we had forty-seven with just one grade level. We can't support those numbers. It's just not possible because of the classes that they take down the road, both coming in, like the Lab Tech class, and the advanced Biotech class which is the research component that we think is really important for them to get that exposure. – *Michael Dunlap, VSD teacher*

### ***Accountability***

Processes of *accountability* were discussed by most adult interview participants. On the one hand, formal assessment and evaluation strategies that were initially planned were unable to be carried out due to the attrition of staff during the financial downturn. On the other hand, informal assessment was ongoing, from developing lists of "lessons learned" in particular programs to individuals making adjustments based on recent experiences. Simply meeting periodically meant individuals were reporting to each other.

> We held each other accountable for what we said we were going to do because we'd come back to the table then and report … "How did the career fair go?" "How did the summer camp go?" "How is the class going?" "What's enrollment?" You know?
>
> *– Beatrice Price, Director Secondary Programs at VSD*

Regular reporting occurred within institutions, with VSD personnel reporting to the superintendent and then publically to the board of education, and MWU personnel reporting to the campus board of directors, the provost, and the president. Such accountability and reporting kept a strong body of support around the partnership, and even as resources waned during the Great Recession, leaders were able to secure necessary means to maintain the partnership.

People involved directly in the programs also engaged in processes of accountability. For instance, both Steve Graham and Tim Rollins recognized that expectations on students in Senior Biotechnology Project had probably been too high, especially expecting them to read and understand some of the scientific literature. So when they worked together initially to plan the Lab Tech Course, the subject of whether it was realistic to expect students to understand scientific literature was raised again, and alternatives were sought. Likewise, much of the interviews with teachers Michael Dunlap and Christine Finley consisted of their reflections on what worked, what did not, and what they had adjusted and what they still would. University personnel reflected on needed adaptations. For example, Susan Rasmussen, Tim Rollins and Robert Tillman all recognized that working with high school students in lab projects required more face-to-face time than they planned, originally hoping to accomplish more of the meetings through distance technology. As Susan noted:

> I think the scrutiny that we're all willing to bring to [the partnership] for continuous improvement is important. *– Susan Rasmussen, Chief Academic Officer, MWU-Vista campus*

***Face-to-Face Interactions Foster a Supportive Climate***

In fact, the process most frequently described as important to the partnership were *face-to-face interactions*. Given the fact that the main MWU campus was two hours away and the local campus was not yet built, face-to-face interactions were a challenge. Nonetheless, interview participants found these critical to the development of the partnership.

> That's very important in a partnership – that you have those relationships, that face-to-face of the people that are working. – *Alice Hughes, former Superintendent at VSD*

Why did interview participants think face-to-face relationships were important? Many interrelated reasons emerged: for establishing bonds, building mutual trust, and creating a common vision. A great deal of learning occurred through face-to-face interactions, especially about others' areas of expertise, roles and cultures, and this learning helped to bridge the differences and synthesize varied interests. Through experiencing each other's professional settings, participants could more easily see each other's point of view and learn about each other's resources that could be used in the partnership.

> [The face-to-face aspect] was understanding. I mean, it's respect for the entities of the partnership, because a partnership implies that there's a sense of equity and equality, and so you can't have a true partnership, whether it's probably a marriage or a business partnership or a partnership between higher ed and K-12 unless you have mutual respect. And you have to also have mutual understanding of what people are bringing to the table. *– Alice Hughes, former Superintendent at VSD*

Interview participants thought face-to-face interactions were important for building consensus, for coordination, for quick and easy problem-solving, and for "reading each other" to perceive difficulties. They were important for identifying common goals, clarifying thoughts, working through confusions, and planning efficiently. Brainstorming occurred, and a climate of *inspiration and synergy* were experienced as individuals were "at the right place at the right time" to say or do something that moved the programs further along. The synergy fostered a climate of *dedication* to the partnership – such inspiration was recognized as valuable and even rare.

> When you collaborate you get a better product. You know, two heads are better than one, but that collaboration is just huge because you're pulling from each other's minds and you get a better product than just something designed solely by yourself. And there are some people who can design something on their own. But I think that's few and far between. – *Christine Finley, VSD teacher*

> I think the part that has surprised and that just continues to amaze me is the rapid rate at which everybody comes to the table willing to solve problems, moving to keep moving, and to put in the work and effort to keep this growing and new. It's like, OK, what are we going to do next, what are we going to do next, what are we going to do next? And the core planning team …, you folks that sit around the table all the time really have just made this hum along. *– Beatrice Price, Director of Secondary Programs at VSD*

Understanding each other's worlds and working through problems together helped nurture a climate of *respect*, *trust* and a sense of *equity*.

> What was important about the face-to-face was that it also necessitated let's say in this particular case higher ed really kind of understanding and overcoming some challenges [about] what can high school kids really do. And is there a commitment there? For the K-12 people, it was really how can we refocus and redesign some things that we're doing so that it realigns with the vision of another entity without sacrificing our core mission. And so then you have to have some trust. And trust is built around, in my opinion, relationships and follow-through – takes a long time to build and can be so easily destroyed. *– Alice Hughes, former Superintendent at VSD*

Seeing each other in action fostered admiration. In addition, common experiences helped build camaraderie and teamwork, a sense of belonging to the group, as well as fond memories to reflect upon. Face-to-face interactions fostered a sense of accountability, as progress reports were often delivered across the table from one another, suggesting a moral dimension to the face-to-face interactions. And again, all of the processes cultivated a sense of dedication.

> I think as a result of our experience and a result of our dedication to the partnership as an entity, somewhere along the line all of us, whether it was at the beginning or the middle or at the end, recognized what has to get put on the back burner for you as an individual for a partnership to succeed. And you know, it can't all be about what's easy for you. It can't all be about your personal time. You can't let it consume you…. But if you always put all that other stuff first, the partnership will not flourish, in fact it will not even make it. And so you have to figure that out that, at some point in time, depending on where the partnership is, somebody has to be putting the partnership first, and that person can kind

> of hand off to the next person.  And I don't know that we ever actually discussed that, but we all knew it.  We all got it.  We all knew who's on first, and if that person didn't have enough gas left, to call for help.  And we all had the partnership as important to us that, you know, we weren't going to let it run out of gas.  And I can see that has become part of our ethos and our first principles just by virtue of all the time working together.  – *Susan Rasmussen, Chief Academic Officer, MWU-Vista campus*

Another important way in which face-to-face interactions were important was simply in showing up, even when a lot of communication did not take place.  For instance, when students made public presentations, it was important that university leaders showed up.  When the new MWU-Vista campus held its grand opening, it was important that district leaders, teachers and students showed up.  Attending such events were a show of respect, appreciation, of supporting each other's work and understanding.  Individuals served as "ambassadors and emissaries," as one interviewee put it.  Alice Hughes shared with me how the presence of one of the MWU leaders at a VSD public event in which high school students presented affected their teacher:

> She was proud of her students that night, pleased that you'd got the associate dean to stay through the entire thing.  That was a big deal.  That compensated for a lot of extra hours of work.  That really did, because that's that appreciation, that's the respect, that's understanding, that's common vision, that's saying what I'm doing means something to people, or what our program's doing – it's not just spinning our wheels just to say that we're doing it.  – *Alice Hughes, former Superintendent at VSD*

Face-to-face relationships were instrumental in providing opportunities for high school students.  Because students interacted directly with university scientists, they were made aware of special programs at the university to further their educational career, and they were able to solicit impressive letters of recommendation from the scientists.  Both district and university personnel noted the significance of these direct connections, as did students.  Face-to-face interactions were invaluable in the educational experiences provided for students.  Because of the distance between the main university campus and the school district, it was originally hoped that much of the learning could be done through distance technology.  However, as Susan Rasmussen states, "I think we got a real sense in the course of the [Senior Biotechnology Project] how much you have to do by face time and how much you can do electronically, and you have to think things out."

*Positive attitudes* in the face-to-face interactions were mentioned often as facilitating a climate to build relationships: cheerful, easy-going, committed, open, respectful, approachable, enthusiastic, positive, and supportive.  No individual overtly said having a sense of humor was important, but they all cracked numerous jokes and laughed often throughout the interviews, and humor was present in many meetings and face-to-face interactions, and is worth noting.

***Communication***

Ultimately, most of the reasons face-to-face interactions were important boiled down to the importance of *communication*.

> I think any partnership does require communication.  You've got to be willing to take time to communicate and to visit.  You know, I think that if you just try to take from that and never give back to that partnership, that's always going to be a problem.  You've got to be willing to invest a little bit of your time and effort into it.  *– Steve Graham, VSD teacher*

Certain individuals often served as proxies for a larger group, or as a conduit to resources.  For instance, as the coordinator and liaison for the partnership, school district teachers and administrators learned through our communications, both formal and informal, about university resources and scientific expertise.

> Without the partnership, we – the school district – wouldn't necessarily have had as easy access … to the resources of the MWU instructors, to you as our liaison, to bring out the wealth of information that you bring to us, to the teachers.  And [otherwise] it would be the teachers out seeking and looking and Googling or whatever they would be doing trying to find resources.  *– Beatrice Price, Director of Secondary Programs at VSD*

In planning meetings with VSD administrators and MWU personnel, teachers represented their students, often with specific anecdotes that helped make student needs personal and immediate.

> I think that's why it's so important with the Animal Health [Program] that Michael in particular is meeting with those students the minute they walk in the door. And developing that connection, and developing that connection not only with them but with the MWU piece, and with you, and having that face and understanding that they have walked into this program that has a partnership with a higher institution. – *Janet Spencer, Science Facilitator at VSD*

Individuals served as representatives of the partnership back in their home institutions. District personnel learned a great deal during their visits to the university, and they shared their new understandings with their district colleagues. A small group of students who visited university labs also would "bring what they learned to all of the students in the classroom." University personnel who immersed themselves in the school setting communicated those experiences back to their higher education colleagues.

In a similar vein, administrators from both organizations discussed advocating for the partnership in their home institutions and stakeholders. University personnel made sure face-to-face presentations accompanied written reports at meetings with board members, deans, faculty and key leaders such as the provost and president. District administrators likewise ensured that presentations of the partnership were made to members of the Board of Education and colleagues within the district.

> I think my role with this partnership … is to be the advocate and support at this level to do what I can to make sure this continues to be part of the district mission. I do a lot of communicating, updating. The Board Report, for example. How do you keep things out in front of people? Well, the Board that's deciding what's going to stay, what's going to go, and what we really need to be passionate about – needs that information. – *Beatrice Price, Director of Secondary Programs at VSD*

***Flexibility***

*Flexibility* in the partnership was seen as important by seven of the twelve adult interview participants, and most notably by Susan Rasmussen and all the teachers. For instance, members of the partnership had to be flexible during the economic downturn, to manage with less money. This meant sharing budgets lines, being resourceful to find additional funds, sacrificing one class in order to create another, and otherwise adjusting expectations of what could be accomplished right away. Flexibility included adjusting to the constraints of each other's institution, such as trying to resolve the desire for an MWU online course for high school students, or dealing with the difference in naming the program Animal Science versus Animal Health. Flexibility involved adjusting to scaling programs up from twelve to one hundred students. Flexibility was required in simply making projects work – dealing with limited lab equipment in the high school and finding ways to meet goals or adjust goals. As Robert Tillman, scientist faculty at MWU noted, the conditions for the experiments were " not ideal, but we'll have to deal with it."

> I think flexibility is huge. You know, you have these ideas and these ideals in your mind of how you want the course to run and what you want to accomplish in the course, but reality sets in and you try to accomplish those, and they're your goals.
>
> *– Christine Finley, VSD teacher*

Flexibility was also a built-in hallmark of the Twenty-First Century Programs. All the teachers remarked on the district-supported flexibility within these programs to experiment, to explore new ideas and projects, and to develop the programs with extraordinary independence. Although these programs interfaced with other teachers and courses in the high schools, "singleton" courses were developed that did not have to stay in lock-step with other sections of a course school-wide or even district-wide. Unique learning opportunities such as field trips, guest speakers, internships and mentorships were developed as Twenty-First Century Program teachers saw fit. These teachers credited the district's flexible support of them as Twenty-First Century Program facilitators to develop relationships outside the school, such as with metro-wide, state-wide and national organizations, and in sponsoring summer learning opportunities and externships. These connections and training kept their skills and understanding of the professional field current, flexible and relevant for students.

Likewise, interacting with students required flexibility. Teachers noted anyone working with students needed to remain flexible in order to meet their needs and to facilitate their learning. The emphasis put on helping students explore their career interests kept teachers flexible in trying to meet the needs of changing students each year. One teacher had difficulty articulating his exact role, because it was so varied and depended on varied contexts.

I don't know what those roles are because I don't think they can be succinctly laid out. And I don't think that would be any fun anyway … to be that rigid: "I'm sorry, I only do these things." *– Michael Dunlap, VSD teacher*

Susan Rasmussen expressed specific satisfaction in creating programs that were flexible enough to include students from families without tremendous financial means.

We tried to create that experience with kids who didn't have those resources behind them. And I think that's really important. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

***Common Vision***

Altogether, such processes and dynamics fostered a supportive climate that nurtured a team of diverse people who could work easily together, and who could hold an evolving *common vision*. It was important to have a common vision, one that benefitted both institutions and continued to inspire the work together. Yet it was also important this common vision evolve to meet the changing times, changing students, and changing institutions. The way such an evolving vision continued to be shared was through the processes and climate described above.

As we learn more about the kids we learn that we need to revise…. And we continue to make decisions and make improvements…. That's evolved. It changes as we go through. What are our needs? Because that's how decisions need to be made: What are our ever-changing needs? *– Janet Spencer, Science Facilitator at VSD*

A sense that the partnership was actually a living entity that was vibrant and alive was voiced by four of the participants, who emphasized its changing evolving quality.

It *is* alive. It's life science – it's alive! It really is. It's not a piece of paper. It's not a notebook. It's not just a class on the schedule. It really has life, and finesse, and all kinds of fun things about it. *– Beatrice Price, Director Secondary Programs at VSD*

Synergy is such an overused word, and you could say one plus one equals three, or the whole is greater than the sum of its parts. But I really do believe that what you have as a result of bringing these institutions together and having them listen to each other and articulate common goals and then try to develop and implement plans, you do wind up with more than you could have either way. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

### ***Roles of the Scientist-Educator Coordinator***

At the beginning of the partnership when Susan Rasmussen was putting resources into place to support the collaboration, she advocated for a half-time coordinator.

> We decided if this was really going to work, we were going to have a need for a translator and a coordinator, someone who could really walk the walk of K-12, and the walk of the university. So we dedicated a coordinator position, and we were able to hire someone with K-12 classroom experience, and a master's degree, a research-based master's degree in biology who was already working on a dissertation in education. So I think who the individual is is much less important than the fact that we understood we would need someone to be a liaison, someone who could help manage the cultural clash that would be nobody's fault but that would result from the differences, and someone to keep us on track. – *Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

I was that person hired, and in full disclosure, this is a difficult topic on which to have objective perspective. Not only did I fill this position for three years, but I also conducted the interviews in which individuals talked about this. I sometimes wonder if they were more effusive in my presence than they might have been otherwise. That said, eleven of the twelve adults interviewed raised the topic of the importance of this position without prompting in response to questions about what contributed to the success of the partnership. Somewhat in contrast to Susan's comment above, she spoke at other times about the importance of *who* that coordinator is. This suggests the importance of seeing through the personality to the qualities of the person filling the role.

> I think that [position] was critical. And I think having that position is important, but I think the individual in it was very important because that's a critical position, bridging two cultures, and two cultures that don't always work well together. And you know, anytime you have that potential choke point or disruption point, and you have somebody

who has a large component of their job focused on ironing out wrinkles and reducing clogs and mitigating potential disasters – I think that's really important.

*– Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

The coordinator position was one in which both institutions invested, knowing it would help ease the teamwork in the partnership.  The university supplied my salary, and the district supplied my office in one of the high schools.  I was in that office for an academic year, and it was an excellent opportunity to get to know administrators, teachers, students, and the educational programs.

I originally participated in the Senior Biotechnology Project, helping communicate, coordinate meetings and resources, and facilitate the educational process.  I sat in most planning meetings for all the partnership activities, and as programs developed, I took an increasingly active and leadership role in the committees.  Over the course of the three years, the committee work diminished and my role grew so that most of the collaboration occurred simply through individual meetings and communication with me as point person.

Based on participants' interviews, there were three main roles I played: 1) *coordinator*, 2) *mediator* between each other's culture, and 3) *scientist-educator* (see Figure 4.5 below).

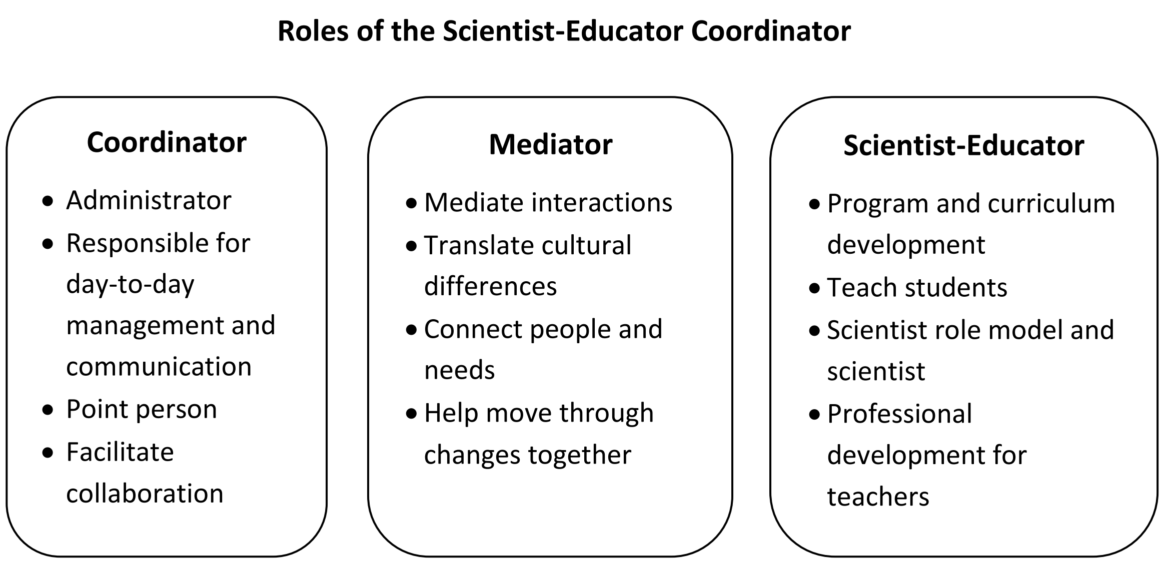


**Figure 4.5  Roles of the Scientist-Educator Coordinator**

As *coordinator*, I was the person devoted to the partnership, who "never let the ball get dropped," who could "connect the dots," who was "on the ground" "where the rubber meets the road" dealing directly with educators in the classroom and district offices as well as with scientists in the university. My time was solely devoted to the partnership so I could manage those things that others with many other responsibilities were too busy to do. I could pull them in at critical times when we needed larger meetings, or agreements, or resources to bear. As "the point person" I kept communication channels open, fielded requests from both institutions, informed others of activities, made reports and requests, and helped keep things moving through strategic planning. As the partnership suffered significant losses of individuals working within and leading the partnership, I also served to orient new people to its goals, context and commitments.

> We are fortunate in that there's been some institutional memory retained in terms of you being in the position and helping to bridge the new people that are transitioning in.
> *– Barbara Shepard, faculty scientist at MWU*

I consider the second role of *mediator* still an administrative role, yet one that benefitted from my significant professional experience in both the K-12 educational culture and the university scientific culture. Five participants specifically noted that I was "sensitive" to the differences between institutions described above, and could "translate" between the cultures. For instance, there was a situation in which university personnel wanted to send consent forms for an upcoming field trip electronically to teachers on a Friday afternoon to distribute to students prior to the weekend. I strongly urged them not to do that, since teachers would likely not even access their e-mail until after school was out, that even if they received the e-mail they would likely not have access to the students, and it would likely engender frustration from them toward the university. More pertinent to programming, interviewees noted that I was sensitive to the needs and resources of both institutions and could help bring them together in constructive ways, targeting university resources to support unfunded activities in the district. The terms used to describe this role were "mediator," "translator," "liaison," "conduit," and "witness."

> I look at you as the liaison, that you're floating in the middle because you float back and forth. And so I look at you as the connection or the lifeline to those [university] people there and us. *– Christine Finley, teacher at VSD*

> I think the liaison, the person who connects the dots – they know all the entities and when they're in the school district, they'll see, oh – this person could work with that program. So it's little and big things. It could be a big way that the program flourishes, somewhat based on personnel. Maybe there's a teacher at the high school who has some level of expertise that can be enhanced by someone at the university. Or maybe it's just an individual student who has the people skills that you're looking for to come [to the university] and market something you're doing. So I think it's the big and the little things. It's the person on the ground. – *Joyce Lancaster, former Science Coordinator at VSD*

Five participants described the importance that of the *mediator* to communicate constraints of each institution to the other. Susan was grateful I elucidated classroom constraints to her, such as the back-to-back teaching schedule teachers have or limited lab equipment, because she could then help troubleshoot difficulties and set realistic expectations. Educators were grateful I communicated the importance of targeting the limited university resources well.

> I think it's important to have you as a liaison to be able to communicate what you're witnessing. I mean, you're witnessing, because you're here in the classroom, seeing what's going on and experiencing and watching the craziness. And you can communicate that back to the university, because they don't have the time to come in. But you can communicate that to them, and help give them an understanding of what we do and what we're experiencing and how they can help us, which in turn benefits them in the long run. – *Christine Finley, teacher at VSD*

The constraints, however, were probably most challenging in the desire to have a K-State online course for students in the Animal Health Program. The university needed to charge tuition; the district could not. I brought members together in a well-prepared meeting to find a solution.

> We had a strong desire to prepare students for more online learning as part of the core goals of the program. What that meant and how it was executed, and what could and couldn't be done in terms of tuition model constraints was something that could have just

> topped everything. And instead, because of the good coordination by the coordination position, and each side's willingness to see the barriers and the paths forward for the other side, we were able to get through that. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The relationships I had with individuals in each institution were strong, creating a solid foundation of trust, respect and understanding. As conditions changed, I was able to keep a pulse on them and help guide interactions to adjust to changing needs of the partnership.

> I see [the partnership] as ever-changing. That's why that liaison's so important, because it can't be: OK, this is the way it is, it's all set up and it's all nice and pretty and then we get to move on. No, it's absolutely changing. It's living and breathing. And we don't know what the needs are of the next group of students that come in. And we don't even know, even as sophomores, what the goals and needs will be when they're seniors. Because we don't know how they're going to change and evolve and grow during this process…. Our decision and agreement was that we have a liaison and we have a partnership and that we are growing together. *– Janet Spencer, Science Facilitator at VSD*

Finally, in the third role as *scientist-educator*, I directly applied my expertise as both an educator and a scientist to specific programs and courses. I helped synthesize understanding of scientists and teachers, for instance, in the Senior Biotechnology Project, helping especially the scientist recognize the importance of students' cognitive understanding, as well as the teacher's need to maintain daily and semester schedules. In the Animal Health Program, I developed and taught the online course, pulling on both my scientific and pedagogical experience. Using my own field biology research as a template, I designed and taught the Field Research Camp. And finally, I collaborated with Christine Finley to design and teach the new Lab Tech Course for freshmen.

> We were lucky in that you were working on the development team, because you happen to have that experience. If you didn't have that experience and hadn't offered that up, I'm not sure if we would have thought to do that, or done it. … It was having the right players at the table at the right time. *– Michael Dunlap, teacher at VSD*

> Things that are happening that would never have happened [without the partnership] is having you there, having an outside connection, that person that connects the university to our K-12 institute. And you working with the kids as a scientist, and having them go out and look at insects and pollination. That would never have happened. – *Janet Spencer, Science Facilitator at VSD*

Two teachers specifically commented on the value of having someone as a representative from the university and as a scientist work with students in a pedagogically sound manner. One teacher discussed at length the natural authority and credibility an outside person has with students.

> What a unique experience and setting, bringing the expertise, someone from the outside, somebody that they haven't really worked with before that they'll automatically regard as an authority: …this person must be somebody, they're from MWU, that kind of thing. They're almost star-struck when we talk about things like that. Not like Justin Bieber just walked into the room, but [like] this person might have a say in something I want to do later on in life. An adult mentor who can be on their level and still be on a different level, and code-switch back and forth with them. That was one thing I thought that you did with the field study last year that went really well. You weren't teacher-in-the-classroom rigid. You sent an expectation, and you were formally informal with them. This is what you need to do. But at the same time, it was pretty relaxed. And it set a tone for them to learn something from, and they weren't intimidated by it, but they were actually doing some medium level to high level kind of stuff. – *Michael Dunlap, teacher at VSD*

I worked shoulder-to-shoulder with Christine in developing the Lab Tech Course for freshmen, pulling again on both experiences as educator and scientist. In this course, as well as the Field Research Camp, I was able to bring a strong sense of the nature of science as it is practiced. We replaced the strict experimental method, which often is understood as the "scientific method" in its entirety, with the understanding that science is conducted in many ways, including experiments, but also through modeling, observation and inference.

Fundamentally we stressed science is "curiosity-driven and evidence-based." As an earth science teacher, Christine was grateful to have the hands-on training with biological systems, which I provided, as well as with other labs. We developed a syllabus for a lab-based course with no textbook, and throughout the first semester developed units pulling on both our strengths. The flexibility of the Twenty-First Century Programs allowed her the freedom to innovate without needing advance approval for the course details. We developed a large class research project based on the school's recycling efforts through which we guided students through the steps of a research study. Through each of the labs, we focused on using specific equipment and techniques in a meaningful context. Christine valued the collaboration in developing the course as well as the hands-on professional development.

> [When] it was determined … that I was going to teach it, I was a little bit scared, because my background is in earth sciences that does not involve a lot of lab work. I remember us sitting down and talking about the components of the program … and it was pretty stressful. … If I didn't have you to collaborate with and get an understanding of and help me brush back up on my lab skills … having that support from you in the classroom and from the university, you know, it's huge…. And you bring to us the university side of it which the kids need to know and how science works in the real world. You know, because we're doing science in the school, we're trying to make it as real-world based as we can. *– Christine Finley, teacher at VSD*

### ***Teamwork for Program Development: Transforming Disciplinary Science Content into School Science***

> Why do we do K-12 partnerships with universities? Why do scientists and teachers come together? Well, there's an opportunity for enhanced knowledge of content area and inquiry process for the teachers. There's the opportunity for scientists to increase their communication and teaching skills. And then most important, there's the opportunity to enrich and enhance science learning experiences for K-12 students who represent our future. *– Susan Rasmussen, former Chief Academic Officer, MWU-Vista campus*

The goals of the partnership centered on incorporating current science content as practiced by disciplinary experts in research and industry into the school programs at VSD. Not surprisingly, a major theme consistently voiced by interviewees and supported by other data sources was the teamwork in this partnership of transforming disciplinary science content into learning for students. This occurred in teams large and small focused on program development. All of the adult interview participants discussed the philosophy, activities, mutual learning and engagement involved in bridging the cultures to provide opportunities for students (See Tables 4.5 and 4.6). The focused teamwork involved in program development was the source of much of the mutual learning.

> We wanted this to be mutual learning. And we felt that it would be extremely valuable for senior and junior scientists to collaborate with high school science teachers, to see the creativity and the intensity that it requires. … The teaching and coaching aspect would be really valuable for anybody who wanted to do education as our young scientists want to.
> *– Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

Table 4.5 (p. 210) shows that the work involved in transforming disciplinary science content into school science occurred in all the units of analysis – the overall partnership and each of the embedded programs. The total number of interviewees discussing each aspect, or unit of analysis, varied with their respective involvement in each. Since the Senior Biotechnology Project occurred at the beginning of the overall partnership development, several more people were aware of and involved in it than the Field Research Camp, for example.

Table 4.6 (p. 210) shows the themes that were discussed regarding curriculum and program development. These include:

- Working within the K-12 school context
- Coursework themes and activities
- Creating program infrastructure
- Alignment with scientific practice
- Developing pedagogical skills in scientists

**Table 4.5 Number of interviewees discussing elements of program development according to participant's role the unit of analysis.** The columns show participant roles, with total number in each role indicated in parentheses at the top. The rows indicate units of analysis discussed.

| Institutional Role / Unit of Analysis | VSD Administrators (4) | VSD Teachers (3) | MWU Faculty Scientists (4) | MWU Junior Scientists (1) | Total (12) |
|---|---|---|---|---|---|
| Overall Partnership | 4 | 3 | 3 | 1 | **11** |
| Senior Biotech Project | 4 | 2 | 3 | 1 | **10** |
| Animal Health 21st C Program | 3 | 2 | 2 | 1 | **8** |
| Field Research Camp | 0 | 2 | 1 | 0 | **3** |
| Lab Tech Course | 1 | 3 | 1 | 1 | **6** |

**Table 4.6 References to curriculum and program development.** The themes that emerged are in the left column, followed by the number of interview sources that discussed each theme, and the number of references for each theme.

| Themes | # Sources | # Ref |
|---|---|---|
| **Translating Disciplinary Science Content into Learning for Students** | **12** | **147** |
| K-12 context | | |
| Pedagogical expertise - strategies, skills, planning | 10 | 45 |
| K-12 constraints | 9 | 32 |
| Coursework and activities | | |
| Mentorship with scientists | 10 | 73 |
| Hands-on project-based experiences | 10 | 34 |
| Nature of Science (NOS) | 6 | 27 |
| Needs of students | 9 | 24 |
| Workforce and career development | 8 | 27 |
| Interface btw secondary, undergrad and grad ed | 9 | 26 |
| Critical Thinking | 5 | 9 |
| Assessment | 4 | 8 |
| Online Learning | 3 | 6 |
| Creating program infrastructure | 11 | 73 |
| Alignment with scientific practice | 9 | 40 |
| Developing pedagogical skills in scientists | 6 | 28 |

### *Working Within the K-12 School Context*

In order for the university scientists and district educators to work together for program development within the context of the school, scientists had to familiarize themselves with that context and culture, which was an ongoing process. They learned to appreciate, and to some degree internalize, the pedagogical expertise of educators. They also learned about and adapted to the constraints in the precollege classrooms. These contextual elements were important in working to create scientifically informed curricula and programs.

#### *The Importance of Pedagogical Expertise*

School district and university members alike thought the pedagogical expertise of the teachers was critical to the success of the partnership, and in developing sustainable programs. From the start, the scientists communicated their respect for this expertise of the district educators and articulated their deference to the educators for such guidance, as reflected in meeting minutes and interviews. Susan commented on it during our interview:

> There were things … that were based not just on the literature but on the school district's very real time experience in that environment in how you recruit students, how you build a group, and we went with that. So that was great. We never could have done this – we would have done it very poorly … without all of that resident knowledge and experience, and people reminding us and not hesitating to remind us of that. – *Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

The teachers articulated some of the general pedagogical elements, from classroom management, lesson and unit planning, and dealing with students with special needs to vertical curriculum alignment – that is, building skills and concepts over years so that a focus in ninth grade is revisited in greater complexity in tenth grade, and again in eleventh and twelfth. They talked extensively about student motivation. Teachers expressed a long view of student learning in the value it would have over the course of their lives, noting that students often only see the short term. Steve Graham, for instance, described how he felt it was important to keep students motivated in the short term, knowing that later in life they would also look back and see the long-term value of their high school learning and how it helped in shaping their careers. The teachers also discussed balancing the need to ensure students feel safe in the learning environment but also the need to challenge them.

> So we're coming down to crunch time for science fair two days after we get back from spring break, and they don't have data. I [told them], "You're going anyway, whether you present with no data and [explain] this is what I'm getting ready to do, that's fine. And you're probably not going to [win] or anything, but you need to go and you need to do it so you can see what other people are doing." – *Christine Finley, VSD teacher*

The teachers also spoke specifically about the pedagogy particular to science. This included aligning their teaching practice with the nature of science, engaging students in hands-on projects that foster learning rather than just busy-ness, and aligning their curriculum vertically across the high school years as well as for students' post-secondary studies. They also considered carefully the cultivation of student careers, particularly trying to understand student interests and passions and guide them to career options that might appeal to them.

Teachers talked extensively about the role of teacher as the facilitator of student learning rather than the source of facts.

> Facilitating is also a key component, because you don't want to just tell kids what to do, and helping them understand that right and wrong answers aren't always the norm in science. But the facilitating part – I think students have the hardest time with that. Because they want that direction. They want to know exactly what they need to do. – *Christine Finley, VSD teacher*

Monitoring student understanding of complex science concepts and having a sense for common misperceptions were important to teachers, and they modeled for the scientists the use of formal and informal assessments. Steve Graham frequently challenged students' comprehension levels as he taught a quite challenging course in cellular and molecular biotechnology. So he worked particularly hard at helping students try to bring all the new techniques and concepts "come together so that they totally understand." Christine emphasized the importance of science students gaining basic skills and fundamental understandings of the nature of science, and noted she was particularly skilled at teaching "the foundations." The teachers were eager as partnership programs developed to have students gain lab skills and research experience in ninth grade and again in tenth grade so that in subsequent years students could have "that edge" to dig into deeper and more independent research explorations. One teacher spoke specifically about wanting to introduce students to college-level science vocabulary and concepts, not wanting them to be paying for a college education when they are exposed to these themes "for the first time." He said he does not necessarily test students on such material, but "I try to expose them to as much as I can in here, even if it's at just a really basic level, so the next time they see it, it looks somewhat familiar." The facilitator of the Animal Health Program struggled because he knew that he needed to provide more opportunities for students to actually care for and handle animals so their conceptual learning also had practical meaning. As it was at the time of data collection, students in that program cared for animals primarily only in their tenth grade year. These were the kinds of science-specific pedagogical concerns teachers and scientists talked about and recognized as important.

***Considering the Constraints of the K-12 Environment***

In order to make programming and curriculum work, it needed to work within the school environment. Scientists quickly found that even scheduling a full-day field trip for high school students was not as easy as it might sound to the uninitiated. Nothing, for instance, could be scheduled on state testing days. High school students have a full schedule of different classes a day, often with important exams and group work depending on their presence. As minors, consent forms needed to be procured, and university staff learned that even photo consents were needed for the university to use images of the students in any publication. District educators needed to accompany students, and if teachers were to come, they would need substitute teacher coverage for the other classes during the day they regularly taught. District transportation costs needed to be covered.

That teachers consistently deal with full classes of students throughout the day may make sense. And it is not surprising to think that students engage in activities after school, such as sports and music, were dependent on the school bus for transportation home, and had responsibilities at home or at a job, and often did not have after-school time to devote to a project. Teachers have to use class time efficiently and meet the needs of numerous students. They have other duties that contribute to the overall school environment, such as hallway duty and lunch duty. Yet when scientists engaged with teachers and students in the school, these facts still surprised them. Tim Rollins discusses this:

> I guess I didn't necessarily understand what all goes into being a high school teacher. At least initially I wasn't really thinking about how busy high school students are in their own lives, but I learned better as time went on. You get a better feel for how busy high school teachers are too. I never really knew how many classes each teacher taught or how much preparation time they had for their classes, you know, all of it. – *Tim Rollins, post-doctoral researcher at MWU*

The high schools operated on an alternating schedule of block and traditional class periods, so that some days the class periods were over ninety minutes, and on alternating days they were fifty minutes. It was of course important to create classroom programming that could fit into this structure, which was not always an easy task in relation to science experiments. So scientists learned to sequence longer lab explorations into smaller tasks that could be accomplished over a number of days. Such sequencing was critical, for instance, in the freshman Lab Tech Course.

Another constraint in the K-12 context was availability of materials and equipment. Even well-equipped K-12 classrooms do not have the specialized equipment used for narrow purposes that university labs have. This also included equipment and precautions used to ensure the safety of scientists. For instance, biological pathogens and harmful chemicals are not safe in high school labs with twenty-five students. So designers of authentic research experiences needed to consider the context of the K-12 environments.

### *Coursework and Activities*

The types of coursework and activities that teams of scientists and educators worked together on during the partnership focused on a number of themes.

#### *Mentorship with Scientists*

Mentorship with scientists was recognized by university and district personnel as being valuable, and developing such interactions within the school context rather than having students work directly in university labs was unique. Tim Rollins, with input from Susan Rasmussen and Robert Tillman, mentored students in the Senior Biotechnology Project. As scientist-educator I mentored students both in the Field Research Camp and in the Lab Tech Course. One teacher noted that aside from the expertise gained from such interactions, students responded to a scientist mentor as a natural authority. Another teacher described how important scientist mentors have been for former students of his as they have been motivated to pursue research and advanced degrees. A student in the Senior Biotechnology Project seemed to be having a similar trajectory since she ended up working as an undergraduate student in the same lab at the university that was involved in their high school research, and she continued to be mentored by Tim Rollins and Robert Tillman.

Not only students but also teachers were mentored by scientists. As scientists mentored their students and helped develop projects, curriculum and courses, the teachers experienced informal professional development.

> I was able to actually pull on the considerable expertise of Dr. Rollins and his methods. Not being a molecular trained scientist, each time my students learn, I'm also learning. – *Steve Graham, teacher at VSD*

### *Hands-On Project-Based Experiences*

Hands-on project-based experiences were a critical element of the collaborations between educators and scientists. In fact, creating these types of experiences was the primary focus of their work together as they addressed a number of questions: What kinds of experiences would facilitate the learning that both scientists and educators felt were important? How could those experiences be made practical for students so that they gained understanding? What were the necessary materials and equipment? What were the necessary procedures? What were the necessary safety concerns? Hands-on project-based experiences formed the core of the ninth grade Lab Tech Course, the tenth grade Field Research Camp, the four-year Animal Health Program, and the twelfth grade Senior Biotechnology Project.

### *Nature of Science*

As part of the development of such experiences, the nature of science was of concern to both educators and scientists. It was important to scientists that they communicated the evolving nature of scientific understanding, that there was still so much not understood, that curiosity drove the enterprise of science. Scientists were surprised by the rigid expectations of scientific research set forth by the regional science fair, because "scientists don't actually do that."

Scientists and teachers both felt that communicating science within a professional community was important to incorporate into the programs, and students became skilled at writing and presenting their findings and conclusions, and discussing it among peers. Given the fact that the partnership worked closely with three Twenty-First Century Programs that represented some diversity in science, the Geoscience, Biotechnology, and Animal Health Programs, differences in methods of scientific investigation could be experienced by students and discussed, especially in the ninth grade Lab Tech Course. When students from the Senior Biotechnology Project toured university labs, Susan Rasmussen made a point to show them the lab notebooks so they could see their own lab notebooks were similar. In the analysis of data in the Field Research Camp and the Lab Tech Course, students commented on the value of interpreting their data to understand what they mean and their implications, as well as the generation of new questions.

#### ***Critical Thinking***

Along the same lines, the theme of critical thinking was discussed by five people, specifically by the three teachers, and two of the scientists working directly with students in this partnership. They saw the importance of cultivating this capacity in students to think for themselves, to evaluate and interpret evidence, to think about what makes sense and what does not. Christine felt the collaboration helped in the development of curriculum that encouraged critical thinking:

> [The collaboration helped] the quality of what is happening. [Without it] I would probably be looking for labs that are already made, like your cookie-cutter labs. But I don't think it would have as much critical thinking, as much detail, and it would be less thought-process in the long run. Without the support I think it would not be as quality of a class as it is now. – *Christine Finley, VSD teacher*

#### ***The Needs of Students***

The needs of students were constantly being assessed. During my interviews with the teachers, all of them told stories of particular students and how they were trying to figure out what they really needed, or of how they figured out what a student needed and how transformative that was when the need was met. Sometimes they discussed the needs of groups of students, such as the Animal Health Program facilitator chewing on the issue of how to create more opportunities throughout the high school years for students to handle and care for animals.

Student needs included time, mentoring, proper equipment and materials, English language learner assistance, structure, understanding, hands-on experiences, mentors, and guidance. The greater needs of students during the economic downturn came up in conversations not only with teachers but also with district administrators. Scientists were concerned that many students were not encouraged enough to pursue science, and wanted to create opportunities for that, to help open doors for them to pursue the field if they wished. Student needs were what conversations came back to over and over again, whether in interviews or in partnership meetings.

***Assessment***

Assessment was referenced by four people, the three teachers and scientist Susan Rasmussen. The teachers primarily spoke about it in terms of the partnership courses and programs they were involved in, about their students, and about their own teaching. They not only talked about assessment; much of their interview involved ongoing assessment and reflection about how the course was or was not meeting the needs of students, what needed to be adjusted, how their own teaching could improve, and supports they needed. They also discussed assessment of their students, how they could learn whether students were understanding and developing skills, and how students could self-monitor and manage their own learning. Informal program assessment was ongoing, not only in the interviews, but my field notes describe most conversations I had with teachers to contain elements of assessment. I usually asked how things were going, and they described their current programs and students, usually with an assessment of what was going well and what was problematic. We would often address the challenges with trying to problem-solve – was there anything the partnership could help with?

Susan's comments on assessment also had to do with program assessment, what we learned, and how things could be done better. She attributed a number of important considerations in subsequent programming to what was learned through the Senior Biotechnology Project. Susan noted too that one of the largest losses of the partnership was the loss of the evaluation team composed of members from both institutions to formally assess the partnership. During the three years studied, that was not accomplished.

***Workforce and Career Development***

Scientists and educators were dedicated to showing students real careers they could strive for, especially ones that they likely had never considered before. Scientists helped the district educators understand the career opportunities in animal health, and they worked together to help students see them.  The Animal Health Program facilitator talked about need in this way:

> The program isn't just for vet students, but for a lot of them, in the interview process, you just could not believe how many just want to be a vet.  They just full-heartedly believe they're going to be a vet and they want to be a vet, and we want to encourage that.  We want to be realistic in our minds and prepare them for other opportunities, because we know realistically that's going [to be challenging]. *– Michael Dunlap, VSD teacher*

Partnership members knew they had to do more than simply list careers, so they created opportunities for students to meet professionals, talk to them about what they do, see their facilities, and conduct internships.  This was accomplished through career fairs, career talks to individual classes, career exploration independent projects, and field trips.

### *Interface Between Secondary, Undergraduate, and Graduate Education*

One of the goals of the partnership was to help remove boundaries between high school and university education, as described by Susan Rasmussen:

> We also wanted this program to really start to make more seamless interfaces between secondary, undergraduate, and graduate education, to have students preparing and understanding what goes on in each of those levels while they're in each of those levels.
> *– Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

Through previous work with STEM outreach involving under-represented populations, university scientists understood that one of the large contributors to students not pursuing science as a career was their unfamiliarity with and intimidation by college campuses, and a lack of understanding of opportunities during higher education, including financial and work opportunities.  University personnel thought it important to bring high students onto campus, into university labs, and into the university veterinarian hospital so they had experience and some familiarity with these environments.  They wanted students to be able to imagine themselves there if they wished, and help facilitate opportunities.

When two high school seniors in the Senior Biotechnology Project visited the university campus, they were introduced to the director of the Developing Scholars Program.  Both students applied to and were accepted in the program, and therefore were placed in researchers' labs for earning work opportunities. One student, Sophia Delgado, was even placed in the lab where Tim Rollins, the mentor to the high school project, worked. All three students who applied to MWU had positive references from university scientists, which in the case of another student helped her gain early admittance to the College of Veterinary Medicine.

During my interview with Sophia, who at the time was a college sophomore, she was determined to apply to graduate school to earn her Ph.D. in pharmacological research. Both she and the student admitted into vet school were planning to pursue graduate degrees.

School administrators valued their learning during their visits to campus and through meetings with university staff about directing students to financial assistance, work opportunities, and academic programs, so they could help the high school students prepare for their futures. The personal connections between institutions allowed numerous introductions to be made between high school students and teachers and university scientists and staff.

#### *Online Learning*

One of the programs under development during data collection for this study was a non-credit online course focusing on animal health content that would be offered to high school seniors. Although the desire had been on both sides for the course to be offered for credit, the tuition requirements were untenable. Yet university and district personnel alike thought that online learning was an important component of twenty-first century learning, and they valued the idea of students learning to take online courses while in the supportive environment of a high school. It would also familiarize high school students with the MWU online platform, something MWU administrators liked. The online course would incorporate common utilities in online platforms, such as message boards, online exams, drop-boxes for uploading assignments, and discussion threads.

### *Creating Program Infrastructure*

From the very first meetings between leaders of each institution, they were learning about each other with the goal of translating the disciplinary scientific expertise of the university into meaningful learning for the students. Sharing information about the curriculum, the laboratories, the teachers, and the students started "the wheels spinning" in scientists' minds about what could happen. Likewise, as scientists shared scientific practices and perspectives, the breadth of careers and engagement opportunities, the educators thought about appropriate school programs and approaches. The scientists brought scientific subject matter knowledge to bear, and the school district brought expertise in the form of pedagogical knowledge and pedagogical content knowledge. Susan describes one of the early conversations discussing the subject of animal health:

> I think that one of the more interesting outcomes of that initial conversation was: What do we mean by [animal health]? What are we going to go with that? What people at universities see and what people in the school districts see as animal health … or vet science or animal science – are fairly different. And you know, that vision is formed for people outside the professions very much by popular culture images and popularity of professional sentiments in animal health …, whereas I think for the people from the university who were dedicated because of their own career paths and for various other reasons who morphed, then, that vision – I think that was one of the really interesting conversations that evolved at the table. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

It was not simply in the classrooms in which the transformation of disciplinary science content into school science occurred – it was in the larger partnership meetings too. Developing a common understanding of what is meant, for instance, by "animal health" was critical to thinking about opportunities for specific programs. In this case study, records show that school administrators worked hard to combine what they were learning from scientists about current disciplinary practice and perspectives with what they knew pedagogically to create infrastructure to support programs. Such infrastructure included program budget lines, staffing, lab equipment, as well as curriculum to foster the collaborations in the school context. Understanding the science pedagogical content and context was important in creating – and justifying in lean economic times – such infrastructure. The programs were developed through the Twenty-First Century Programs that focused on skills and real-world experience in a professional content area with a great deal of flexibility existed to innovate, plan and improvise. The processes and climate described above, such as face-to-face interactions, respect and flexibility were important in this work, and the programs developed in unique contexts that could be nimbly adjusted as needed. It was a very collaborative round-table approach.

***Developing Pedagogical Knowledge in Scientists***

True to the mutual learning commitment of partnership members, not only did educators learn a great deal from scientists, but also scientists learned a great deal from educators. It was important to Susan Rasmussen, university leader of the partnership, that scientists not go into the schools with an attitude of knowing more than the teachers, or trying to tell the teachers how to teach. Rather, she chose individuals who would not only respect the expertise of educators, but also be willing to learn. Tim Rollins below describes the importance of learning something about pedagogy:

> I was learning how to interact with high school students. I gained experience working with different types of people, teaching different types of people how research is done and how you do it properly. I have a little bit greater ability to break it down and deliver it to somebody who's not an expert. – *Tim Rollins, post-doctoral scientist at MWU*

***Alignment with Disciplinary Scientific Practice***

Partnership members experienced the challenge of aligning K-12 science education with authentic scientific practice. The challenge was largely due to the constraints discussed above: the school schedule, the schedules of teachers and students, the limitations of equipment and materials. Challenges also arose due to the differences between expert scientists and novice high school students – foundational concepts need to be grasped before complex concepts can be understood. And yet both scientists and educators were committed to aligning school science to the actual practice of disciplinary science experts as much as possible, and they succeeded in many cases. For instances, the way the Animal Health Twenty-First Century Program developed was informed by and aligned with scientific practices.

> The coursework in this program was very closely aligned with the Geosciences and the Biotechnology programs. That was a very good thing from the school district's standpoint, because it did not require a lot of new resources in a very resource-limited environment. It was a very good thing from the standpoint of the sciences at the university, because we see science as very multidisciplinary. We don't believe that there's a silo for animal health, and a silo for biotechnology, and a silo for geoscience. So creating a course structure that reinforced that message was something that was very attractive to us. And then the ability to define animal health broadly with careers and

> field trip opportunities that span the spectrum was really a positive thing. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The Senior Biotechnology Project was entirely based on an authentic research question, and nearly all the procedures students carried out were in accordance with scientific practice. The content of the Field Research Camp was also based on actual research practices and protocols of ecologists, which one teacher noted gave students an authentic sense of what field research is if they come across such opportunities in the future. The Lab Tech Course also gave students a sense of multiple authentic means of evidence gathering and assessment in different scientific fields.

The challenge of aligning school programming with scientific practice is addressed more fully in this study in the section on Challenges below titled Two Professional Cultures (p. 234).

### *Challenges to the Partnership and How They Were Met*

During the three years under study of the partnership, it faced four major challenges. The two most frequently identified challenges, cited by eleven of the twelve adult interviewees, were intertwined: *budget constraints* and *personnel attrition*. The third challenge identified was the *physical distance* between the MWU flagship campus and the City of Vista where the school district and the new campus were. The fourth was not frequently identified as a challenge *per se* by interviewees, but they all discussed it to some degree, and that was the challenge of *two professional cultures*. Each of these challenges was addressed in different ways and these will be discussed below. Ultimately the commitment partnership members had to working together helped meet these challenges. Table 4.7 below outlines the challenges and the ways they were met.

**Table 4.7 Challenges to the partnership and how they were met.** The numbers in parentheses indicate the number of interviewees discussing the challenge.

| Challenge | How It Was Met |
|---|---|
| Budget constraints and economic crisis (12) | Targeted resources, sharing resources, synergy through the partnership, clarify roles |
| Loss of personnel (9) | Created new relationships when possible, strengthen existing relationships, limit collaboration |
| Distance (6) | Targeted resources, flexibility of staff, investment in video conferencing technology |
| Two professional cultures (12) | Commitment to mutual learning, strong relationships, culture of understanding and respect, training ground for scientist-educators, scientist-educator coordinator |

***Budget Constraints and Economic Crisis***

Neither institution had a large surplus of funds to devote to the partnership even before the economic collapse in 2008. In fact, the initiation of the partnership was due to the City of Vista bestowing the resource of land to the university. And the way for MWU to secure an important revenue stream for the satellite university was through the county tax initiative. So establishing the partnership was "a leap of faith" – as two people described it – since neither the district nor the university had an abundance of resources to dedicate to it. Phillip Hendricks described the funding situation:

> What the goal initially was – based on our memorandum of understanding with the City of Vista, who donated the land for this campus prior to any funding being established for building any kind of campus – was that we had to develop a relationship with different entities. And one of those entities was the Vista School District, because in [this county] as a whole, education informs your base foundation for everything they do. Vista emulated that and said, if MWU's coming in, the whole reason we're giving you the land is because we want you to impact our youth. And so I think the very first goal was to figure out a program, quite frankly, with no funding. – *Phillip Hendricks, Dean of MWU-Vista campus*

Susan Rasmussen put the situation in an even broader societal context when she described that science education may not even a priority in the best of modern times:

> Science education not [being] considered a priority can be true in our school systems where testing tends to focus more on literacy and math, and in universities where getting the dollars to do the science is more important than actually educating people about the outcomes of the experiments. In both contexts, partnership activities can be viewed as an "add-on." *– Susan Rasmussen, former Chief Academic Officer, MWU-Vista campus*

Yet the partnership started, and remarkably, both institutions contributed just enough resources to make it work. The former superintendent talked about "getting people to the table" and "building on assets … already in place." The university committed resources for the coordinator position and the Senior Biotechnology Project in the summer of 2008. Yet the reality of the economic collapse became real that fall, just prior to the November elections.

> That's when the economy crashed, and we didn't have any money to build…. With the economy tanking, that … was tough, because there was no money to be had…. That's why getting the [county tax] initiative passed was so important and again, we worked very hard – it passed. That got us the money to pay for … the building. So did the stars align? Yeah. But there was an awful lot of hard work that went in behind it. So that memorandum was a legal document that said if we didn't get that going, then the land would revert back to the city. *– Phillip Hendricks, Dean of MWU-Vista campus*

The Great Recession started, with economic shock waves felt deeply through public and private entities. In the case of the brand new satellite MWU campus, execution of plans and promises made in flush times were suddenly jeopardized. Both partner institutions relied on public funds, and the devastating impacts on their revenue bases would not be fully realized for years, but the impacts started hitting each institution that fall of 2008. From the beginning of the partnership to the end of this study in 2011, the Vista School District lost a total of $28 million in direct state funding, with more cuts promised. The university's impacts were more diffuse and harder to calculate, since not only direct state funding but also federal funding in multiple streams (research grants as well as programming support) were reduced. The MWU-Vista campus encumbered large administrative salary burdens, which were also eventually curtailed. Funding that had been originally anticipated for the partnership was no longer available.

The impacts from the recession forced each institution, especially the school district, to reorganize. Both administrative and teaching staff members were cut through direct lay-offs and by not replacing individuals who left through retirement or other reasons. Positions were reorganized and combined. District class size increased, teachers were assigned more teaching duties, and their budgets for supplies, materials and activities were slashed. Administrators left for other jobs when faced with some of the impacts. While not all staff turnover was due to the economic crisis – there were some retirements – vacated positions were often either not replaced or were reassigned to more junior staff.

The budget cuts affected personnel, and they also affected programs. The new Animal Health Twenty-First Century Program was proposed to the Vista Board of Education in December 2008, and it was approved only on the condition that no new teachers, no new classes and no new expenditures be incurred. This placed significant constraints on the new program, and a cascade of challenges resulted. The former superintendent and a teacher recalled the board meeting:

> I can remember that night. One of the board members said, "How can we do this?" Because that's when the cuts were already starting. And Dr. Bratton [associate superintendent] said, "Well, we're doing it without any change in staff. We're redesigning our current naturalist program … and we're doing it with what we have. And so we're not asking for a budget increase." And we had to do it under those – not to the level we wanted if we would have had the funding, but we did it with what we had, and redesigned and reprioritized. – *Alice Hughes, former Superintendent at VSD*

> Part of the proposal when we first took that leap forward [with the Animal Health Program] was, the school board said OK, we've got another Twenty-First Century Program *if* you don't spend any new money, *if* you don't create any new classes, because creating any class creates a new teacher. – *Steve Graham, teacher at VSD*

So classes were reorganized. All tenth graders in the Animal Health Program would take an existing class, Student Naturalists, but be scheduled together. A year later when ninth graders joined the high school, and still no new class could be added, an existing class was "tweaked" and put to use for not only the Animal Health students, but for all students in the science twenty-first century programs, the Lab Tech Course. The title of that course was because it was originally taught by the biotechnology teacher, Steve Graham, who had junior and senior students interested in lab techniques helping him prepare his lab classes. Because of the financial constraints, he felt the larger need was for freshmen to have a class, so he sacrificed his lab prep course. While it was wonderful for the nearly one hundred freshmen who would take it annually, it also meant all his lab preparation became his own responsibility in his own time, usually during evenings and weekends.

Each teacher I talked to had similar stories. In order to execute the plans made in the partnership, to start a new program, to provide extra opportunities for students, they had to make personal sacrifices of time inside and outside of their school day, take on an extra class or new course, and add more students to a lab-based course than was normally practical. Each of the Lab Tech Course sections Christine Finley taught had over thirty students in each class, a number stretching safety levels in labs. The Twenty-First Century Program students were not the only students these taught, and they needed to maintain their other responsibilities as well. Through the budget cuts, teachers were stretched with more responsibilities and less time.

> As both organizations have dealt with budget, it also means that staffing has been more difficult as people on staff have assumed additional responsibilities. That means more of their time is being carved out for more things…. We know that the teachers who are delivering the content are being asked to do that much more, and I mean, budget is just the big overriding deal. *– Beatrice Price, Director of Secondary Programs at VSD*

> We're overloaded at the high school, I mean in the budget crisis. We are overloaded. And there's no end in sight with the cuts, the seven million that we're going to be cut next year. I mean, there's going to be no new staff, and there's going to be more kids. And you know, a class of thirty-three, it's been a thing to manage in a lab setting. With the stuff that we do, it's pretty tight. … We are all overloaded. It's just the reality of the times. Nobody has any extra time to help formulate ideas. And that's really sad at this point in time, because we used to have tons of time when we were helping each other out, prior to budget cuts. *– Christine Finley, teacher at VSD*

Christine touches on an important reality here: with less time for internal collaboration, there are fewer opportunities for creativity, for "helping each other out," for innovation or even simple exchanges of ideas.

The effects of district budget cuts impacted the lead teacher and facilitator of the new Animal Health Program in interesting and nuanced ways. Normally, every facilitator of a Twenty-First Century Program at VSD was supplied a small stipend to compensate for the extra hours he or she spent not only teaching but also organizing and coordinating the program. Every facilitator of a Twenty-First Century Program at VSD was also provided a budget to support specific activities such as field trips, lab supplies, and projects. All the other Twenty-First Century Programs in the district had been initiated during flush economic times, so although their budgets were being cut during the economic crisis, they each still had a budget and a facilitator stipend. Given the timing of the launch of the Animal Health Program, however, no new funds were to be allocated. Hence, while a lead teacher and functional facilitator was identified in a relatively new teacher in the district, Michael Dunlap, he could not be offered a stipend nor a budget. This caused confusion and a certain amount of tension. One of the administrators recalls:

> I think Michael had a hard time understanding his role because he wasn't a facilitator at that point, and I think that was really difficult that these expectations were put on him, but yet he didn't have that role. … It was never assigned or defined for him. … So I'm seeing some misunderstandings or roles that aren't clarified. And we had to go back and say, He needs that role, because the things we're asking him to do shouldn't be asked of a teacher who's just teaching. We're pulling him into this partnership, asking him to facilitate this program, but what's his role? We need to define that for him.
>
> – *Janet Spencer, Science Facilitator at VSD*

> So Michael is kind of a facilitator doing what he needs to with his program, and I'm a facilitator doing what I need with my program. The only connection we have so far is money. Michael has no money. I'm the one that has money…. If the district would just say, OK, here's the amount of money to support those students. – *Steve Graham, teacher at VSD*

The district was in a bind as it had no funds to allocate to a new program, and was under strict constraints from the board of education to not create new budget lines. So Steve shared his program budget line with Michael. But as long as this was the arrangement, through no one's fault, it implicitly undermined the legitimacy of the new Animal Health Program, and Michael as facilitator.

> I never feel disrespected, overlooked might be a better [description]…. [The program is] not its own because it doesn't have its own budget…. So I have to dip into [Steve's], which I try to respect. – *Michael Dunlap, teacher at VSD*

The university, and specifically the MWU-Vista campus, also experienced tightening budgets. The sales tax revenue generated fewer dollars than projected due to county citizens spending dramatically less after the recession hit than before. The grant proposals that had been submitted to national agencies for the partnership were not funded. The construction underway to complete the first building at the new satellite campus was a priority.

Another important way in which the Great Recession impacted the partnership was not through either institution directly, but through the families with children enrolled in the district. The high school that housed most of the partnership programs, Vista North High School, was a high poverty school, as were its feeder schools (middle and elementary schools). Although the district as a whole was not high poverty, this particular region was. Families who already were considered in low socio-economic status (SES) suffered greatly during the recession, and most of these families' poverty levels were magnified. With the increased financial stress in families, many parents took on additional hours in their jobs or extra jobs. District educators reported that their teenage students were more frequently asked to either contribute to the family income with jobs they held themselves, or to take on responsibilities such as child care for younger siblings, and housekeeping chores to help the family unit. Teachers in the high school noticed that students needed more help and assistance during their school day, and teachers liberally gave time to help tutor, mentor and scaffold their learning.

> I would say it's been pretty tough the last three years. And our building is tough too, because of our economic status. We have a lot of poverty in the building, so not only are we working with budget constraints, but we're also helping kids in poverty be successful.

> So those are other things, you know, with AYP and those kinds of things. So we have a huge load on our shoulders….Vista's poverty is growing, and poverty is the key. It is the one component that affects student success. It's not race, you know. It's not religion. It's SES that affects you. Your kids are working jobs to help support their family. They have to watch siblings – they can't stay before or after school, or a sibling's sick and they have to stay home because the parents have to go to work, so they're missing school. They're not getting extra help – they don't have that consistency at home. The only thing that's consistent is the school day. And so poverty is huge. So that's another thing that impacts the load of the teachers in our building…. And when you have those kids captured [during the school day], make the most of it, you know. So going back to the partnership, it's nice to have that partnership at this building because we can help offset the effects of poverty on our kids. *– Christine Finley, teacher at VSD*

While the main challenges facing the partnership were the financial collapse and the requisite budget constraints and staff turnover, the partnership was also a resource for meeting some of the challenges. When teachers were "overloaded" and couldn't help each other and had students needier than ever, they turned to the partnership to help them in their courses, in their program offerings, and to help leverage resources to provide things together that neither could do alone. For instance, the district could not support one program more than another program – there had to be equity on their end. So while the district could support perhaps one field trip a year per Twenty-First Century Program, the university could target resources to help support additional field trips. The time I spent in the classrooms supporting teachers and teaching students helped take up the slack. By targeting such teacher support, either through ongoing informal professional development, through program development, or through student support, the university targeted its contributions to add value to budget lines already supported by the district (see Figure 4.6, p. 231).

> You know, for the school district, I think having engagement by the university at the level that occurred really helped them expand their resources at a time of great resource retrenchment. It allowed them to continue to build on the model that they had tested of the Twenty-First Century Programs and collaboration with industry and capturing student interest…. I think the loss of personnel and diminishing resources and the terrible

economy – and the terrible economy affects children and parents and state agencies, and all the people in them. And this was a significant recession. That is by far the greatest challenge that we faced. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

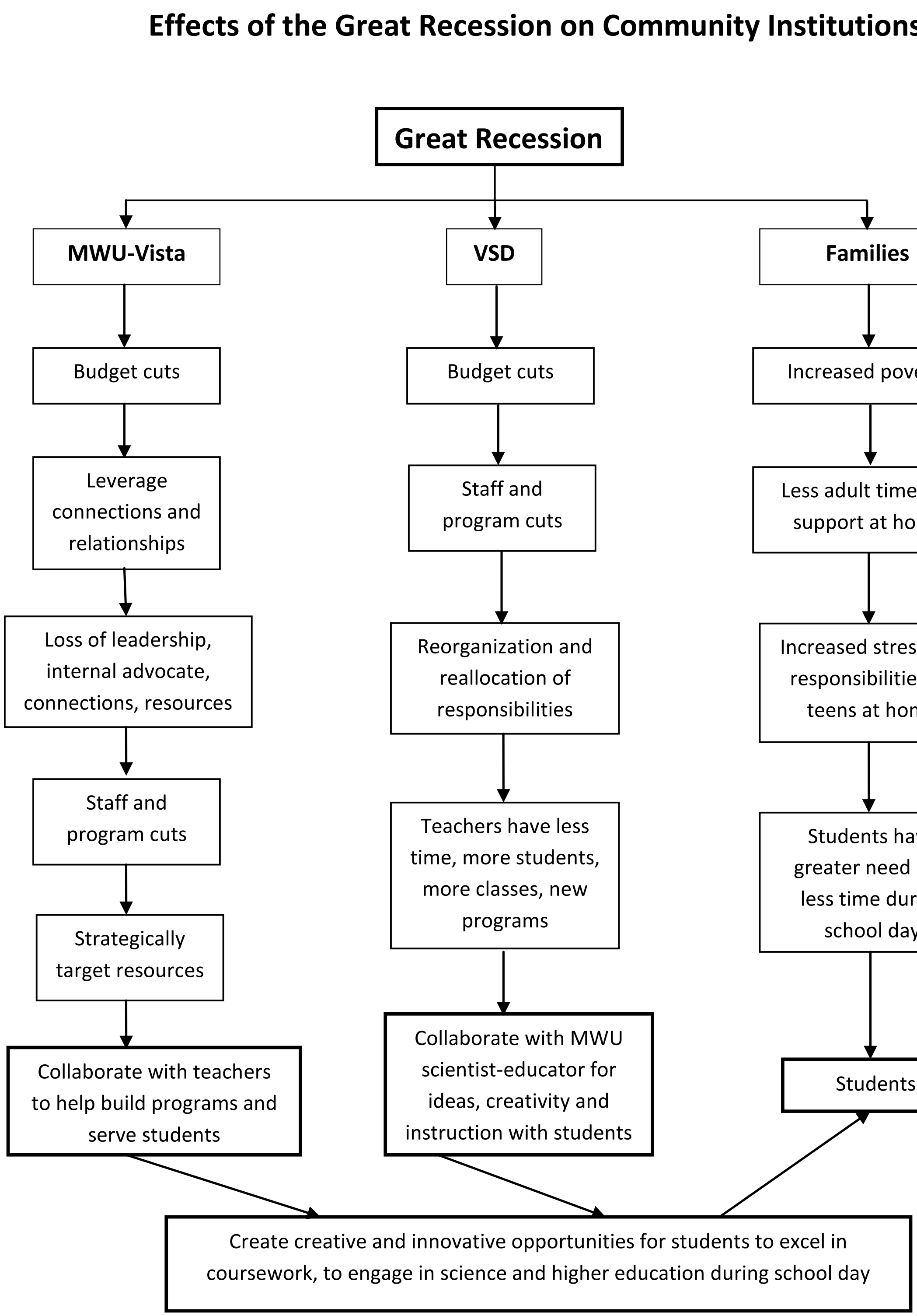


**Figure 4.6 The Effects of the Great Recession on community institutions.** The four boxes in bold at the bottom represent the synergy involved between the university and school to help overcome the challenges of the recession to serve students

***Loss of Personnel***

The loss of certain individuals, such as Joyce Lancaster, the Science Coordinator at VSD, delivered a blow not only because of the loss of those roles, but also because of the assets those people brought to their roles: their institutional knowledge, experience, relationships and credibility. Janet Spencer took over many of Joyce's responsibilities and proved a valuable and enthusiastic partnership member, however her contract did not include summer months, and much of the context of the partnership was unfamiliar to her. Kelly Johnson, the district's Evaluation Coordinator, resigned and her position was not replaced in the severe budget crunch.

On the other hand, when Alice Hughes, district Superintendent retired, her position was fully replaced with someone who demonstrated full support of the partnership, requesting a report to the board of education and publicly recognizing the institutional collaboration.

The departure of Susan Rasmussen at MWU impacted the partnership greatly. The scientists and resources she was able to put into play for the collaboration through her many connections at the university were largely lost, including the active involvement of animal health scientists and university advisors. Also lost was the involvement of the institutional evaluation office. Susan's position was reorganized and Mark Merino was hired to fill it.

> I don't think there's a lot of visibility on the [home MWU] campus for what's happening at the Vista schools as a result of the partnership…. And I think that's not the result of any one event. I think it's the result of a conflation of events, including personnel turnover at both partners, and budget constraints at both. – *Barbara Shepard, faculty scientist at MWU*

As staff from both institutions left, resident knowledge of the partnership was threatened, as were connections, especially at MWU, that could support the partnership (see Table 4.8 below).

> We started out in a much more flush economic time than we wound up. And I think we started out with assets that we thought would be there the whole time that we lost. And when I talk about that I'm not so much talking only about individuals – although I think individuals are really important – but reorganization really changed the types of positions that we had. The bad economy forced retirement, turnover, and replacement of very senior people with more junior people who have less experience developing and

managing large projects…. So in the end we had a lot fewer personnel to deliver. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

**Table 4.8 Loss of staff originally involved in the partnership over three years 2008-2011**

| MWU | VSD |
|---|---|
| Susan Rasmussen, Chief Academic Officer<br>Replaced with more junior staff | Alice Hughes, Superintendent<br>Fully replaced |
| Tim Rollins, Post-Doctoral Scientist | Joyce Lancaster<br>Replaced with more junior staff |
| Robert Tillman, Senior Scientists | Kelly Johnson, Evaluation Coordinator |
| Judith Lightner, Scientist Advisor | Twenty-First Century Program Secretary<br>Fully replaced |
| Institutional Evaluation Office | |

***Distance from the Flagship Campus and the City of Vista***

The two hour distance between the MWU flagship campus and the city of Vista, where the school district was as well as the offices for the new campus were, proved to be a challenge that was alleviated through targeted resources, traveling, and technology. Both the chief academic officer and I had moved our personal homes to a town mid-way between the main MWU campus and Vista and we commuted regularly between the two. The post-doctoral researcher working with the Senior Biotechnology Project drove at the university's expense from the main campus to the Vista classroom each week or two to guide the high school students in lab work. The university underwrote field trips so district students and educators could travel to the home campus. And some of the discussions were held through software the university owned, with MWU-Vista providing a web camera for use in the classroom. While some of the small partnership group meetings could occur face-to-face, video conferences helped bring people at a distance together for meetings. Both the school district and the university had teleconferencing capabilities in particular buildings, and so meetings tended to occur there. The technology was not always perfect, and sometimes cell phones were brought out to tap the audio components. Nonetheless, flexibility, good will, and humor seemed to smooth over these difficulties.

> We can recount all of those video conferencing [meetings] that went well and didn't go so well – only because of the technology, not because of the conversations. The conversations were always good if we could just make the connections on that. But we had a lot of interest of people. *– Steve Graham, VSD teacher*

***Two Professional Cultures***

This partnership was no different than others represented in the scholarly literature in that two distinct professional cultures existed in the K-12 school district and in the university. This was true in relation to science as well as to general institutional culture, and participants from both institutions were cognizant of these differences from the start.

> Scientists and K-12 educators live in different worlds and cultures. They have different levels of autonomy: university faculty control their time; K-12 teachers do not. There's the difference in the level of understanding, expert versus novice. And the available resources. Resources are tight in both cases, but the types of resources available are very different. Spending your day dealing with students who are essentially adults is different than spending your day dealing with students who are minors. *– Susan Rasmussen, Chief Academic Officer, MWU-Vista campus*

Even still, many of the differences proved surprising to participants. For instance, some of the remote communication plans proved to be difficult, as the technology that would work easily in a university setting was challenged with the more limited bandwith and strong firewalls in the high schools. One scientist was surprised at the technical support for teachers:

> [The teacher] doesn't really have an office or anything like that. I mean, he's got a little tiny desk area with a computer that occasionally works, you know what I mean? So it's very different to have different budget constraints. Here (at the university) everybody has a computer to work on. *– Tim Rollins, post-doctoral researcher at MWU*

The university scientists, impressed with the level of equipment in the high school lab, thought it would work well to conduct the Senior Biotechnology Project in the high school lab. However, once the group reached a certain stage of the experiment, the scientists realized the school did not have the equipment at hand that would have been used in a university lab to capture an image of the results. Susan realized, "Just because they have thermocyclers, and just because they have gel boxes doesn't mean they have the things to [record the results]." The teacher, Steve Graham, and the scientist, Tim Rollins, ended up improvising with the students to use a traditional film in a darkroom at the high school to capture the image. The improvisation, they thought, was good for students to experience, since that is very much a part of what scientists do in their work.

The issue of equipment related also to the difference of science teachers having great breadth and scientists having great depth.

> You look at what a twelfth grade science teacher with an advanced laboratory class has to do in terms of breadth, and it knocks your socks off! I could *never* conceive of having that breadth of knowledge at more than a scratch-the-surface level, certainly not the breadth of knowledge that those teachers have to try to make their students' projects work. And to go back and forth from whatever they were doing with the plants, and the cheek scrapings, to the animals, and to do it without a lot of professional training and to do it in extremely resource-poor environments. Now, I mean, when you look at those classrooms, on the continuum of what you can have in K-12, those are pretty darned well-equipped classrooms. But if you look at the questions they were trying to answer experimentally, and what normally someone who was completely focused on that question would have, I mean, it's a whole different story. Because if [a scientist] buys equipment to answer one question, you have everything you need, and the best of everything you need. If you have to buy equipment to teach K-12 students and then they develop these questions, I mean it's just amazing! So I think that I really didn't have an appreciation for the world of that classroom and how that would impact how we would work together. And so it was good for me, because I came away with this incredible respect for what they work on every single day and how much they read outside of class, and how broad their knowledge is and how interested they are in so many different aspects of things. *– Susan Rasmussen, Chief Academic Officer, MWU-Vista campus*

My field notes contain comments about the difficulties of communicating by e-mail with teachers, and I found it easier just to go to the high school and search them down. The level of busy-ness of teachers was astounding to one scientist, who even noted that he thought teachers often were not aware of how busy scientists are. Teachers put in time beyond their contracted hours, in the evenings, weekends and summers. They not only worked with students but met with parents as well. The time spent with people versus the time spent on a computer with easier access to e-mail was a major difference between teachers and scientists.

> I guess I didn't necessarily understand what all goes into being a high school teacher … but I learned better as time went on…. You get a better feel for how busy high school teachers are too. I never really knew how many classes each teacher taught, or how much preparation time they had for their classes. Teachers have to deal with a lot of kids at once. Most labs I've worked in – I've either been by myself or there's two, three, maybe four other people that are working in there too. So it's a much smaller number of people than having twenty-five kids in a classroom, having to keep an eye on that. *– Tim Rollins, post-doctoral researcher, MWU*

> This is not like a university schedule for preparing for class and with large blocks of time for teachers to do whatever they might need to do. This is very much still an industrial model where, on a seven-period day, … those teachers are teaching five sections, with a section for support in the school, which, when you're dealing with minor children, could be anywhere from helping with discipline issues to tutoring kids, and then an hour of plan, which doesn't necessarily help you when you're trying to transition from one class to the other with five minutes in between. *– Alice Hughes, former Superintendent at VSD*

> I think teachers are some of the busiest people around, you know. I mean you talk about workaholics, CEOs of companies and how much work they do and they're never home. Teachers are probably right up there. *– Christine Finley, teacher at VSD*

A teacher drove the point home about the importance that when scientists advise K-12 teachers, they need to understand the classroom culture.

> For instance, just trying to do a particular protocol, well, no problem. [The scientist advises,] 'Just do this protocol.' Well, I can't … because I've got to go onto the next lesson, and I've only got fifty-five minutes here to do this, and then I've got another group of kids coming in who are doing something totally different. You know,

> [scientists] don't quite understand that transitioning. … A two-hour lab that they told me to do, and I only have fifty minutes – it just won't work. – *Steve Graham, teacher at VSD*

Scientists, too, felt that most people did not appreciate how busy they are. A meeting was even held for university personnel involved in the partnership and other outreach projects in October 2009 to develop a system for limiting the number of high school tours in labs. The prime challenge was "limited faculty time." When school personnel interacted with scientists, who were often open and happy to offer tours and talk about their research, it was often unclear to teachers and students that it took time away from their research, teaching and other responsibilities.

> I don't know that the teachers sometimes appreciate how busy people who work at the university are. – *Tim Rollins, post-doctoral researcher at MWU*

> Just working out the logistics of how you get students to campus with a teacher and where they're going to stay, and who's going to take them around, I mean, all of those are things that have to get done – they're not insurmountable. And again, you leverage every relationship you have, and you listen to your staff: 'What, did you get a photo release?' 'No.' 'Did you get a permission slip?' 'Well, yeah.' You know, you get through that kind of stuff. – *Susan Rasmussen, Chief Academic Officer at MWU-Vista*

The university and school district were not able to be all things to each other. As much as they interfaced, each institution also had to protect its own culture to maintain its integrity. In the example above, scientists couldn't accommodate an unlimited number of high school classes wanting to visit. One teacher who was aware of the overload that might cause for scientists reflected on the dilemma:

> On a protective side, a cautious side from MWU sharing that [openness for lab tours], if we start sharing [with other teachers the opportunities], I could see this being a problem on the university's end … every school's going to want to go do it. And that's not going to be possible … because then we might end up closing the doors for everybody. – *Michael Dunlap, teacher at VSD*

On the other hand, the high school could not be the venue for scientists to have students work at an expert level with research. In the Senior Biotechnology Project, all involved thought they aimed too high in expecting students to understand without building the foundation first.

Another difference between cultures was in how they engaged novice students in research. A common practice among high school science teachers flummoxed scientists: having students choose their own research projects, their own questions to investigate. In the university labs, even graduate student research was usually guided by the primary investigations of their advisors. A university scientist describes the differences:

> I knew we couldn't just let students make up a project. And one of the things that I find completely freaky about the high school is that students get to develop their own question. But sometimes they're impossible to answer – they're impractical questions. … So you look at what is a real-world question of importance where there's something going on at MWU and where they can really contribute. *– Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

Susan also was careful about which scientists she arranged to work with high school students. She needed to know they were open to secondary students and would have the time and patience to mentor them. Steve Graham who had considerable experience working with scientists as mentors to his students, talked at length about the challenges involved with university researchers mentoring high school students.

> The university culture is totally different than the public school's. And it's like working with any researcher – they definitely want to help, but they don't know all the nitty gritty of dealing with the student at that maturity level. And so it takes the expert in that area – if you want to call me an expert – in dealing with those high school students and dealing with the researchers so there's not some big rift that occurs. From the very first kid that I ever put in a lab, I had to mentor the mentor *and* the student, because the mentor expects this and the kid expects this and they don't communicate well. So you have to lay it on the line. ….The culture of the university is they don't know how to bring those kids to that level. And so I'm trying to bring kids to that level so that kids can benefit from that

> mentorship…. I'm kind of massaging both sides to keep them together. That's just part of my responsibility. *– Steve Graham, teacher at VSD*

School science is often different than actual scientific practice. When the biotechnology high school students entered their project into the regional science fair, this point came in high relief to the scientists.

> The students got great [research] results. Their results actually contributed to the ongoing investigation in the scientist's laboratory. Their confidence and their skills [grew] as they learned to design and perform sophisticated experiments. They exhibited their project at the Metro Region Science Fair. And it was very interesting to us on the university side to see that, because we had worked so hard with the students to make them understand the animal health context of the problem and what they were looking for, it never occurred to us that the biggest thing the science fair [judges] would be looking for would be sort of a very rigid [structure]: this is your hypothesis, this is how you tested it. Because real scientists actually don't use the scientific method that way. So that was something that emerged as a point to address later on. *– Susan Rasmussen, Chief Academic Officer at MWU-Vista campus*

The scientists were truly surprised by this rigid use of the "scientific method" as a means for evaluating students on their research. Susan felt she had let the students down in a way by not preparing them better: "It was not on my radar screen at all."

While some differences in culture affected students directly, others were contained strictly in the institutions. Something as seemingly benign as the name of a school program caused great consternation at the university. As the Animal Health Twenty-First Century Program was being prepared, school administrators created flyers and brochures to distribute throughout the schools and community to recruit students to the new program. University scientists had expressed frustration with other outreach efforts that emphasized the light, fluffy side of animal health. Recruiting students into the animal health field by appealing to children's desires to pet soft, cuddly, cute animals belied the reality of working with the whole organism, with blood, disease, and other aspects of real life. The unrealistically "soft" messages rankled the scientists, and they stressed the science side of the field. So, to maintain fidelity to these perspectives, school administrators initially called the program “Animal Science,” thinking they were emphasizing the science in the field. Unbeknownst to them, however, the university distinguished between “animal health” as primarily related to the College of Veterinary Medicine, the college in which Susan Rasmussen was associated, and “animal science” as primarily related in the College of Agriculture. When colleagues of Susan’s in the College of Agriculture saw she was involved with an “Animal Science” K-12 program and had not directly involved them, they were understandably upset. A great deal of diplomacy and a name change of the program to “Animal Health” resolved the problem.

One of the initiatives that highlighted the different constraints of each institution was the plan to develop an MWU online course for the Animal Health Twenty-First Century Program high school students. Susan offered early in the planning that it could be possible to provide scholarships for a small number of students. However, the district wanted all students in the program to take the course, and there were not enough scholarship funds to support them all. The district, being part of the public education system, could not charge tuition to their students nor require their students to do anything in which cost would separate out those who could afford it and those who could not. The university, however, could not waive tuition for students, especially in an online course which involved an academic division outside a particular college or campus. So in fact, the university needed to charge students. The constraints were in direct opposition to each other, but through honest conversations and creative thinking, a solution was found. I, as coordinator of the partnership, would create and teach a non-credit online course for the students with no tuition costs and just a small registration fee, which the university underwrote. The loss was that students would not earn college credit.

Nonetheless, both institutions were committed to education and hence were student-centered. They shared a desire to cultivate an educated society, as well as a deep commitment in helping students develop their careers through their passions and interests. The student-centered nature of the partnership was at the heart of the common vision that allowed the partnership to succeed. The differences and commonalities of both institutions are represented in Table 4.9 below.

**Table 4.9 Differences and commonalities of the K-12 school and university cultures –** Differences are shown in either the left or right column only; commonalities are shown across both columns in the bottom three rows.

| School Culture | University Culture |
|---|---|
| Technology somewhat limited – strong firewall | Technology highly supported |
| Science labs equipped to conduct variety of research investigations | Science labs equipped to conduct very focused investigations |
| Scientific breadth | Scientific depth |
| Minor students require supervision (including between classes), and meetings with parents | Adult students are independent |
| Pedagogical expertise | Scientific expertise |
| Teacher's time highly scheduled | Scientist's time autonomous |
| Students can choose own inquiry questions | Students guided in labs |
| School science (emphasizes rigid "scientific method") | Science in practice uses many approaches for being evidence-based |
| Cannot charge tuition | Depends on tuition |
| Both very busy | |
| Both committed to education | |
| Both student-centered | |

When necessary, how were the differences reconciled? Repeatedly, participants talked about understanding and mutual learning. Once there was understanding between the two institutions, solutions for challenges could nearly always be found. Sometimes that understanding occurred through visiting each other's contexts, for instance, scientists being in the classrooms and witnessing the classroom constraints, or district educators visiting the university. Sometimes it occurred through formal meetings with issues to be solved, as in the case of finding a solution to the creation of an online class. The difference of school science emphasizing primarily an experimental version of the scientific method in contrast to more varied ways of conducting research was addressed in subsequent program design, emphasizing that science is "curiosity-driven and evidence-based." Sometimes the differences were reconciled through one person "massaging both sides to keep them together," as Steve Graham described. In his case, he had spent time in scientists' labs conducting research himself.

> I think my biggest benefit was spending a summer in a research lab. I think doing research ought to be just pretty much required … for the teacher to know what the research culture is. – *Steve Graham, teacher at VSD*

In fact, people who understood both cultures were credited with much of the success of the partnership. An MWU faculty advisor to the partnership told me:

> I think it's critical that we had people like Joyce Lancaster [VSD administrator] who understood both cultures involved from the very beginning as well as people like Judith [MWU faculty advisor] and Susan who understood both cultures. And obviously your role cannot be minimized – a foot in each campus. I think that helps translate the challenges faced by the two components in the partnership. – *Barbara Shepard, MWU faculty scientist*

There were individuals in the partnership who had some understanding of both cultures. Further, through the commitment of mutual learning, one of the outcomes of the partnership was that it was a training ground for scientist-educators, hybrid professionals who had experience in science research as well as K-12 education. The teacher Steve Graham was considered a scientist-educator from the start, and as he described above in his work with scientist mentors with his students, he did a great deal to help mediate and interface the cultures. A coordinator who was a scientist-educator was recruited as the coordinator of the partnership. In addition, the partnership itself was committed to being a training ground for additional scientist-educators.

***Summary of Partnership Challenges***

The MWU-VSD partnership faced significant challenges, yet to a large degree the partnership was strong enough to weather those challenges, and even grow stronger because of some of them. The budget constraints motivated a greater working together to "do more with less" and help create synergy so that the work together was more valuable than work apart. The challenge of the distance was overcome simply by the willingness of individuals to travel and communicate electronically, and of the institutions to support the travel and electronic technology. The differences between the two professional cultures required a willingness to learn about the other, to respect and understand. The differences were actually what precipitated innovation and creativity. The challenge of staff turnover was perhaps the most threatening of all, especially when the key leader for the partnership at the university was lost. All the challenges necessitated a high degree of clear communication, strong relationships and good will to understand each other, work creatively together, and keep the students best interests in the center of the work.

### ***Summary of Successes and Challenges in Embedded Programs***

The four embedded programs studied in this case also faced challenges as well as successes.  Since most of these have been discussed in other contexts throughout this chapter, I summarize these in Table 4.10 below.

**Table 4.10 Successes and challenges of embedded programs** (continued on next page)

| Program | Successes | Challenges |
|---|---|---|
| Senior Biotechnology Project | • Students' research yielded important results for Dr. Tillman's lab<br>• Students learned how to design and implement sophisticated experiments<br>• Students' first-hand experience increased their lab skills and confidence markedly<br>• Students presented findings in paper, presentation, and metro science fair<br>• Students experienced rigorous peer review<br>• Students gained experience and confidence presenting their work and explaining the concepts and experiments<br>• Students visited MWU campus and labs<br>• 3 of 4 students MWU-bound<br>• Project presented at national conference | • Finding and dedicating resources<br>• Distance between MWU lab and high school<br>• How do students "own" the project that is a piece in a larger research program?<br>• Expectations of conceptual understanding by students too high<br>• Time commitment and scheduling with four students |
| Animal Health Twenty-First Century Program | • Designed and implemented new 4-year program<br>• Animal health content unique<br>• Animals attract students to STEM<br>• Program incorporated One Health concept integrating animal, human, and environmental health<br>• Program contains rigorous math and science coursework, including biotechnology and research components<br>• Program includes a non-credit online course<br>• Connections forged to local animal health industry<br>• Students learned about many options in animal health careers<br>• Students visited MWU campus and labs, and numerous industry facilities<br>• Students attended animal health conferences<br>• Students cared for and worked with animals in hands-on settings<br>• Students learned how to design and implement science research projects<br>• Students gained experience and confidence in interacting with scientists<br>• Very popular program among students – more student applicants than places in the program | • Struggled with identifying a leader at the beginning<br>• Due to budget crisis, no new classes, no new budget lines allowed<br>• Program was developed on an accelerated timeline<br>• Recruiting diverse students into program |

**Table 4.10 (continued) Successes and challenges of embedded programs**

| Program | Successes | Challenges |
|---|---|---|
| Field Research Camp | • The scientist-educator coordinator was the "right person at the right time" to develop it<br>• Integrated a One Health perspective integrating animal, human and environmental health<br>• Low-cost program utilizing natural areas<br>• Students immersed in outdoor field experience<br>• Students worked closely with a research scientist with ecology expertise<br>• Students participated in and helped design a field research project<br>• Students collected observation-intense data<br>• Students gained experience identifying plants and insects<br>• Students analyzed individual data daily to look for small-scale patterns<br>• Students pooled data with class to look for large-scale patterns<br>• Students interpreted data and prepared reports<br>• Students presented research findings to each other | • Program dependent on the scientist-educator<br>• Summer scheduling not always easy for students<br>• Requires summer staffing<br>• Certain safety concerns to consider with outdoor setting |
| Lab Techniques Course | • The course filled a need to orient new 9th grade students to science-focused 21st Century Programs<br>• Course was text-book free and developed through collaboration of teacher and scientist-educator to meet needs of students and programs<br>• Developers had freedom to innovate as it was a "singleton" course<br>• Students experienced an introduction to a variety of research skills<br>• Students gained experience in designing and implementing research projects<br>• Students gained experience in analyzing and interpreting data to find patterns and meaning<br>• Students gained an introduction to the nature of science in various disciplines (biology, chemistry, earth science)<br>• Students developed lab-related skills, such as measuring, pipetting, recording, use of equipment<br>• Students were exposed to scientists and other career role models<br>• Students gained confidence in presenting to peers and the public<br>• Students gained a foundation in research techniques | • Biotechnology teacher sacrificed an advanced-level course to make this one possible<br>• Teacher assigned to teach and develop the course was changed<br>• MWU lost the post-doctoral researcher originally assigned to help develop the course<br>• Unable to pursue Adapted Primary Literature project due to budget constraints<br>• Students in the spring semester felt unconnected to program during the fall semester (later changed to have all sections taught in fall)<br>• The experimental method was still used as a representative of the whole "scientific method" because of confusion among students taking other science classes |

## *Benefits Gained Due to the Partnership*

Interview participants identified numerous benefits that each institution and the individuals involved gained from the partnership. Figure 4.7 below shows school district, university, and common benefits.

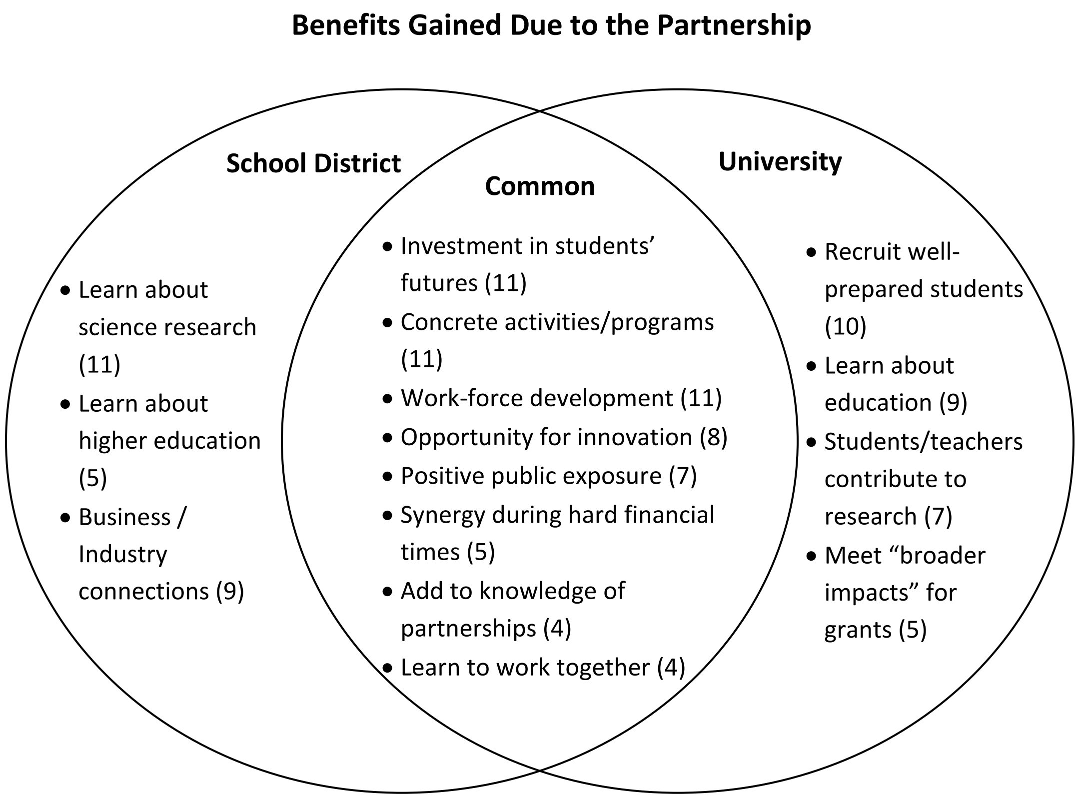


**Figure 4.7 Benefits Gained Due to the Partnership. –** Gains for the school district alone are on the left, for the university alone on the right, and common gains in the middle. The numbers in parentheses indicate the number of interview participants who identified each benefit.

### *Common Benefits*

Nearly all interview participants identified a common benefit as *the investment in students' futures* as a primary benefit of the partnership.

> The gain is in the students' experiences. That's the gain. And that's the purpose, to give those students those experiences and that knowledge and that information…. So that would be the number one gain. – *Christine Finley, VSD teacher*

> I think it's always good to do K-12 outreach, because I think that you can't count the value directly in the year that it happens. I think that happens down the road, and there's a long pay-back curve, and that's one of the reasons that we should do it.
>
> *– Barbara Shepard, MWU faculty scientists*

Interviewees listed many of the specific experiences students gained: experience conducting research, visiting MWU labs and the animal hospital, working directly with scientists and mentors in classes and on projects, and the opportunities in college due to direct university scientist references and contacts. Three of the four students in the Senior Biotechnology Project, for instance, earned scholarships to attend MWU. Two of them worked in veterinary labs as freshmen. One applied for and gained early admittance to veterinary school while she was a college freshman, having been able to secure a letter of recommendation from the former associate dean of the college, Susan Rasmussen. Others talked about student gains in developing confidence through experience and in learning about the breadth of career opportunities. Student gains were characterized by the educators as possibly students discovering that something they thought was a career interest was in fact not something they wished to pursue further as a career. Ultimately participants described the benefits of opening doors for students to participate in science.

> The Vista Schools gained a lot because of the opportunity for those students to not only participate at the high school level, but has continued on for them to have connections when they went to MWU, and continued to have an opportunity to do research, and continue their interest in a science profession. So whether there were opportunities provided for me, or for the school – you know, I think that whole thing is centered around providing opportunities for the students. *– Steve Graham, VSD teacher*

A direct benefit of the partnership to both institutions was the development of *concrete activities and programs* with strong student enrollment. By the end of the third year, there were seventy-five students enrolled in the Animal Health Twenty-First Century Program, all of whom would participate in the Field Research Camp. Sixty-seven students from three different programs had taken the Lab Tech Course in just one year, with an estimate the following year of over ninety students enrolling. We had presented our work with the Senior Biotechnology Project at a large national conference, and the partnership as a whole at another national conference.

> How do you sit in the school board meeting and listen to these people tell you what it meant and how it's grown their programs and got all these kids involved without saying, you know, they see it as a great return on investment as well? In fact, they want to grow it obviously. So it benefitted both. *– Phillip Hendricks, Dean at MWU-Vista campus*

Looking at the future from the community's perspective, participants recognized a common benefit the partnership contributed to was *workforce development*.

> I think that we have created in the school system, building upon the excellent foundation of the Twenty-First Century Programs and the way they were laid out, activities that give students an opportunity to see where the boundaries are blurred between biotechnology and life sciences and animal health, giving students a broader understanding of what animal health and One Health concepts mean in terms of career options, contributions to society. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Another common benefit participants repeatedly identified was the *opportunity to innovate*. Not only did members talk about innovation as contributing to society and increasing the value of each institution, they also talked about it in terms of its intrinsic value to those involved – it was exciting, interesting and a challenge to meet novel needs. The innovations identified were those in relation to: establishing a school district – university partnership that was not identified with the university's college of education; focusing on animal health with an interdisciplinary approach highlighting broad career options and research; and developing an integrated curriculum that spanned four years of high school and interfacing with college.

> Our shared goals were to educate students about animal health, to engage students in the whole range of careers within animal health, and I think this was a fairly innovative goal. There are a lot of programs in high schools that focus on animals. There are a lot of pre-veterinary camps. But there are not that many that say animal health careers are everything from being a small animal veterinarian to a large animal veterinarian to a

public health sanitarian and a biomedical researcher, etc. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

We created the program based on two mutual interests, the interest of MWU to provide some services to the district, and the district's desire to utilize some of their expertise in the animal health field. And now we've tried to continue that partnership by continually looking at what MWU has to offer, how VSD can make use of that to benefit the students. And so we have got a pretty good foundation as a program that starts with ninth graders and progresses through their senior year. And so kids have a unique opportunity that is very very unique. I don't know that you're going to find anything like it. I know when I started the Biotech Program, you either had to go to the east or west coast to find biotech programs. And so I'm not sure if there's any place else that really has an animal health program. I don't think you're going to find many. – *Steve Graham, VSD teacher*

Both institutions *received positive public exposure* through their collaboration with each other. The school district housed innovative programming developed with the university, and they were the first in the county, state and region to have such a program. The nascent MWU-Vista campus also benefitted, as the new campus was an untested entity in the county, promising great things but still initially too new to have delivered on any of them. Before it even had a building, MWU-Vista started the partnership with VSD. The mandate for the partnership in the land grant from the City of Vista was a motivating factor not only for initiating work with VSD, but also for showing early success in that venture to the public. Establishing credibility with the county had high stakes: MWU was campaigning for the citizens of the county to pass a tax to help support it. The citizens needed to feel there was value in supporting it. Fortunately, the school district had a good reputation in the county and was well-supported by residents. So, as Alice Hughes described it, partnering the two institutions was good branding. The school district also benefitted from the association with MWU.

Having a regents' institution [MWU] locate in the Vista School District in the City of Vista was good branding – that was good brand. The Vista School District is a good brand. So when you say to the entities [citizenry], we're going to partner two good brands – that means something to the private people…. I used it for public relations. I

> used it for great public relations.  I used it so our parents would know that there were partnerships, that their kids were in some place special and that they had special opportunities.  *– Alice Hughes, former Superintendent at VSD*

Some interview participants spoke specifically about the benefit of *adding to the knowledge of scientist-educator partnerships* among scholars, to contribute to the body of knowledge from which a broader community can benefit.  Also stressed was the value of simply *learning to work together* for the general benefits of broadening one's own institutional perspective.

> I think the result of a partnership is an opportunity to just interface with different personnel, different perspectives, which I think provides growth opportunities for an organization.  *– Beatrice Price, Director of Secondary Programs at VSD*

Interviewees reported *synergy during a national financial crisis* that affected both organizations profoundly since they depended on tax dollars.  The partnership started in "economically flush times."  The vision was developed then, and commitments made.  When the Great Recession hit, neither partner backed away from the collaboration.  Rather, interview participants credit the partnership for help and creativity that each offered the other.

> I think there's always a good side and a bad side of being resource-limited.  So, I think the bad side of being resource-limited is that it's just not easy sometimes and you do have to ask people to do more with less at every level.  But there's always a silver lining in the cloud of being resource-limited, and that is that it forces you to be more creative and more collaborative. … So I think we were able to do that with [various] funding opportunities.  We were able to look at who might want to be involved because it was in their self-interest as well as out of the goodness of their heart.  And I don't know if we had had more resources, we wouldn't have been so forced to make those connections.  And those connections will be good in the long run.  *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

> And the other gain is back to that piece of collaboration and being able to make things better and improve things and be more real-world and helping out when we're

> overloaded. You know, we're overloaded at the high school, I mean in the budget crisis. We are overloaded. And there's no end in sight with the cuts – the seven million that we're going to be cut next year. I mean, there's going to be no new staff, and there's going to be more kids. – *Christine Finley, VSD teacher*

***Benefits for the School District***

Benefits for the school district included *learning about science research, learning about higher education,* and *gaining business and industry connections* through university contacts. All the district personnel valued learning about science research. The teachers were able to directly implement much of what they learned directly in their instruction with students, and they acknowledged that even when their students were learning from the scientists, they were also learning.

> I think the first thing that comes to my mind is the fact that I was able to actually pull upon the considerable expertise of Dr. Rollins and his methods. And so not being a molecular trained scientist, you know, each time my students learn, I'm also learning.
> – *Steve Graham, VSD teacher*

Administrators too valued what they experienced from scientists in terms of research. Janet reported that she was able to help the middle school and elementary teachers understand the kind of research students would be exposed to if they wanted to enroll in the Animal Health Twenty-First Century Program. Another administrator told me what she learned from the scientists about the animal food production chain directly influenced her mentoring of teachers.

Most of the district personnel also described how they benefitted from learning about higher education in terms of helping their students interface with university programs.

> We learn about how an institute works at the college level … how some students can go to undergrad for three years and be accepted into … [the vet] college. And those are good things that I can learn about, the opportunities in the animal health field that I can then bring back to students and share. – *Janet Spencer, Science Facilitator at VSD*

Finally, all the district personnel also described their gaining business and industry connections through their university partners, especially through Susan. These connections would prove fruitful when Michael Dunlap approached these businesses to allow students to visit their facilities during field trips and to work as interns. He also was able to garner financial support from them to help underwrite certain aspects of summer programs and field trips.

***Benefits for the University***

Benefits for the university included *learning about and recruiting well-prepared students*. One teacher was particularly insightful about universities using their work in pre-college settings to plan for the incoming generations of students, and get a sense of how they might need to adjust their higher education practices:

> I think it helps with the university thinking more about what they need to provide to students that there might be a disconnect on, kind of bridging that gap…. "Are we continuing to meet the needs of a changing academic population that's coming in?" You know I think sometimes there can be a real disconnect between what goes on and has been going on at the university versus what's coming down the pike. And when you have people in the field providing resources to our educational system to see, whoa – have you ever considered they [students] are much farther ahead on these kinds of things, or they're lacking here – expect that. I think that's good data. *– Michael Dunlap, VSD teacher*

The university also *learned a tremendous amount about education*. Susan learned about the culture of science fairs better, and felt in the future she would be better able to prepare students presenting in them. She learned from the district educators about good pedagogical practice, such as developing a four-year curriculum with increasingly challenging learning goals, and cultivating student learning communities. She and Tim Rollins both discussed the value of learning about K-12 teaching, the constraints that educators work with, and their enormous expertise.

> I think interacting with different understanding levels … I think that has been a great benefit. You know, learning some of what it takes – I mean, I can't claim to be able to teach a high school class or anything like that at this point. But learning some of what goes into the teaching process, essentially, has just been … professionally beneficial to me. *– Tim Rollins, MWU post-doctoral scientist*

Another benefit for the university was *the opportunity for high school students to contribute to research.* On the one hand, the educational benefits of students conducting authentic research with university scientists in active research programs were highly valued. Yet scientists also valued the benefits to research to have fresh eyes on their investigations.

> It was nice to see a different – you know, a bright smiling face, who was really interested in being here. *– Robert Tillman, MWU faculty scientist*

> And I think another – it sounds very hokey but I really do believe this – when you have the eyes of people from outside the discipline in your laboratory, so you have very motivated students and teachers at a high school level, their ignorance is a tremendous value to the inquiry process. And sometimes you're so blinded by the dogma and what you think is going to happen and what your cultural norms tell you, that having a question that none of your colleagues would ask because it would be a kind off-the-wall comment, out of the mouth of a high school teacher or student has the opportunity to move the wheels of your brain to a new direction of inquiry. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Aside from the direct intellectual merit students and educators could offer scientists, the partnership also provided scientists the vehicle to *document in their research programs "broader impacts to society,"* a requirement for many tax-supported grants. Applying their research projects to educational settings allow scientists to fulfill a critical requirement of many grants, and researchers who worked with the partnership benefitted in meeting their grant obligations.

> I'm still using the Vista partnership as an outlet for K-12 activities for my grant…. And I have an interest in the project, so I'm still invested in it. *– Barbara Shepard, MWU faculty scientist*

> I truly believe that K-12 needs to participate when researchers have a K-12 outreach component to their [grants]. You know, NSF funds are our tax dollars at work. And if we don't all work together then our tax dollars aren't working. So I think that's very important. *– Joyce Lancaster, former Science Coordinator at VSD*

## *Outcomes of the Partnership*

Interview participants identified major outcomes of the partnership, and these included:

- Innovative programs developed in context
- Diverse students engaged in science
- Sustainability
- Mutual learning

### *Innovative Programs Developed in Context*

The various innovative programs developed through collaboration of district educators and university scientists were a primary outcome of the partnership. The programs would engage ultimately over one hundred and sixty students each year who chose to study science, most of them specifically in the animal health field. These students would interact with university scientists and expert teachers as they learned current understandings, skills and career options in the field. Through the mutual learning, *innovative programs were developed in context*. Instead of university outreach programs being developed at the university and delivered to students either at the university or in their classroom, the programs developed through this partnership were created within the context of the district curriculum in the classrooms, and largely taught by teachers themselves.

Having the programs developed within the district classrooms was not the only *innovative* aspect of the programs. The fact that they were developed within the twenty-first century programs with their flexibility, connections to community experts, and focus on student interests meant that the partnership programs benefitted from the district's innovative educational approach. Dedicating a scientist-educator coordinator who could work directly with teachers and students in the classrooms and interface with scientists at the university allowed for flexible and creative program development that could meet immediate and changing needs. For instance, when the "scientific method" discrepancy between research science practice and school science emerged, the coordinator broadened the methodological perspective by emphasizing in subsequent program development that science is "curiosity-driven and evidence-based." When district staff wanted an in-depth hands-on research experience for a whole class, the coordinator offered a Field Research Camp. While numerous university-school partnerships throughout the country focus on biomedical themes, developing the partnership with a focus on animal health themes was unique. In doing so, scientists emphasized creating greater awareness and opportunities for students in the many varied fields of animal health.

> I think this has been and is a unique opportunity, and I think that we need to nurture it. It's something of value that we are creating something that no one has tried to do at this level before. And I think it's really easy to forget that when you're struggling in the trenches, especially in times of limited budgets. I think we all ought to remember how important this is. – *Barbara Shepard, faculty scientist at MWU*

Table 4.11 below shows the four programs developed through the partnership.

**Table 4.11 Comparison of Embedded Programs**

| Program | Purpose | Students Served | Partnership Activities | Outcomes |
|---|---|---|---|---|
| Senior Biotech Project | Contribution to research Senior project | 12th grade Biotech students (program of choice) *4 students* | Research mentoring of students and teacher by scientists, Funding | Student learning, Scientist learning, Teacher learning, New research findings, Presentations |
| Animal Health 21st Century Program | Create new curricular track, Workforce development | 9th - 12th grade Animal Health students (program of choice) *~75 students during study (~100 when fully implemented)* | Advising by scientists, Teacher taught/facilitated, Create curricular opportunities (courses, field trips, research mentoring), Networking, Funding | New curricular track created with endorsement, Full enrollment (~28 per year), Teacher created new networks and sponsors |
| Field Research Camp | Intro to field research, Intro to research methods | 10th grade Animal Health Students (program of choice) *30 during this study -- (~25 each year when fully implemented)* | Scientist-Educator designed and taught | New short course created, Student learning, Teacher learning, Research findings, Presentations |
| Lab Tech Course | Intro to research methods and lab techniques | 9th grade students enrolled in one of three science curricular tracks (programs of choice) *~90 students during study (~90 each year when fully implemented)* | Teacher and Scientist-Educator co-designed and co-taught | Course curriculum created, Student learning, Teacher learning |

***Diverse Students Engaged in Science***

By developing innovative programs in the context of school programs, especially in a school with a high level of diversity, and by developing a level of sustainability in the programs, opportunities to explore science and to interact with scientists became accessible for under-represented groups in science, including minorities, females, low SES students, and students who had no one in their family attend college before. One of the four students in the Senior Biotechnology Project was African-American and another was latina, and they both joined the Developing Scholars program at MWU, designed to help support students from under-represented groups in science pursue interests and research in university science labs. One of them, Sophia Delgado, already in her sophomore year at MWU when I interviewed her for this study, had worked in the same lab that initiated the Senior Biotechnology Project for two years as an undergraduate. She planned on earning a Ph.D. in biology to pursue her interests in animal health pharmaceutical research, and she directly attributed the high school project for piquing her interest and creating opportunities for her to pursue (student voices will be highlighted in the next section). Once the programs served more students, opportunities for an even greater number of under-represented students were available. Students visited labs and science-related businesses and saw scientists, both young and old, of different races, ethnicities, and genders. While females are under-represented in science in general, they are over-represented in animal health fields. While the Animal Health Program did in fact tend to attract predominately white female students, male students did enroll, and a number of students from otherwise under-represented groups (culturally and linguistically diverse, economically disadvantaged, first-generation-to-college) did enroll. This was considered a success of the program, as well as one that would continue to require recruiting attention.

> We tried to create that [research] experience with kids who didn't have … resources behind them. And I think that's really important. We tried to pick everything to make it work, to have a good outcome …. But we did not pick students who had means behind them. And if we had, it would have been more likely to work. I mean, it would have been a different experience, but it wouldn't have been as transferrable an experience. I'm very proud of the fact that that wasn't a factor in what we did. We tried to create something that – could it work all the time? Could it work with any student who

expressed interest? – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

One thing that this program does – we take them out to the field, and we take them to the rabies conference, or we take them to MWU, and even the kids – we have a lot of diversity of ability, we have wide diversity of ethnicity, we have socio-economic diversity. And I think what's so wonderful, amazing with this program is that these kids … see science, or animal health, is not a generic guy in a vet's [clinic] or in the research lab. They are seeing different ethnicities. They are seeing different age groups, females, males. They're seeing this wide diverse group of people out there, and they can picture themselves in that position, and not as a white male who's a vet that they're going to. And that's what I think one of the most important things we can do for these kids is show them that they can be a scientist, or they can be a researcher…. And we are taking kids and showing them that science is more than Einstein, a white crazy guy with crazy hair. Because when they think of science that's what they think of. … When they think of animal health, they think of a veterinarian, and it's so much more than that.

*– Janet Spencer, Science Facilitator at VSD*

***Sustainability***

The instances in which teachers were not the primary instructors, they were either facilitators of scientist-student interactions, or were developing the understanding and skills to teach, as in the instance of the ninth grade Lab Tech course. While the Field Research Camp was taught by the university scientist-educator, the teacher was well aware, through participation in the course, of its elements. If MWU were unable to teach it in the future, either he could teach it himself, or he could find other opportunities, such as at a local zoo or botanical garden, to have students engage in group research projects using the Field Research Camp as a template. By taking the approach of developing innovative programs within the context of the K-12 school district, a level of *sustainability* was achieved.

[The Field Research Camp] was led initially by a scientist-educator associated with MWU-Vista, but during the initial offering not only were the students taught but the teacher was trained so that this would be something that would be sustainable and

> institutionalized within the school district's structure. The activities were documented for the future. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

In addition, sustainability was achieved through the targeted investment in certain activities, especially during the economic downturn. Administrators talked about the need to prioritize what investments would be made: rather than investing in five new opportunities, they would invest in one at a time until they were on solid footing. Teachers also created new partnerships with the business community, especially those in the animal health industry. Michael Dunlap, the facilitator of the Animal Health Program, reflected on the possibilities that an over-reliance on the university could overtax it to the point of collapse, whether it was burdening scientists in requesting multiple lab tours, or by relying on it as a funding stream. He initiated contacts and procured ongoing funding for field trips through at least two animal health business donors. While the district's involvement with MWU in developing the program lent credibility to his request, he cultivated multiple sources of support to ensure program stability.

Being a pilot project, the Senior Biotechnology Project was not immediately sustained, although there were hopes for additional senior project research opportunities with scientist mentors once the labs in the new satellite campus were operational. The sustainability of high schools seniors working with MWU scientist mentors would be linked to the sustainability of MWU's new campus. So it was helpful that the partnership provided positive public relations in the community in which it was building the new satellite campus. When the nascent campus was still just a plan, the MWU-Vista leaders focused on successfully developing the partnership with VSD, and in so doing, built credibility to convince the county citizens to levy a sales tax on themselves to help create a revenue stream to support the campus. By doing so, MWU gained solid footing in the valuable metropolitan region.

> I think MWU got something, and MWU should look at going forward and how they can show that their presence here and their partnerships with K-12 here on this campus are so critical to the future of MWU. And I think that was partly [the former president's] greater vision – how do you take the [home MWU campus] and keep it on the radar of the largest and most affluent county in the state? This is the economic engine of the state. So MWU put their campus in the economic engine of the state. – *Alice Hughes, former Superintendent at VSD*

What [the partnership] did for me immediately was all of a sudden I had allies with Alice Hughes, who could talk about the value of MWU coming [to the county] because we had already added value to the system. – *Phillip Hendricks, Dean at MWU-Vista*

Would the university's new campus achieved credibility without the partnership with VSD? It likely would have through other avenues. The university also had an excellent reputation in the state, and had a strong following in the metropolitan region. So while the university's credibility did not depend solely on the partnership with the school district, the partnership undoubtedly showed the community that the university was committed to it and its children.

MWU has gained some visibility and good will among the Vista citizenry and denizens of the school district in terms of their contributions. – *Barbara Shepard, MWU faculty scientist*

The partnership also achieved a level of sustainability for itself through its own dynamics. While individuals in some instances expressed their convictions that sustainability requires building partnerships that depend on systems and infrastructure, they also said that in fact the dynamics enacted by individuals were what actually sustained the partnership. Having individuals who could maintain an awareness of needs and changing conditions, and who could actually create and implement programs in an evolving way sustained the partnership.

Over the last several years that the partnership has been sustained, it was not only a partnership on paper, but in fact there are very concrete examples of that partnership continuing to evolve and emerge. – *Alice Hughes, former Superintendent at VSD*

Things continue to evolve – there were new programs added, there was innovation, there was continued dialogue, people were still friends. You know, a partnership that sustains itself and that's focused on summative and formative evaluation steps to be formal or just to be continuous improvement … I think that's incredibly successful. I think that's much more important than, you know, was there something we wrote on a bullet on a planning document one day that we never got to? Well, that happens all the time. But it's not that we didn't get to it because you're not continuing to work together. We didn't get to it because we had to postpone it or something else had priority. This is not like something [in which] you go to a website and [say], "Oh this sounds great," and then you call people up and they [say], "Oh well, we used to do that but we don't do that anymore*." – Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

The largest threat to the sustainability of the partnership was in fact the high turnover of staff, especially the loss of Susan as a key leader.

***Mutual Learning***

The mutual learning gained by both institutions proved key to "the whole being more than the sum of the parts." Through the partnership, educators learned continually from the scientists in order to align school science more with the disciplinary content of research science and career opportunities. In learning more about the science research, district administrators were able to help create organizational infrastructure to support current disciplinary practices, and teachers underwent informal professional development as they worked side by side with scientists. In addition, school staff learned more about how higher education institutes work, which increased their capacity to support their students to continue their education beyond high school.

The university grew in its understanding of future students and in how to support and recruit quality students. University personnel learned a great deal about the K-12 environment and how it could interface with it for the benefit of all. University scientists also learned a great deal about teaching skills, and they were able to apply these to their own work back at the university. Additionally, both institutions learned more about partnerships, and were able to communicate this learning to their local stakeholders and national scholarly communities.

In solving the challenges to make science opportunities available for all students, the two scientists besides me most involved in the work, Susan and Tim, spoke appreciatively about their own learning. In fact, the scientist who headed the lab that the Senior Biotechnology Project contributed told me his greatest wish was that he had more time to come into the classrooms and learn from the teachers and students. Susan described the experiences as transformative and valued the partnership as a training ground for future scientist-educators if scientists continued to partner with educators.

> You have something that's a rich training ground and proving ground for a new breed of hybrid professionals who really have knowledge and understanding of what it takes in the scientific research world, and the pre-college education community. And we were fortunate to hire somebody who had this as their major responsibility, to facilitate our partnership, and we had a teacher who certainly had those skills coming in. But I would say as the senior scientist involved in the project, and I've had this conversation with the more junior scientist involved in the project, it was a transformational experience for us. And we certainly consider ourselves more scientist-educators now having gone through the partnership than before. And both of us take those skill sets to every collaboration that we enter into, whether it's with a school district or another entity that has a culture different than scientific research. So I think that this is a really a model for the future. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

## Multiple Constituents' Experiences (Research Question 3)

*How have multiple constituents (administrators, teachers, students, scientists) experienced the partnership?*

Much has already been documented regarding how multiple constituents have experienced the partnership. In this section, however, I will discuss participants' personal motivations to be involved in the partnership, how they viewed each other, how valued they felt, and their concerns and anxieties about the partnership. Student experiences with the partnership are also shared here.

### *How Personal Motivations Drove Participants' Involvement in the Partnership*

Although the external drivers for the partnership were dictated by political concerns, most notably the land grant to MWU by the City of Vista, each person had his or own personal motivations for being involved that usually went beyond their job description. In fact, both top leaders at the MWU-Vista campus interviewed for this study recognized that the partnership could have very easily been a "pedestrian" one were it not for the unique individuals involved. Nearly all individuals involved attributed the people, their time, and their extraordinary dedication to the success of the partnership. They put in extra time to make the partnership work, to develop the programs, to support students in their work. Why? What were these personal motivations? Even though no single question I asked in the interviews directly queried their motivations, each interviewee discussed certain beliefs, certain ideals and commitments that explained their extra efforts in making the collaboration work. In turn, each participant was inspired by these very qualities, which positively nurtured their continued motivation for collaboration. They tapped into ideals that inspired them, which included a love of learning, a commitment to serving students, a belief in a positive future and society, a premium placed on education and on science, and a drive to innovate (see Table 4.12, p. 263, and Figure 4.8, p. 264 ). They also seemed energized by sharing these same ideals with others, which provided meaning to their work together. Interestingly, these personal motivations tended to be similar to, and at least related to, the outcomes of the partnership: help pre-college students engage in science and learn about career options; learn from each other; develop innovative programs in the K-12 school setting; train scientists in pedagogical approaches; create sustainable programs that serve diverse students.

### *Motivated to Serve Students*

All adult interviewees reported having a *commitment to serving students* (see Table 4.12 below) – it was likely the overarching belief that united them. The altruistic idea of serving students was related to all the other motivations. They all told stories about being inspired when they saw individual students succeeding. Susan Rasmussen created a whole program based on the question she encountered from student Chantal Morgan. Scientists wanted to expand students' views of what science is and what it means to have a career in science. Everyone wanted to see the students motivated to develop their own futures, inspired when they saw this happening due to their efforts. And nearly all recognized the importance of inspiring minority students and students in poverty to work for a career they were passionate about.

> I'm thrilled every time I hear about a student going to the next level and doing well. – *Steve Graham, VSD teacher*

**Table 4.12 Breakdown of participants' motivations for involvement in the partnership**

| **Role/Motivation** | **Love of learning** | **Value education** | **Optimistic future and society** | **Driven to innovate** | **Value science** | **Commitment to students** |
|---|---|---|---|---|---|---|
| **VSD Administrators (4)** | 3 (75%) | 4 (100%) | 3 (75%) | 2 (50%) | 3 (75%) | 4 (100%) |
| **VSD Teachers (3)** | 3 (100%) | 3 (100%) | 0 (0%) | 3 (100%) | 3 (100%) | 3 (100%) |
| **MWU Faculty Scientists (4)** | 2 (50%) | 2 (50%) | 2 (50%) | 2 (50%) | 4 (100%) | 4 (100%) |
| **MWU Junior Scientist (1)** | 1 (100%) | 0 (0%) | 0 (0%) | 0 (0%) | 1 (100%) | 1 (100%) |
| **Total (12)** | **9 (75%)** | **9 (75%)** | **5 (42%)** | **7 (58%)** | **11 (92%)** | **12 (100%)** |

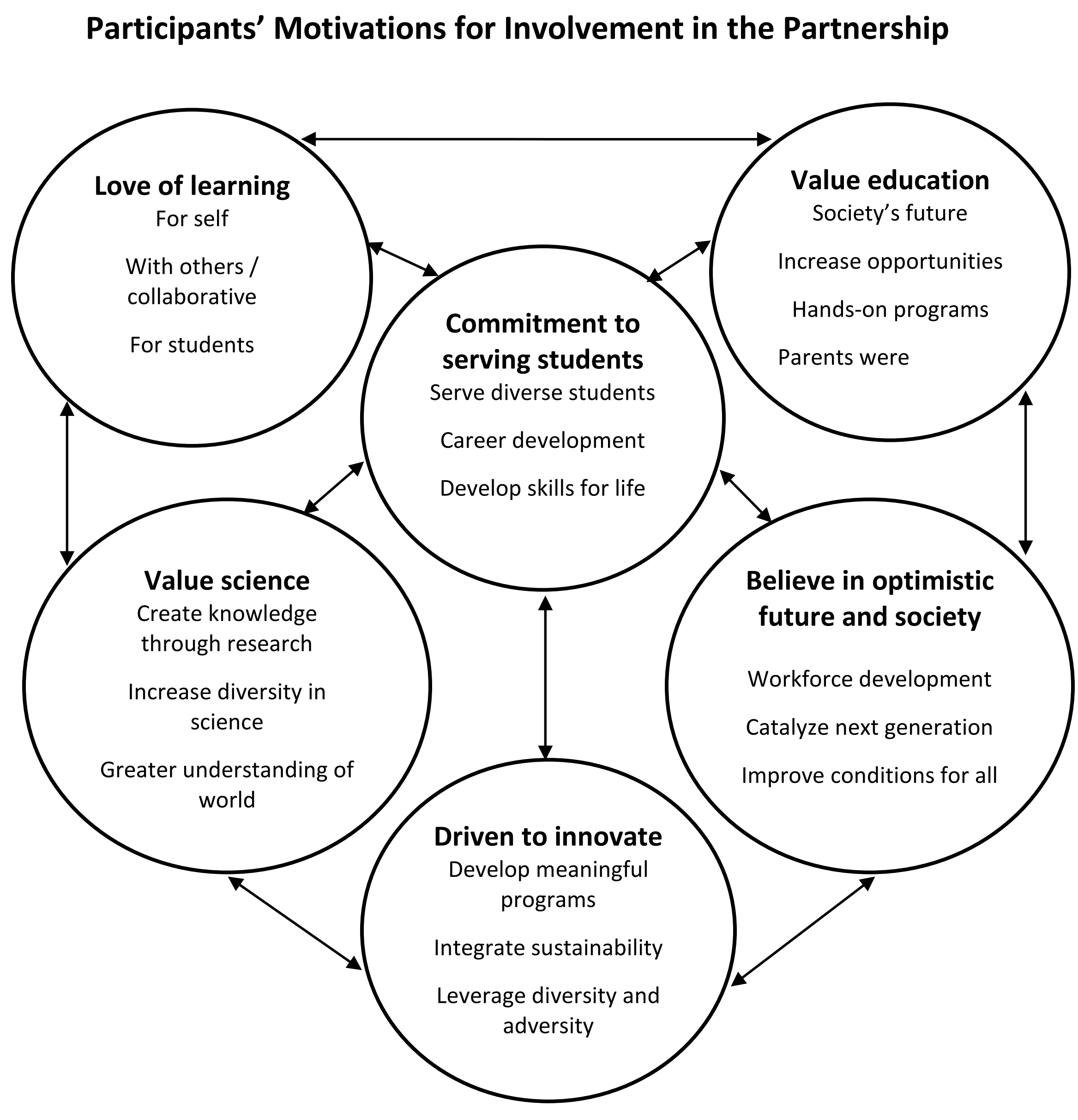


**Figure 4.8 Participants' Motivations for Involvement in the Partnership –** Different motivations are related according to the arrows. For instance, love of learning is closely related to valuing science and valuing education; however valuing education and being driving to innovate are not necessarily closely related.

***Motivated by Love of Learning***

Both scientists and educators *loved learning* in and of itself. Learning gave them a charge, a sense of inspiration, a surge of wanting to learn more. Three-quarters of participants specifically talked about this love of learning – all the teachers, three-quarters of the VSD administrators, half the faculty scientists, and the junior scientist. This does not mean the other one quarter did not experience this love, but rather they simply did not discuss it. Those that spoke about it loved learning by themselves, in the context of collaborating with others (mutual learning), and they were passionate about sharing this love of learning with students.

***Motivated by Valuing of Science***

Related to a love of learning was the *high value participants placed on science*, because as Tim Rollins stated above, science research is a "journey of discovery," essentially of learning things that have never been known before. This creation of new knowledge was recognized as the central undertaking of science, deeply motivating individuals in their personal work and in the partnership. The researchers loved employing their deep curiosity for the world to gain a greater understanding of it, to act with greater knowledge, to share with others the value of this earned body of knowledge. This was true whether others were interested in actually becoming a scientist or not. One of the faculty scientists described this motivation:

> I think it's also to create an awareness among those students who do not go on to the university of activities of the university, and make them aware as citizens of the value that research is bringing to them and to the country. *– Barbara Shepard, faculty scientist at MWU*

School administrators also valued science, and specifically wanted to tap into the deep curiosity of scientists, and have their students "rub shoulders" with these "Ph.D.-types."

> Student-teacher-scientist partnerships are really important for K-12 students. And I mean this from the kindergartner participating in the Monarch Watch project all the way to a high school senior submitting a paper to a journal along with a college researcher. I think it's important because … we're tapping the resources of the folks who decided that this line of work is what they've committed their lives to. And the scientists have a tremendous dedication. They also have insights that we might forget in K-12 … the kind

> of lofty thoughts that we can share with our students about the wonder of nature, and those scientific research questions are extremely specific, to the point that students sometimes feel like they're dealing with minutia when they work with a researcher.
>
> *– Joyce Lancaster, former Science Coordinator at VSD*

All but one VSD administrator volunteered information about the high value they placed on science. And three scientists and two teachers were specifically motivated to increase the diversity of those working as scientists. They wanted to create opportunities for students who would not normally consider a science career to be exposed to those opportunities and inspired by scientists who look and think like them. Two scientists took long diversions in their interviews to discuss how deeply committed they were to increasing the diversity of scientists in their field. In fact, one scientist discussed growing up as a minority and how much that influenced his outlook.

> I don't think we have an avenue to some of those students that are thinking about biomedical research…. No, I don't think we have a crack at that student. But now I think we do. I mean, I think minorities are underrepresented in veterinarian medicine. I understand that – coming to the Midwest – it's a little bit different. So it's nice that we have a crack at students…. You get the students going in the right direction, or they get to play in the labs they want to play in, they get exposed to what they want to be exposed to, have some sort of avenue where this college can also generate publications related to education and recruitment of future veterinarians – maybe it's going to be environmental research or in clinical sciences or in pathobiology or infectious disease…. You can be technically driven rather than intellectually driven – it's still a career. *– Robert Tillman, faculty scientist at MWU*

***Motivated to Innovate***

Over half the participants were *driven to innovate*, and this drive animated their work. If they were not thinking creatively, developing a new program, innovating to meet the needs of a student, they were looking for the next problem to solve. This drive was present in all the teachers. Constant reflection, evaluation, discussion of what they want to do better filled their interviews. They each spoke of seeking out sources to "generate new ideas" to try to meet the needs of their students. Each of these teachers was special – they not only were teachers but also facilitators of a Twenty-First Century Program. Hence, they were recognized by their colleagues and supervisors as competent, creative, responsible and collaborative, and able to lead an innovative program. Each of these facilitators reached out to the community to find experts in their fields, mentors for their students, speakers for their class, relevant labs. They designed programs focusing on hands-on experiences and career exploration, as well as rigorous coursework that developed independent learning skills. Each of the teachers spent much of their interviews talking about particular students and how they had created specific opportunities to encourage and challenge their interests. They valued the partnership because it magnified their ability to innovate on behalf of their students. Through leveraging the diversity of students, they created multiple tools in their pedagogical toolbox (contacts of mentors, reliable resources for cutting-edge information, new lesson plans and labs, field trips that would expose students to careers, college recruitment programs, etc.) to incorporate into their larger coursework, integrating sustainable elements to inspire current and future.

The two lead administrators involved in the partnership, Alice Hughes of VSD and Susan Rasmussen of MWU, were also deeply driven to innovate. Surely throughout each of their careers, they innovated in the same way as these teachers – finding solutions to puzzles that confronted them in their classrooms and labs. However both these leaders had very sophisticated philosophies of innovation, and in their interviews, they repeatedly referred to them as animating their leadership style.

Alice Hughes, for instance, spent time describing the genesis of the Twenty-First Century Programs, successful innovations in themselves that had been incorporated into the district's high schools six years prior to the start of the partnership. She discussed other partnerships she brokered with community industries and businesses with the school district. Even during our interview, she mapped out plans for the future as if she were still the active superintendent. Hers was a politically astute drive – she knew how to build and leverage relationships based on people's deep beliefs and commitments. She encouraged teachers to build a host of mentors in the community for students:

> I have this kid. I have this idea. "Could you possibly – ?" It comes back to that relationship, so that comes back to face-to-face experiences. *– Alice Hughes, former Superintendent at VSD*

She "pushed the envelope" to bring creative and productive people together to innovate on behalf of the students. Her commitment to creative programming to serve the families in her district in poverty was especially strong.

> We have [in the county] … a strong partnership with [the community college], the hospital, [the large private university], and the school district…. And you're sitting on the second largest school district in the state now, the largest in the metropolitan area, and a top quality school district. Now if we can't figure out something that takes the future of educating all kids, including minority and poor kids – because that's the work force of the future ... that's your workforce of the future! *– Alice Hughes, former Superintendent at VSD*

Meeting adversity with ingenuity to serve the students and the best interests of the community were paramount to her leadership style – and she was held in high regard by others for these qualities. Her philosophies of innovation would see her through many forms of adversity.

> I've always said in my role, the best time to plan is when you have no money. Because when you have money, you're busy implementing. And I've had a lot of people over the years, way before these terrible times, say, "Well, why would we work on this when we don't have the money? Where's the money going to come from?" Well, if you develop a good plan, the money will follow. And so planning needs to always take place. And people look at it and say we don't have money for that, we can't do that, we can't do that, we can't do that. Yeah, we have a plan. And maybe the plan has to be shelved for a while. But usually in that planning process as something gets going, then the money either surfaces, or it's realigned with something in existing budgets, or you know, it's compelling and people say that's important enough to put some money behind it. *– Alice Hughes, former Superintendent at VSD*

Simply studying this one leader would be a project in itself. She was identified as one of the main reasons the partnership was so incredibly productive. She was undoubtedly a superb strategic leader who galvanized people behind her ideas. Her vision of the partnership in relation to the bio-technology and animal health industries in the metropolitan area helped drive it:

> My dream when this first happened was, you know, we talk about bringing in scientists from all over the country. Why can't we just grow our own right here? Just grow our own scientists. We don't have to worry about bringing them in from another country, or from the east and west coasts…. We can grow them right here! *– Alice Hughes, former Superintendent at VSD*

Susan Rasmussen also articulated a sophisticated philosophy of innovation, and in her case, she came at it from the point of view of a scholar. She referred to a study published in 2005, *Innovate America* (Council on Competitiveness, 2005), saying:

> Their thesis is that innovation, which they describe as a sort of junction of invention and insight, "will be the single most important factor in determining America's success throughout the twenty-first century." And they looked at the major components or building blocks of innovation as talent, investment and infrastructure. And for those of us who are educators, talent is something that we try to cultivate every day. They define talent as the human dimension of innovation: knowledge creation, … and then training and workforce support. The recommendations that came out of this report supported "a culture of collaboration, a symbiotic relationship" that brought research and commercialization, and life-long skills development together. … We're at a time of very tight economy, very few resources, and very big demands being put on both higher education and K-12 to do more with a lot less. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

She referred to the National Academy of Sciences report, *Rising Above the Gathering Storm* (2007a) and its top recommendation to federal policy makers to enhance science and technology so the nation could be more competitive globally: "Increase America's talent pool by vastly improving K-12 science and mathematics education." She availed herself of the scholarly literature on science education partnerships, and was aware of common pitfalls in collaborations between scientists and educators. Yet she felt strongly that through such collaborations and creative tension, "teachers and scientists working together are able to accomplish far more than either alone."

Susan had a track record at the university of creating, and collaborating to create, novel programs recognized nationally that inspired K-12, undergraduate and graduate students in STEM fields. She was especially driven to try to create programs to serve under-represented students in the STEM fields, expand their horizons about career opportunities. In order to do this, she knew it was important to develop programs with sustainable infrastructure that would reach a wide spectrum of students over time.

> There was this student [from a wealthy school district] who was very interested in swine operations and ground water quality, and wanted to PCR a particular bacterium out of some of the effluent. And there were dedicated parents as well as dedicated teachers willing to drive the student out to a confinement swine operation, and meet an MWU Extension specialist out there, and someone at the university willing to have that come back into their laboratory, start the process there and work with the teacher. And so the trouble is, those are such small instances. You know you're impacting one student tremendously, but you're not reaching a lot. So I think, while those stories are very gratifying, looking at how to create something systemic that's maybe less effort-intensive but where teachers and scientist feel very well supported to do the collaboration, and the collaboration works well with the context and impacts more students – I think that's one of the real challenges. *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Susan channeled resources from the university into these experimental programs, not knowing how well they would work but having a strong drive to take the risk in order to learn. Reflecting on the first project of the partnership, the Biotechnology project, she said:

> We were all aware of [the] hurdles, and we knew that it would be really hard, and we weren't sure it was going to work but we really wanted it to at least work, and we wanted to learn in the process. I mean, I think all of us went in knowing this could be a real disaster, but – let's try to make it fun and let's try to learn lessons along the way…. I wanted there to be sustained interaction that didn't frustrate anyone to the point that they

would walk away – not the students, not the teacher, and not the faculty. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

So while all three teachers / program facilitators in this partnership innovated constantly on behalf of the students in their classrooms, the two institutional leaders, Alice and Susan, also were driven to innovate on an institutional level, to develop meaningful programs that integrated sustainability through its infrastructure, and to leverage diverse and adverse conditions to efficiently and creatively meet large goals.

***Motivated by Optimism in the Future and a Better Society***

Both Alice and Susan also talked extensively about their *beliefs in an optimistic future and creating a better society*. They thought seriously and concretely about workforce development, and knew their communities – whether regional and national, or professional – that would help shape society in the future. They recognized the importance for the future of "catalyzing the next generation of American innovators and empowering workers to succeed in the global economy" placed great weight on educating students today. So they both had these broad visions related to society in the future and channeled those ideas into the importance of their own institutions innovating through education. They shared these motives in the collaboration, and they talked about these ideas often in meetings. When meetings might get bogged down in details or difficulties, both these leaders would interject their larger belief in the future, and the importance of students to create better conditions for society. While they may have been trying to keep themselves positive and motivated to work through the challenges of the moment, they also motivated others by speaking these thoughts out loud. They were infectious and optimistic thoughts, ones that inspired others and created common cause among the group.

***Connections of Motivations to Serving Students***

Interestingly, while others from both the university and the school district also talked about their motivations of a better future society, the teachers did not specifically talk about this. Instead, they talked about their *commitment to serving the students* in front of them for *their* futures. I believe they owed their dedication to teaching at least partly to an indomitable belief in a positive future, however they identified through their students first rather than society at large, and they talked primarily about wanting to prepare their students for their futures. They wanted to tap into and cultivate their students' passions, help them develop curiosity and inspiration for something they wanted to pursue, to connect them to the world around them. They wanted to help students develop skills to interact in positive and responsible ways in the world, to bring creativity and rigorous thinking to problem-solving. They wanted to reach those kids who were not always easy to reach, who had adversity in their lives, who needed extra help. They wanted to connect them with professionals who might inspire them, offer an internship, or write a reference letter. Every teacher said that having their students work in the focus of their program (animal health, biotechnology, geosciences) was not their ultimate goal. Rather, they wanted to help students develop transferrable skills so if they did not want to pursue such a career, they still gained from the program. Primarily, these teachers wanted to be part of the partnership because "it benefitted the students," "it expanded their horizons," "it gave them career connections," it helped "the kids be better prepared for college."

In this light, all the school district staff and two of the five scientists explicitly discussed their value of education as a motivation for their involvement in the partnership. They felt education was important as an investment in society's future, and to increase opportunities available to students. They especially valued hands-on experiential education, even though it takes extra effort.

> They have to get it in an experiential way. And it may be as small as a simulation, but usually simulations aren't good enough…. A challenge with experiential learning [though] is it takes teacher time, student time, and then if you're going to have it related to industry or higher education, it takes time on the higher education side and the industry side of staff, and time is major. *– Alice Hughes, former Superintendent at VSD*

The two scientists who talked about the value of education as a motivating factor revealed that their parents were teachers. They both spoke movingly about the value of education. As I will discuss below, one scientist in particular talked about how more people in higher education might appreciate the work done in pre-college classrooms.

### *How Participants Viewed Their Roles and the Roles of Others*

The scholarly literature on science education partnerships often suggests different values and sense of respect those involved feel for scientists in contrast to K-12 educators, with scientists often revered at the expense of K-12 educators. Specific interview questions in this study queried how participants experienced their roles in relation to others in this partnership. Overall, there was a remarkable sense of mutual respect and appreciation for each other's roles. The educators generally sensed they were very well respected by scientists, understood they had pedagogical expertise most scientists did not have, respected the scientists for their specialist knowledge, and were interested to engage in the mutual learning that took place. The scientists were impressed by the teachers' pedagogical expertise, and while they recognized their own specialized expertise, they showed great respect for educators and generally deferred to them in making pedagogical decisions.

There were, however, some interesting anomalies to the sense of understanding of each other's roles and cultures. None of these individuals reported feeling specifically disrespected within the partnership, but they revealed, either through their words or activities, a sense that the balance of power between scientists and educators was not quite equal. In three of these four cases, they involved one of the teachers. I discuss these below.

#### *Steve Graham and Tim Rollins: Teacher Deferring to Scientist*

One situation was relatively subtle, and it involved the interactions between Steve Graham, teacher in the Senior Biotechnology Project, and Tim Rollins, post-doctoral scientist. As described in how the program developed, Steve had his eye on the high school academic calendar. In September he expressed the need to finish the project in October or November so students could then prepare for the Metro Science Fair in early April. Tim noted that while that would be a good time frame, "bear in mind experimental science often doesn't work so neatly."

While both Steve and Tim reported feeling a great deal of respect toward and from each other, with a strong sense of equality between them, Steve in fact was very deferential to Tim in his planning even to the point of compromising his own pedagogical principles. For example, Steve would tend to move the project along by asking questions like, "So what are our next steps?" Tim, responding as a scientist, would describe the next research steps. Steve would agree and make plans with the students and Tim made for a following session. The project continued through October, November, and past the winter break. Steve did not assert again the students' academic timeline until mid-February when the students actually had experimental results, and he expressed his wish to give students time to prepare reports. Even then, though, he still asked Tim for direction for next steps, deferring to Tim's natural tendency to develop additional experimental tests. As a former teacher, I could see the mounting tension – not a personal tension between them, but the pressure that Steve felt to give students reasonable time to prepare for science fair presentations, end of year presentations, and graduation activities. Tim was simply unaware of these pressures and did not understand that Steve's comments about giving students preparation time was implying that the project should end as soon as possible. Tim simply responded to Steve's questions as a scientist, and suggested new tests for the students to run. I finally spoke up suggesting that rather than developing new experiments, we could consider the project done. Both Steve and Tim were completely happy to do so. In subsequent weeks, Tim assisted students in preparing reports and presentations, activities at that point that were directed primarily by Steve.

This situation revealed how subtle the interactions between respectful teachers and scientists can be in still creating an imbalance in power. Steve's deferential attitude toward Tim, and Tim's unawareness of the pedagogical implications of some of Steve's comments, played into creating the dynamic. Interestingly, age did not seem to be part of the equation: Steve was considerably older than Tim. I believe the deference was based solely on their roles as teacher and scientist. I also learned that one of my main tasks as a scientist-educator coordinator was to gently intervene and guide participants to equalize the relationship and translate some of the implied meanings each participant tries to communicate.

***Michael Dunlap: "The Scientists Must Know More than We Do"***

The second anomaly involved Michael Dunlap, the teacher and facilitator for the new Animal Health Twenty-First Century Program. Several district interviewees for this study discussed the confusion around Michael's role, and a number of factors played into the confusion. Michael did not participate in the early large planning meetings between the university and school district. In fact he was new to the district in fall 2008 when much of the planning occurred. Michael came onto everyone's radar when the first year's coursework for the new Animal Health Program was being ironed out. District educators wanted all the new students in the Animal Health Program to take one class all together, to serve as a bonding experience with each other and the program leader.  Michael taught several sections of the common course identified: Student Naturalists.  Because Steve Graham, teacher and facilitator of the Biotechnology Twenty-First Century Program, was involved in some of the planning meetings, he took on much of the program leadership roles.  However, he was overloaded and district administrators tried to protect him from being the sole leader.  Michael was brought into planning meetings, and he was being considered as a potential facilitator for the new Animal Health Program.  However because of the severe budget cutbacks and the financial stipulation that no new budget lines for the new program could be added, there was no remuneration to offer Michael.  There was also no budget to operate the new program.  So Steve shared his program budget, and they were considered co-facilitators, even though Michael received no stipend in recognition of that.  These details are clear in retrospect, however at the time, a great deal was unspoken and Michael's role was unclear both to him and to others.  His sense of confusion was exacerbated by the fact that he was new to the district, and although not a new teacher, he was still trying to understand the new district and school culture.

He joined the planning meetings in the late spring of 2009, without nearly the context others had.  When the school year ended, it was understood that he would teach the one class the new Animal Health Program students would take together, but that he would not be the facilitator of the program.  By fall 2009, however, he assumed the general co-facilitator role, even though it was not well defined.  Over the course of the 2009-2010 school year, the full curriculum of the program was developed.  His experience as described below reveals the lack of clarity he experienced not only of his role, but also of the role of the district educators in contrast to the university scientists.

> There was a big period of time where I felt like we were floundering because we were looking for somebody to say something profound and make a decision.  And so while we have lots of decision-makers at the table, no one was really making a decision.  And so a lot of that had to do I think with a misunderstanding on some of our parts of what MWU's role was, and that was also in development.  …And then after meeting a couple different times and it felt like the agenda never changed – and then the development just kind of turned into, well – we just need to make decisions. ...I remember going to Beatrice [and saying,] I don't understand, where are we trying to go?  Is MWU telling us

> what to do, or are we saying what to do? And then … it was just expressed that we make decisions for our students. And so once we made decisions for our students, then it was really easy to figure out where MWU fit. *– Michael Dunlap, teacher at VSD*

Although Michael refers to "we," it is unclear if his perception was truly shared among other district educators and a shift in understanding the balance of power was clarified in private meetings, or whether much of the confusion Michael felt was due to him not being included in earlier meetings and not having the background context. Since all three teachers felt some imbalance in relation to scientists, and none of them were included in the earliest planning meetings, it is probable that Michael's reporting that "we" needed to clarify where the decision-making power was did in fact include others in the district. He articulated the most clearly the underlying assumptions:

> [It was] perception: Well, [the scientists] must know more than we do. But no one said that. And I don't think everybody at the table thought that. I think it was more … at that time there was actually no leader. There was no facilitator. It was just a group of people getting together. *– Michael Dunlap, teacher at VSD*

Unique to Michael's situation, his role was undefined, as he alludes to above. There was no official facilitator for the new program at the time, and that was a function of the budget constraints in the district. Without funds, the district administrators' hands were tied to offer a leadership position to him. And without the funds, there was no recognition of such a leader. Yet he stepped in, along with Steve, to assume such responsibilities. Michael contended with several conditions that contributed to his confusion about roles: 1) he was new to the district, and hence still trying to ascertain its culture; 2) he was not in the ground-level partnership meetings, and hence did not have all the context when he did join; 3) he was essentially invited to the meetings as a potential facilitator for the new program, so he felt certain unspoken responsibilities; and 4) with no funds, there was no possibility of formal recognition of the leadership role. It is to his credit that he persevered and became facilitator of such a rich program.

### ***Christine Finley: Felt Others Do Not Understand Teachers***

Like Michael Dunlap, Christine Finley, teacher of the Lab Tech Course, did not participate in the early meetings of the partnership, and in fact she only participated in the operational meetings toward the end of the second year in preparation for designing and teaching the new Lab Tech Course. When asked if she felt her role was understood by partnership participants, her reaction was interesting. She expressed a general sense that MWU scientists did not understand her role as a teacher, but also that was not unique to MWU scientists. Rather she felt that society members at large do not understand and often do not respect teachers and the work they do. And she quickly added, "I mean, my husband still doesn't understand my role as a teacher a lot of times."

So Christine's feeling that her role was not understood seemed a more general one. She also admitted candidly that she was not sure she understood other people's roles in the partnership. It is noteworthy that she did not participate in partnership meetings in which other scientists were present, although they sometimes visited her classroom, and so her impressions were likely general. The world of the university scientists seemed distant for her in the partnership, and I was virtually her only connection with MWU. In fact, she noted, "I feel like you're part of my team, versus a part of their team – does that sound weird?"

> So if we talk about that, then I think you respect me a lot. You communicate that to me. And I think we have a mutual respect in the classroom, and I greatly appreciate your help from the partnership…. You know, when you come in, Teresa's here – yeah! I feel like you are part of this program that exists at North. – *Christine Finley, teacher at VSD*

Despite Christine's sense of mutual respect with me, she did not in fact identify me with the university; and the cultures of university scientists and of K-12 education did not seem very integrated for her.

### ***Susan Rasmussen: It Lowers Your Status***

The final anomaly is one that Susan Rasmussen discussed only by way of inference. Yet she took such a long diversion in our interview, and discussed it with such passion, it is worth relating. She personally was awed by teachers and their work and held them in the highest regard. She also felt deeply respected and appreciated by the educators. Yet she experienced attitudes of others, possibly in the community at large, possibly in the university – she did not say. Yet she felt an "external perception" of being judged about working with K-12 initiatives, and felt that it lowered her status in the eyes of some.

> One of the things that I never let bother me but that really could have bothered me in becoming very identified with the K-12 partnership initiative – I think there was an external perception about what that meant to my value to other things, like economic development, like you couldn't be good at doing economic development and K-12. If you cared about K-12, you weren't a serious business person or a scientist. Not if you cared about, but if you actually got involved in making it happen rather than just saying, "Oh, it looks good." It does [lower your status]. And I think that's a lesson that kind of surprised me, because I inherently value education. I mean, my mother was a first grade teacher, and I know how hard she worked and I know how much she contributed. And in my family education is very much an ideal. So I don't have that status thing, which probably allows me to operate in these environments a little better than if I did have this status thing. But when it came back on me, I was just like, well, these people are just ignorant. I can't help their ignorance. What I do – I'm not going to stop doing it.
>
> *– Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Susan did have a model in Carl Wieman, Nobel Laureate in physics who has devoted much of his career to science education and currently serves as Associate Director for Science at the White House Office of Science and Technology Policy. She recently had the opportunity to hear him speak, and felt vindicated in his dedication to science education, quipping, "And nobody's out there saying, 'Oh he's not a good scientist.'" So as much as she may have felt the judgments from others, she also held steadfast in her resolve to work on behalf of K-12 education as a scientist.

> I think one of the outcomes of the partnership over a ten- or twenty-year period should be the value of these partnerships and the value of the interaction between scientists and K-12 educators, and what each brings, and the value added by having people willing to bridge that gap. That no one – no one should gain anything less than warm respect. The outcome should be that everyone who's willing to take on that added work is seen as a

hero, and seen as an innovator, and seen as someone doing something really important. – Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus

### *Partnership Members' Anxieties and Concerns*

Participants inevitably talked about their worries, anxieties and concerns in relation to the partnership, the largest being staff turnover (see Table 4.13 below).

**Table 4.13 Anxieties and concerns of participants about the partnership**

| | Staff turnover | | Institutions maintain commitments | | Balance partnership with other needs | Does not create sustain-ability |
|---|---|---|---|---|---|---|
| | Loss of institutional advocates | Loss of scientist-educator coordinator | During district budget cuts | University loses commitment | | |
| **VSD Administrators (4)** | 1 | 4 | 1 | 2 | | |
| **VSD Teachers (3)** | | 2 | | | | 1 |
| **MWU Faculty Scientists (4)** | 2 | 1 | | 1 | 1 | |
| **MWU Junior Scientist (1)** | | | | | | 1 |
| **Total (12)** | **3** | **7** | **2** | **3** | **1** | **2** |

One district administrator and two scientists were concerned about the loss of leaders who are advocates for the partnerships within the institutions. Alice Hughes related this back again to the importance of personal relationships to the partnership:

> [What's] very important in a partnership is that you have those relationships, that face-to-face of the people that are working, and again, the sustainability of leadership. Where the worry comes is when the internal champions on each side of the partnership may move on, and is there a transition to bring somebody else in who will see the vision, buy into it, not feel compelled to make major changes unless they're necessary, and carry on? – *Alice Hughes, former Superintendent at VSD*

She and two of the scientists were concerned about the turnover of leaders. Seven people, six of them from the school, raised the concern of what would happen to the partnership if the coordinator role were eliminated or significantly changed. The concerns ranged from having someone in the future lacking an important skill set, to simply not having an active coordinator. For instance, Janet and Alice were worried about a future coordinator not having the background and skills that had been important in the partnership up to this point:

> Having specifically you as a liaison, then we can say, 'Hey, we need this online course.' Well, you have that education and background, and you get it working…. But if we just had a person, someone who doesn't have any background that's just serving in this capacity of "Oh, I'm going to be the in-between," then it wouldn't happen. – *Janet Spencer, Science Facilitator at VSD*

> What MWU has to realize is that they've got to take care of, just be sensitive, like you're supportive of those faculty members at the K-12 [level]. You know, I don't know what your future is, but there's got to be somebody like you that's encouraging or supportive or gets people to see. – *Alice Hughes, former Superintendent at VSD*

Susan voiced concern that the coordinator role simply needs to be maintained in the future:

> The MWU-VSD Partnership could not have happened without your contribution, and if that position gets too much redefined, or too diluted, or goes away, even if everyone else did the same, and they were the same dedicated and committed individuals, the realities of the day jobs and the different cultures I think would take their toll on the nature of the partnership. So my greatest word of advice would be there has to be someone whose job it is to focus on the partnership. – *Susan Rasmussen, former Chief Academic Officer at MWU-Vista campus*

Loss of staff turnover was also related to a concern about institutions not maintaining their commitment to the partnership and letting it languish. Three people were concerned about the university losing its commitment, and one school administrator was concerned about teachers maintaining their commitment to the partnership especially during the stress of budget cuts. One scientist voiced a concern about needing to balance priorities, needing to place the needs of the partnership in context with other campus needs, suggesting a basis for the district concerns about the university maintaining its commitment. One teacher and one scientist worried about the partnership not being able to actually create sustainability for the programs.

## *Students' Experiences of the Partnership*

Students were interviewed about the partnership: A) two students who participated in the Senior Biotechnology Project and who were now sophomores in college; B) four students who were in eleventh grade in the Animal Health Twenty-First Century Program and who also participated in the Field Research Camp; and C) four students who were in ninth grade and participated in the Lab Tech Course. I describe below first their impressions of the different programs. Then I discuss their perspectives of science.

### *Student Impressions of the Programs*

#### *Students from the Senior Biotechnology Project*

The students who participated in the Senior Biotechnology Project were college students when I interviewed them, and their comments were with two years' distance from the project. I interviewed two of the four students involved in the project. They reported that they thought the purposes of the Senior Biotechnology Project was to conduct "research with doctors at MWU," "to give us experience to see if doing research [was what] we wanted to do in the future," and to "build the connections … and get a foothold into that school." These were consistent to the goals that partnership members of both institutions had in formulating the project. In fact, one student interviewed was astute enough to know that MWU was creating a collaboration with the district to build a presence in the Metropolitan region, and that the project was to "put students in the mix, so students can be involved and understand what the animal health" industries in the region are about. These perceptions were in retrospect, however. They said that at first they really did not know what they were getting into, and were surprised that they ended up conducting authentic research. It was more challenging than they thought it would be, and they gained skills and connections at the university.

Students' comments also validated the adults' perception that the material might have been intellectually too challenging.

> The only thing I found challenging was sometimes they would explain it to us, but it totally want over my head. I couldn't deal with what they were talking about sometimes. But towards the end it got easier. So once we started doing it hands-on – like if he just explained it, then I had no idea of what he was talking about. But then once we started

> doing the experiment, it got easier. *– Kaitlyn, former student in the Senior Biotechnology Project*

Sophia also appreciated the experiential aspects of the project, and the sense of self-worth she gained from the project:

> We got a tour of the Vet campus, and that really helped put a visual to what we were doing. And I think that gave us a better understanding of the kind of research we were doing, because it's different when you actually see it than when you see it written on paper or have it explained to you. When you have that actual hands-on visual, you kind of feel like you're more part of it rather than, "Oh, you're just helping us out with this." … We were really a part of it. We were like undergraduate research students. That's how we were treated – we weren't treated like anything less. And that really made me feel like we were worth something to the program and not just there for their benefit, but for ours as well. *– Sophia, former student in the Senior Biotechnology Project*

Both Kaitlyn and Sophia earned scholarships to MWU, both using the connections they made through the project to advance in their college careers. Kaitlyn received a letter of recommendation from Susan Rasmussen, and was accepted into the Early Admittance program of the College of Veterinary Medicine, which will save a place for her in vet school while she earns her undergraduate degree. Sophia discovered she was keenly interested in research, was accepted into the university's Developing Scholars Program (DSP). Partnership staff directed her to this program when she was in the high school project, she was accepted, and was then placed as an undergraduate student researcher in Robert Tillman's lab, continuing the same research with Tim Rollins.

> I continued on with Dr. Tillman and Dr. Rollins with my DSP projects. That background knowledge helped tremendously in getting myself ahead of the game in everything while other students had to catch up and learn those skills. *– Sophia, former student in the Senior Biotechnology Project*

While Kaitlyn wanted to pursue veterinary practice as a clinician, Sophia got truly hooked on research, and she was already planning to apply to graduate school to earn a doctorate and pursue pharmaceutical research. She previously thought she wanted to be a vet clinician, however her career options were expanded through participating in the project, and she was excited about the impact research can make on the world. She could imagine the difference that the research in the pilot project might make in the future:

> I can imagine years from now, I see on TV, "Oh, NSAIDs have been reformulated with no side effects!" And I can say, "Hey, I was a part of that! " – *Sohpia, former student in the Senior Biotechnology Project*

Both students said the project benefitted them by offering real-world experiences with authentic research, cultivating their skills and experience in science, building personal connections with university researchers and staff to help the transition from high school to college, expanding their career options, and building their confidence to pursue science careers.

***Students in the Animal Health Twenty-First Century Program***

I interviewed four students of the first cohort from the Animal Health Twenty-First Century Program, all of whom were finishing their second (junior) year. All four described that they thought the purpose of the program was to inspire people who think they want a career with animals, to expand their ideas of career options, to build connections with others in the field, and to give them a variety of experiences. Again, the student perspectives were consistent with the goals of the program designers.

> I would describe it as a way to learn more about the animal jobs, not just a vet, and also give you lots of experience outside the classroom that you wouldn't normally get if you were not in it…. I think the goals are to widen people's views about the animal health industry and what all it offers. It's not just helping animals and fixing things. It's discovering new diseases and rehabilitating them – very many things. … I experience it as a way to make connections, definitely. Different people in the industries, like food science, … and then people that are vets, and people that do rehabilitation. – *Zoey, student in Animal Health Program*

All four students discussed the value of the field trips they took. They attended a large animal health conference, and by touring the exhibit hall were exposed to many aspects of careers they had never thought of before.

> I saw hydrotherapy, so I thought that would be kind of cool to get into…. It's like a treadmill, and it fills up with water and you can put your dog in it and they start walking on the treadmill in the water. Instead of taking them out on a walk right after surgery or something. You can do it in the water and it wouldn't be as much weight on their legs.
> *– Jessika, student in the Animal Health Program*

Jessika was in fact planning on conducting an internship with professionals who worked with animal hydrotherapy. Another student had a difficult time synthesizing her many interests, and even thought of leaving the program. She learned about career options from the program facilitator and other adult mentors she encountered in the program.

> They open your eyes to what animal fields there are. And someone who, like me, thought, "Oh yeah, I want to be a veterinarian; I want to go to MWU." It's opened my eyes to like, I could be a biologist, or I could be a food science person. So I think it's a good opportunity to explore all the different careers that you can go into…. [I've learned] that I can incorporate photography with the animals, and do two things that I love…. I wanted to drop the program last year, but I'm glad I didn't. I just didn't think it was for me because I didn't want to pursue a veterinarian degree [anymore]. … And I'm glad I didn't, because of the opportunities I've gotten. … I don't have to go to school to be a veterinarian. There are other jobs that incorporate animals. *– Brooke, student in the Animal Health Program*

All the students loved caring for the resident animals such as birds, snakes, turtles, lizards and a ferret in their sophomore year, and missed not doing that in their junior year. They also did not have a common class anymore like they did in their first year, and they missed being together as a group. They valued mentoring from program facilitator Michael Dunlap, and all expressed their wish to have a common class with him each year to stay connected to the program.

Three of the four students valued the endorsement guide, which set out the program requirements in terms of coursework and endorsement hours (e-hours). E-hours were required of students in all twenty-first century programs, and they earned these hours by engaging in relevant activities outside the classroom. Such activities could involve field trips, internships, work experience and research projects. The endorsement guide outlined requirements for earning endorsements at different levels: proficient, highly proficient, and highly proficient with honors. The number and type of e-hours earned, and their grade point averages in math and science courses determined their endorsement levels. Interestingly, this endorsement, which would show on their transcript, gave students extra self-motivation to do well in their program.

> The guide that they give us of what classes you need and how to endorse – it's good, because I'd probably be taking really easy classes if I didn't have a reason to be in all the science and math [courses]. … It's challenged me. *– Jessika, student in the Animal Health Program*

They felt that students in the Twenty-First Century Programs were more self-motivated than other students.

> I think people who are in programs want to apply themselves more. They're more interested in their future. And other kids, they just are on the boat down the river to get through high school. *– Brooke, student in the Animal Health Program*

Whether the more motivated students self-select into the Twenty-First Century Programs, or whether the programs foster motivation is a question, and likely it is a combination of factors. Yet it seems clear that certain elements of the program helped motivate the students. These would include the field trips, the hands-on experiences, learning about careers of interest and learning how to prepare for them, striving for an endorsement rather than just a diploma, earning e-hours, having a program facilitator who mentors them, and developing connections with other adult mentors.

***Students from the Field Research Camp***

All four students interviewed for the Animal Health Program also participated the previous summer in the summer Field Research Camp that was focused on plant-insect ecology. They thought the purpose of the camp was to learn what a biologist does, to investigate a research question, and to see the "biology side of animal health." They realized this was another "career opportunity for exploration that we could possibly get into." They all reported enjoying it because of getting an outdoor experience and because of how much they learned.

> I had fun being outside. Being outside is a great thing, and watching how the pollinators did their thing is very cool, because I've never been one to actually go up to a bee on a flower and say, "Oh, so that's how you do it." But given the opportunity to do that, it was very interesting. *– Zoey, student from the Field Research Camp*

> I thought it was fun. You don't really realize how many bugs that are pollinating those flowers. You're just sitting in a field and it was rainy and hot and rainy – it was cool. And then seeing the big bees and everything. Just coming to the flower and getting the stuff off and flying away. It's just a whole different world, and it kind of puts it in perspective, like, they're like us, but they have wings, and they live off plants and feed off of pollen. *– Brooke, student from the Field Research Camp*

Three of the four specifically felt that a highlight of the camp was putting all the data together at the end of each day and end of the week and see patterns and trends. They discussed this in contrast to the tedium they experienced of hours sitting quietly collecting data. These comments underscore the satisfaction in science of creating meaning and understanding through hands-on investigations.

> At the beginning it was collecting data and watching the flowers. And at the end we got to combine that data, talk about it, and make a graph, and present. I didn't think we were going to have to do anything with the data, but then we did and that was really interesting to see the patterns of sunlight versus shade, and wet versus dry, because we had a big rainy day in the middle of the camp. *– Zoey, student from the Field Research Camp*

Zoey's comment about not thinking they would have to do anything with the data begs the question of whether she's had previous experiences of collecting data but not making sense of them. If so, that leaves out the purpose of scientific investigation – to create understanding.

***Students in the Lab Techniques Course***

I interviewed four freshmen students in the Lab Tech course toward the end of the semester. Although they were initially eager to be interviewed, they all seemed rather timid talking with the recorder on. Their answers were shorter than the older students and less confident. Nonetheless, they revealed interesting perceptions about the course. They all knew the course was an introductory class, to "help us get ready to do labs that we will be doing in the Twenty-First Century Program classes throughout the high school years." They also knew it was to help them orient to their own program cohort. Students from three science-based Twenty-First Century Programs took this course, and students had some confusion about having all three programs mixed, especially for the students who were in programs that had a different facilitator than the teacher, Christine Finley. The teachers noted this and intended in future years to introduce all the facilitators early in the course and try to integrate them more.

They all liked the hands-on investigations that formed the core of the course, "doing stuff on our own instead of having the teacher do everything and you just watch." They enjoyed the lab groups, "working with a group of people to figure stuff out." They realized that there were different types of scientific investigations, some that focused more on pure observation, some more on experimentation.

> I've learned that there are different things in nature that you don't really know, but somehow you can expand and learn about them rather than just seeing it straight forward. There's different ways to go about it. *– Anna, student in Lab Tech Course*

They all felt that one of the important things they learned in the course was "getting a feel for how to do a proper lab write-up." They learned how to communicate what their research questions were, how they investigated them, and what they learned from them. They felt this was an area in which they grew the most, and they did so through practice and feedback from the teacher.

> [I learned] that, besides the individual things that came with each lab, there are different ways to do a lab write up, because someone puts the date at the top, and someone puts the date at the bottom, and you kind of have to adjust. *– Alexis, student in Lab Tech Course*

> The hard part was giving your opinions and actually drawing the conclusion. And I think that gathering your whole thoughts about the entire thing was pretty hard as well. … At the beginning I did really bad because I couldn't think of anything, but now I'm thinking. I think about the lab as I'm doing it and I have my opinions of the lab as well.
> *– Anna, student in Lab Tech Course*

As with the Field Research Camp, these students seemed to appreciate most the thinking involved with making sense of their investigations, even if it was challenging to do so.

> It's challenging to get to know what you're doing exactly, just the steps it takes, the procedures. And some of that is challenging, and some of it's easy. But once I get going and it clicks, it's done. *– Dylan, student in Lab Tech Course*

The focus on career exploration also seemed to expand the possibilities for students to consider for their futures. Dylan seemed pretty sure that he wanted to be an anesthesiologist at first, but then he found the fossil lab fascinating, making him "more interested in looking at fossils and finding different creatures that used to live on the earth millions of years ago. I think that'd be kind of cool too."

> I learned that there are a lot of different things out there that you could be, and how it all relates one way or another to everything. I like that. *– Dylan, student in Lab Tech Course*

> I've learned that being a scientist is a lot of work. *– Luke, student in Lab Tech Course*

Overall, the students' experiences aligned with the intentions of the course and program developers.

### ***Students' Views of Science***

When I asked the students how they would define science, I wondered if I would get more sophisticated answers from the students now in college as compared to high school freshmen. Interestingly, they did not differ much in terms of maturity or age level. Both college students said it is the "study" of things "in the universe" and of "what basically makes the world click." One of the ninth graders similarly said science is the "study and theories of life and the things that make life possible." One eleventh grader also defined science as a study, in this case of "our earth environment." Another high school junior thought science was "a way to answer all our questions of why things happen and how they happen and when they started happening." So many students defined science in terms of a process, a study, or a way of answering questions.

Other high school students tended to focus on the body of knowledge or even the objects of study themselves. For instance, one ninth grader thought science was mainly knowledge and understanding about the world, and one eleventh grader said science explains things. A ninth grader said science was the biotic and abiotic features of the world, and another said simply that science is "pretty much everything – everything is science."

One of the more interesting definitions of science came from one of the Animal Health Program students, although I could never quite understand what she was thinking:

> There's kind of a few different ways of science. There's science that has to do with numbers. And then there's science that has to do with sicknesses, illnesses, people. And then there's the animal side. So there's kind of like three sides to science. – *Jessika, student in Animal Health Program*

All these students had been exposed at this point to the concept of scientific research through partnership programs as well as through their other science classes. For instance, all high school freshmen were taking biology at the same time they took their Lab Tech Course. Their answers to what scientific research is did show a difference in terms of maturity between older and younger students.

The college students who had participated in the Senior Biotechnology Project, an authentic research study, were more articulate about defining scientific research. They referred to investigating a problem, testing solutions to the problem, and gathering evidence.

> Research is kind of like a puzzle. And putting that all together is a lot of fun, just knowing that you can make those connections. *– Sophia, former student in the Senior Biotechnology Project*

The high school students showed more individual differences than differences between grade level, except for one thing: the juniors tended to mention the aspect of writing one's results as a part of scientific research while the freshmen did not. But otherwise, they all discussed research as a process of trying to "obtain scientific knowledge" or "figure things out," which involves observing, watching and looking for details. They thought scientific research involves following the "proper steps" of forming a hypothesis, data collection, forming a conclusion and analysis. One freshman student referred to looking for "trends over the course of time," one described "going out in the field," and one emphasized forming your own opinion but "keeping the facts straight" and basing opinions on evidence. Two juniors gave examples of researchers, which included a marine biologist, pollination biologist, wildlife biologist, chemist, and crime scene investigator.

I asked them to describe what a scientist is. In the same way that some students gave examples of scientists to explain scientific research, many students described scientific research in explaining scientists, essentially saying a scientist is one who engages in research. Differences among students' descriptions of a scientist remained individual rather than based on age level. One of the characteristics mentioned often was someone who learned or discovered new things "that no one else either thought about or could find out about."

> They put things together that normal people wouldn't. They see how things actually work, and get to make new things, and they're the smart end of the stick that everybody looks to for answers. *– Zoey, student in Animal Health Program*

Two other students mentioned intelligence, in that a scientist would be "very knowledgeable," and that the work of being a scientist "gives you a bigger brain." Yet other personal characteristics attributed to scientists were perhaps not as stereotypical. They noted that scientists want "to take a chance," they "want other people to experience what they experience," they "have a desire to just learn."

I would say a scientist is someone who's very passionate about finding out the answers, and wondering, and proposing a question and then trying to figure out how to answer it. And going deep into – not just what they can find in books, but what they can do, hands-on, and going into the field and finding it out. So I think that it's someone that's not lazy, someone that wants to really answer their question that they proposed, maybe even ten years ago. – *Brooke, student in Animal Health Program*

Many of these students had ideas of scientists that seemed more than just the "white male in a lab coat." It is not surprising that eight out of ten students could see themselves as a scientist, especially since they were enrolled in a science Twenty-First Century Program (see Table 4.14, p. 294). What was surprising, however, was that six of those eight said their program helped them change their perspective on being a scientist. The two students who participated in the Senior Biotechnology Project reported the program had a large impact on them, with Kaitlyn reporting that she learned that she likes research and opened up possibilities to her, and Sophia pursuing research actively in labs and in applying to graduate school.

Since I've decided not to go to vet school anymore, I've actually – my title is going to be a scientist! … Starting out in high school I didn't want to be in a lab all day – I didn't want to be stuck inside. But I realized as years of research went around, I realized being a science researcher, you can do anything. I can be outside researching the trees and the flowers. It doesn't matter what I look up. … I kind of want to go through a pharmaceutical company. I want to try to see how that goes to do drug testing and things like that. … I love behavior. I would love to see something … like – I don't know if you've ever heard on the news about dogs who can sense hypoglycemia? That's always been a big interest of mine. *– Sophia, former student in the Senior Biotechnology Project*

Two of the high school juniors in the Animal Health Program could see themselves as scientists. Two originally wanted to be veterinarians, and had decided to pursue research. They attributed the program and coursework to expanding their career horizons. Brooke realized she could be a biologist and travel and do photography. Zoey realized how much she loved chemistry and probably did not have the social disposition to be a vet clinician.

> I kind of imagine myself in a lab experimenting and mixing like grains and oats or something together to make a food that is better for horses since they have such a difficult stomach, and they're so sensitive to grass or different foods. And they have to have a certain diet or else they'll get really sick. So I imagine myself in a lab creating that, with mainly different enzymes or different types of food that we have available on the earth.
>
> *– Zoey, student in the Animal Health Program*

One of the students in the Animal Health Program decided she does not want to be a scientist "in a lab" but rather a clinician, and she attributes the program with helping her develop "more respect for scientists" than she had previously. Another student in the Animal Health Program was not sure she could see herself as a scientist, because she did not know many answers. I drew her attention back to the fact that she described a scientist as someone who had a lot of questions, and she puzzled over her inconsistency. Nonetheless, she did not say she could definitely see herself as a scientist, through the program made her "more open" to the prospect.

Three of the ninth graders could imagine themselves as scientists. One said that although he had always wanted to be a scientist, the program broadened his interests in different subjects he might pursue. Two of them said the program had not changed their perspectives, because they always wanted to be scientists. Anna talked about being a scientist because it's fun:

> It's in your everyday life. You've done science since you were a little kid, no matter what, like with baking soda and vinegar. You always experience that by accident, you never know what happens, but it's really fun and cool to do. *– Anna, student in Lab Tech Course*

One ninth grade student, Alexis, could not imagine herself as a scientist because "I don't do well with the method that you have to follow." When I asked her if the program had changed her perspective on this, she said no, it was her biology class that convinced her she couldn't be a scientist:

> Biology, how to do a major research project. And my imagination really couldn't go out far enough to try to create a hypothesis for something that isn't already proved.
>
> *– Alexis, student in the Lab Tech Course*

This comment underscores how students can be turned off to pursuing science when the expectations in school science are not aligned with how science is actually practiced. This student decided at the age of fourteen that because she could not think of a hypothesis to test for something that has not already been discovered, she is not cut out to be a scientist. This is evidence of the discouragement to students that can be caused by a strict and even misguided adherence to the experimental method as the primary means of inducting students into science research. The fact that other students were positively encouraged to pursue science through their high school programs leaves some room for other influences to affect this student.

Table 4.14 below shows how students responded to the questions: Can you imagine yourself as a scientist? Was your perspective changed by the program? The student responses indicate that in seven of the ten cases, the partnership programs they were involved in changed their perspective on imagining themselves as scientists, and in six of the seven cases it was in the direction of being a scientist. In one case the program changed her perspective in that she learned she did not want to be a scientist, which also aligns with the goals of the programs of exploring the field to see if it fits and individual's interests. In two of the cases, the program did not change their perspective because they wanted to be a scientist since they were young children. Overall, seven of the ten students could imagine themselves as scientists.

**Table 4.14 Student responses to imagining themselves as a scientist**

| Program | Student | Imagine yourself as a scientist? | Perspective changed by program? | Comments |
|---|---|---|---|---|
| Lab Techniques Course (high school freshmen) | Alexis | No | No | Discouraged by biology class |
| | Anna | Yes | No | Wanted to be scientist since a little child |
| | Dylan | Yes | Yes | Broadened horizons |
| | Luke | Yes | No | Wanted to be scientist since a little child |
| Animal Health Program and Field Research Camp (high school juniors) | Brooke | Yes | Yes | Wanted to be a vet, now a researcher |
| | Jessika | No | Yes | Wants to be a clinician, has more respect for scientists |
| | Kayla | ? | Yes | Is unsure, but program has made her more open |
| | Zoey | Yes | Yes | Wanted to be a vet, now a researcher |
| Senior Biotechnology Project (college sophomores) | Kaitlyn | Yes | Yes | Opened up possibilities |
| | Sophia | Yes | Yes | Wanted to be a vet, now a researcher |

# CHAPTER 5 - Discussion

Within the three years that were examined in this case study, the science education partnership between the MWU-Vista campus and the Vista School District created a collaborative culture that resulted in four innovative programs with varied scope addressing students in all high school grades. Three of the four programs studied showed evidence of sustainability. The partnership fostered mutual learning, including scientific professional development for teachers, pedagogical awareness for scientists, and science and career learning for students. High school students interacted with university scientists, gained access to their labs, and contributed to authentic research. Three students were already recruited by MWU where they continued their education, research contributions, and career preparation. Within the three years, over one hundred and sixty high school students in four grades were exploring science in collaboration with MWU. A pathway for the regional biotechnology and animal health workforce was developed, indeed "growing our own scientists."

Development of this partnership conformed to a number of best practices reported in the scholarly literature. It also had unique characteristics, both in relation to its own dynamics and the cultural context in which it was situated, that can inform future educational partnerships. These will be discussed below.

Differences between the university scientific and K-12 educational cultures were deliberately addressed in the partnership through creating supportive infrastructure and through a commitment to equity and mutual learning. Even still, some of the differences surprised participants and provided challenges to student understanding. These challenges can be informative to science education program and curriculum development. These will also be addressed in the following discussion.

Finally, this partnership was situated in a particular cultural context of both science practice and educational reform. As such, it embodied a spirit of innovation and problem-solving during challenging economic times. The overt goals both institutions had of interfacing with industry as well as with each other can provide a window into such approaches, especially in relation to education. This case study of the partnership between MWU and VSD can offer a model of education reform and innovation for the twenty-first century, as well as caveats and cautionary notes. These will also be addressed below.

## The Culture of the MWU-VSD Science Education Partnership: “It Was Built on Relationships”

The three research questions addressed in the previous chapter contributed to the overarching question of this study: *What is the culture of a science education partnership between a university and a K-12 school district?* This case study of the MWU-VSD partnership consisted of unique drivers, inspired leaders, sound processes that fostered balance and enthusiasm for the collaboration, strong relationships between many individuals, and teamwork to interface the cultures of the two institutions for the benefit of students. The partnership experienced a number of challenges that threatened the success of the partnership, and may still in the future.

Figure 5.1 (p. 297) illustrates the overall model this case study revealed of the culture of this science education partnership between a school district and university scientists. The general theme is that “it was built on relationships,” as participants described in multiple ways.

This partnership had unique drivers, especially in relation to its inception, being created as a stipulation for a gift of land. A tax was also raised to help support the efforts, although the tax supported many other priorities too. The proactive and innovative leaders “pushed the envelope” and committed mutual resources to the venture.

These drivers set the stage for processes that created a healthy culture. The processes included collaborative decision-making, strategic planning, accountability, face-to-face interactions, and communication. Such processes strengthened the drivers: the leaders and the community investments. They also cultivated a climate of respect, equity, trust, understanding, dedication, flexibility, synergy and inspiration. As individuals interacted through these processes and supportive climate, common vision was found together, and it continually evolved through the interpersonal dynamics.

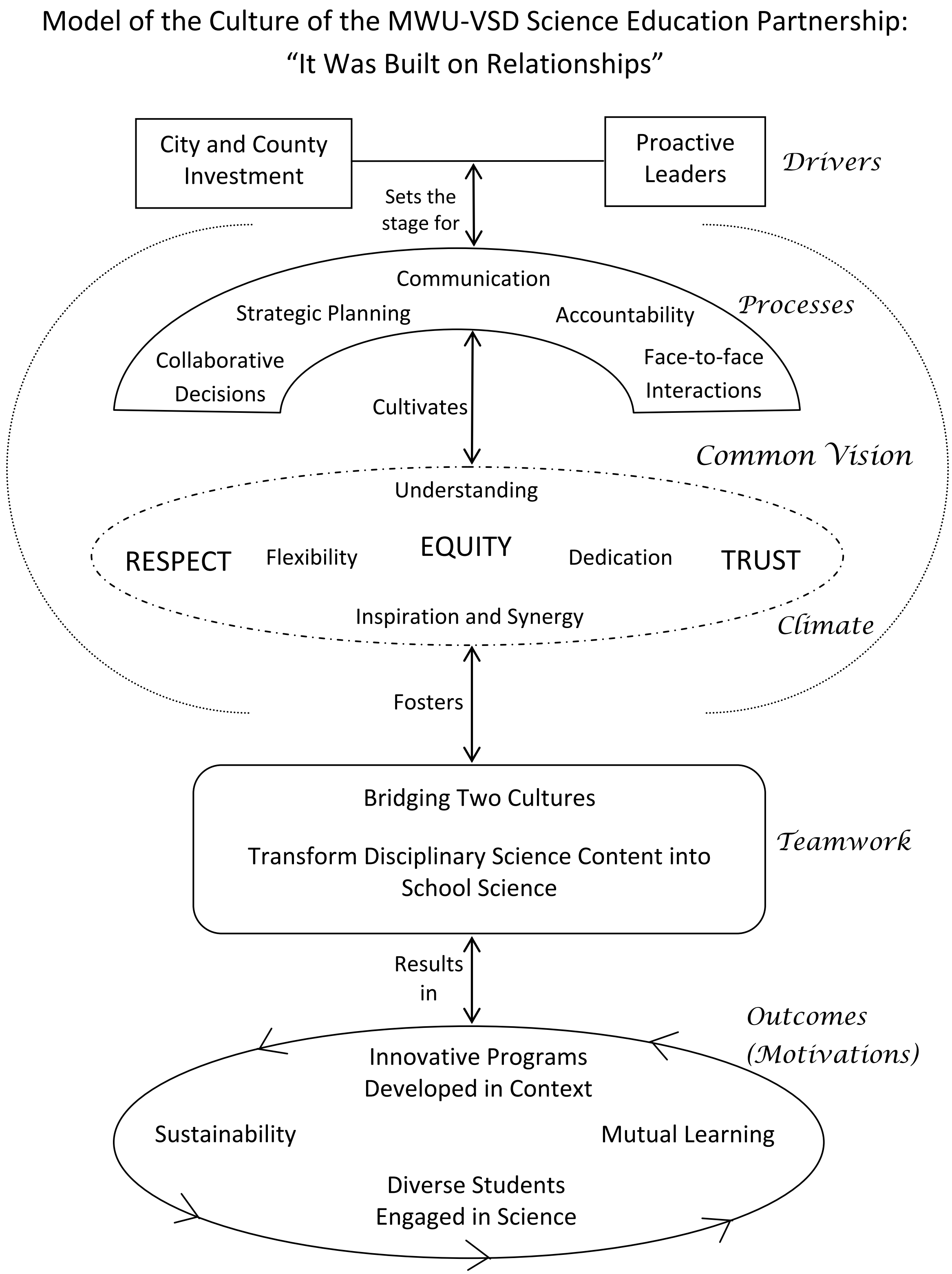


**Figure 5.1 Model of the Culture of the MWU-VSD Science Education Partnership.**

The common vision included goals and approaches that guided the teamwork for program implementation. The teams of scientists and educators worked together to interface disciplinary science content with pre-college education to develop sustainable programs that met the real needs of students. The teamwork resulted in innovative programs that were developed in context, that engaged a diverse student population, and that were relatively sustainable. They also resulted in mutual learning that provided a training ground for scientist-educators. Interestingly, the outcomes are somewhat similar to the motivations that inspired participants to engage in the partnership.

While this model illustrates the dynamic culture, the partnership also required important resources, and provided numerous benefits besides those listed as outcomes. The challenges the partnership faced certainly threatened it, and any one of those challenges could have, and could still, drastically change the culture. The partnership seemed strongest when the greatest number of individuals was involved, and the most strained when resources and involvement from the university waned after the departure of a key leader there. The partnership provided support for the institutions and for students during the economic collapse that began in 2008, and the strength of the relationships buffered the fallout from the cascade of staffing losses. When the partnership was strong, it appeared to have a great deal of resiliency. The infrastructure that had been established provided stability, yet it was clear from the anxieties and concerns expressed that participants could also imagine their fragility. Such infrastructure included the coordinator who was also a scientist-educator, other staff members whose responsibility included the partnership, communication and reporting lines, budget lines, and formal commitments. The strength and resiliency of the partnership seemed to truly be based on the relationships between skilled experts in their fields, and the ability for them to form strong personal working bonds across the different cultures. The commitment to mutual learning and to engaging students in multiple ways in learning about and doing science helped maintain in an intangible yet palpable way the relationships and the culture of this partnership.

I will discuss below the culture of the partnership in this case study and its implications.

## Implications for Establishing and Maintaining Science Education Partnerships in Light of the MWU-VSD Case Study

Precollege science education in the United States has virtually always been influenced by university scientists to one degree or another.  The intense involvement of university scientists in U.S. school science education in the middle of the twentieth century, energized by the launch of the Russian space satellite *Sputnik 1*, provided multiple models of educators and scientists collaborating (Rutherford, 1997).  The numerous efforts since then that have joined educators and scientists together for the benefit of students have also contributed to an even greater diversity of types of collaborations.

By the early years of the twenty-first century, scholars in the field were noting that "partnership models are replacing one-time summer courses and workshops as vehicles for improving science, technology, engineering, and math (STEM) education in the United States" (Tomanek, 2005, p. 28).  Dolan and Tanner (2005) proposed that for collaborations between scientists and educators to be effective and successful in the twenty-first century, three major shifts must occur: "1) the adoption of a mutual learning model of partnership, 2) the integration of partnership into the training of scientists, and 3) the development of sustained infrastructures for partnership" (p. 35).  Scholars have also proposed that successful relationships forged in partnerships should foster equity between partners such that mutual resources are committed, a two-way flow of information occurs, and mutual benefits are gained (Tomanek, 2005).  Such equity and mutuality has at times been difficult to achieve in scientist-educator collaborations when scientists are often perceived to have higher status and power than teachers (Bellamy, 2005).

While good theoretical work exists in the scholarly literature on partnerships, and the challenges to science education partnerships are well described by practitioners, empirical research studies on science education partnerships between university scientists and school district educators are sparse (Cole, 2005; Dolan et al., 2004; Dolan & Tanner, 2005; Shepherd, 2008; Tanner et al., 2003; Usselman, 2004).

*The purpose of this instrumental case study was to describe the dynamic culture of the science education partnership between MWU and VSD in order to identify specific ways to foster collaborations in university / school district partnership in science education.*  This case study demonstrated a number of characteristics of an authentic and effective science education partnership between university scientists and K-12 school district educators for the purpose of "growing our own scientists." In order to use this instrumental case study for analytic generalization, I relate below the emergent themes and perspectives of this study with those in the scholarly literature. In this way, practices that foster partnerships between university scientists and precollege educators can be elucidated.

### *Establishing Mutuality and Equity in the Partnership*

Equity theory in relationships, including organizational relationships, stipulates that a relationship is balanced and partners are satisfied when a sense of fairness exists in mutual investment and mutual benefit between partners (Guerrero, Andersen, & Afifi, 2011; Huseman, Hatfield, & Miles, 1987). Although at no point in this case study were specific dollar amounts of investment or the exact value of benefits compared between institutions, participants reported a sense of equity in investment and gain between partners. Equity theory states that it is the *perception* of fairness, not the actual equality, that leads to relationship satisfaction (Guerrero et al., 2011; Huseman et al., 1987). In relation to science education partnerships, mutuality and equity have been identified as key in both partners claiming ownership and being invested in making the collaboration work (Cole, 2005; Elgin et al., 2005; Tomanek, 2005).

In the MWU-VSD partnership, participants generally reported not only satisfaction in the relationships, but also enthusiasm, dedication and synergy through them. According to the model shown in Figure 5.1 (p. 297), the supportive climate of equity, understanding, respect and trust was cultivated in the MWU-VSD partnership by processes and dynamics set in place at the partnership's beginning, and they were maintained throughout the three years studied. Those processes, dynamics, and supportive climate helped create and renew a common vision that allowed teams to be very productive in creating programs to engage students and that also resulted in mutual learning between partners. While the drivers of this partnership were not typical, it is important to consider them in the light of how they helped ensure equity and mutuality between partners.

***Mutual Investment in Each Other Fosters Equity in Relationship***

The start of the MWU-VSD science education partnership was unique in that it was borne from negotiations that were not directly involved in the substance of the partnership. Rather, it was mandated by a third party, the City of Vista.

In contrast, the scholarly literature reflects that most science education partnerships between universities and school districts are formed because university faculty and district educators want to improve science education in the K-12 schools through programs targeted to students, teachers, curriculum development, or a combination of these (Sussman, 1993). Most of these partnerships originate when teachers ask for resources, or when university faculty, either in science departments or the college of education, initiate grant opportunities and want to share their expertise (Dolan, 2003; Haase, 2008; Hsu & Roth, 2010; Scherer, 2008; Shepherd, 2008). Medical schools often have a mandate of educating local and regional communities for public health improvement and to recruit students into the medical field (Carline & Patterson, 2003; Logan, Davis, & Parker, 2010). Scientists are often motivated to conduct outreach to schools through the broader impacts mandated by public agency grants such as those from the National Science Foundation (Dolan et al., 2004).

The origins of such partnerships often set the stage for the "uni-directional learning" that can take place, with university faculty sharing their knowledge with teachers or curriculum designers. Exceptions, however, exist in which the origin of some partnerships include from the outset mutual learning in which not only do university experts influence school district education, but also that district educators influence university faculty and programs (Scherer, 2008; Tanner et al., 2003). Such simultaneous renewal or simultaneous reform models can be seen when university teacher education programs partner with school districts (Darling-Hammond, 2010; Magolda, 2001; Scharmann, 2007; Shroyer et al., 2007). Many of the NSF-sponsored Graduate Teaching Fellows in K-12 Initiative (GK-12) programs also originated with mutual learning as a goal with graduate students and post-doctoral researchers collaborating with classroom teachers (Gengarelly & Abrams, 2009; Usselman, 2004). Another example of mutual learning is in mentorship and citizen science projects in which scientists can gain information by having students engaged in research projects (Dolan, 2003; Doubler, 1997).

The origin of the MWU-VSD science education partnership, however, was unique in that the partnership originated without a particular focus at all, but rather because of a mandate by the

City of Vista: the city wanted the university's involvement with the school district to improve the community in exchange for a gift of land. The nature and form of the partnership was not stipulated, but rather developed jointly after the agreement had been made. In this sense, the partnership originated in ways more typical of how business partnerships develop. According to Rosabeth Moss Kanter (1994), typical business partnerships develop much like many marriages. First there is a "courtship" in which two companies meet, are attracted and discover their compatibility, almost always relying on the rapport between chief executives. In the case of the MWU-VSD partnership, such executive leaders were the former MWU president, the City of Vista mayor, and other local government leaders involved in the land grant agreement.

Kanter (1994) also found in her research of business partnerships that an important indicator of success is that the partnering companies mutually invest in each other, which in the business world might entail purchasing stock in each other's company or exchanging personnel. This shows a commitment of good faith, and that each company's success is tied to the other's success, providing a sense of equity: they both will benefit in accordance with their investment. Businesses obviously differ from educational and government institutions, and as such investing in the other's commodities such as stock is not applicable. As public servants, however, both the university and the city in this study were dedicated to serving their communities, and agreeing to mutual service would be an appropriate investment in each other. It is easy to imagine Vista city leaders thinking, "If we invest in the future of MWU and its students, we want MWU to invest in our future and our students." The way the city leaders saw fit to mandate the mutual investment to serve its community was to stipulate a partnership with its school district.

The original deal was made by the executive leaders of the city and the university. Once leaders from the district and the new satellite campus met for the first time, they were both invested in the venture themselves: the new university campus leaders through the memorandum of understanding attached to the land grant; and the district in order to maximize opportunities for its students. Additionally, both could see the good public relations that would come from the partnership, the university even more than the school district since it had to establish credibility as it gained a foothold in the coveted metropolitan area and tried to raise additional revenue from the local community. The opportunity for positive public relations provided a sense of accountability, especially on the part of the university as the new campus established credibility with the community. While most educational institutions that partner do not invest in one another in the same way as businesses, the case of the MWU-VSD partnership in fact did involve a tangible holding in the form of real estate given to the university with the documented expectation of its investment in the school district. This created an extraordinary opportunity for both institutions to be on equal footing since they could create their focus and goals together.

In this case study, a sense of equity was established early through the stipulation connected to the land grant: each party was receiving something of value, and each party was committed to investing something of value. This mutual investment was publically announced and reiterated numerous times to reinforce not just the mutual commitment, but actually the mutual investment in each other. It was a bond that both partners seemed proud of, and it had a renewing effect through the public accountability it afforded.

Although this pathway of initiating science education partnerships is far from typical, establishing mutual investment can be done in numerous ways and is worth considering for other partnerships since this study demonstrated its value in establishing equity. Mutual investment in each other is not the same as common and mutual investment of resources to the partnership, which will be discussed below. The type of mutual investment in each other as described here has the quality of each partner being individually invested in the success of the other, and that each partner's individual value will increase if the other partner's value increases, and vice versa.

The implications for other partnerships is to consider how each partner might invest in the other, recognizing that such mutual investment can help create positive bonds of interest in the other and renewed common vision. The examples of simultaneous renewal models of university teacher education programs partnering with school districts can be seen to have mutual investment in each other, such that school educators invest in improving teacher education programs, and teacher education programs invest in improving school programs (Darling-Hammond, 2010; Magolda, 2001; Scharmann, 2007; Shroyer et al., 2007). If articulated clearly and tended carefully, mutual learning can serve as a mutual investment.

### *External Facilitators Can Help Establish Equitable Relationships*

The district superintendent in this case study invested in a third party with expertise in brokering partnerships and strategic planning to guide the partnership meetings in the first year. These external facilitators guided the process of getting to know each other, of creating a common vision, and setting common goals and plans. The ways in which they helped are described below.

#### *Having a Deliberate Conversation: "Is Collaboration a Good Idea?"*

The Vision Lead facilitators guided the strategic planning meetings between members from both the university and the school district during its first year. One of the first things they did was to help the two organizations move beyond the mandated partnership, "the shotgun wedding," and find common meaning in working together. Kanter's research on partnerships between organizations indicates this stage of the relationship is akin to "getting engaged and meeting the family:"

> The rapport between chief executives and a handful of company leaders must be supplemented by the approval, formal or informal, of other people in the companies and of other stakeholders (Kanter, 1994, p. 102).

In these early meetings, participants who would actually be responsible for the partnership moved from having the partnership externally mandated to taking ownership themselves. The Vision Lead facilitators carefully structured the meetings so that members from each institution listened to the others regarding what each thought they could offer based on their own institutional strengths. It was a joint vision-in-the-making that extended over several months. This is in marked contrast to members from one institution approaching the other to collaborate on an already-defined project. Rather, the partners in this case were already established through external drivers, and later the means of collaborating were decided among all participants.

Magolda (2001) asserts that collaboration can sound so intuitively right in educational settings that it can deter participants from "posing a seldom asked, but important, question: Is collaboration a good idea?... Posing the question engages stakeholders in a moral dialogue that encourages inquiry, rewards, intellectual curiosity, allows for shared meanings to emerge, and reveals core assumptions about what is good" (p. 356). In the case of the MWU-VSD partnership, the Vision Lead team directed the group to deliberately address the question of whether collaboration was a good idea. Although it had been mandated by entities outside that room, it would not work if those individuals working for it did not believe in it, and think seriously about the value of it. Having been guided to explore possibilities, partnership members agreed that yes, there was great value in collaborating with each other, and they together articulated their goals. In the words of a VSD administrator, such a discussion moved the group past “the shotgun wedding” to truly seeing the value of working together. Such deliberate conversations placed both institutions on equal footing from the start to set common goals and to freely commit to “nurturing and learning together.”

Many science education partnerships originate through mandates to show “broader impacts” in public science grants, through teachers requesting help of scientists, and through university education researchers wanting to secure grants. Although partnering can seem to be a naturally good idea, taking a step back to have a deliberate conversation about whether partnering is actually a good idea sets the collaboration on firm and articulated footing. It gives partners a clear-eyed opportunity to express hopes and wishes as well as constraints and concerns. It helps prevent one partner feeling pressured into collaborating. It helps partners appreciate and commit to the value in working together. Usselman (2004) suggests such a conversation can include considering the degree of pre-existing relationships and experiences between partners. In evidence in the case of the MWU-VSD partnership demonstrates that this conversation helped members set their own agenda, create their own goals, and develop their own ways of achieving them without these being mandated from an external source.

#### ***Shared Decision-Making***

Another value of having the external facilitators guide the foundational stage of the partnership was to ensure that all stakeholders were involved in the strategic planning and design process, a key aspect of forming common vision that embeds equity and respect (Cole, 2005; Kanter, 1994; Magolda, 2001; Scherer, 2008). Institutional strengths were identified, such as the school district’s Twenty-First Century Programs and the university’s animal health programs, and points of collaboration identified. Specific common goals, objectives, timelines, and plans were articulated and agreed upon. Communication channels and reporting structures were established. Guided by the external facilitators, decisions were formed collaboratively and by consensus, another hallmark of successful partnerships (Logan et al., 2010; Scherer, 2008).

The Vision Lead team ensured that the planning meetings were not dominated by one side or the other. They documented and distributed minutes, and established a rhythm and set of expectations in the meetings. Simply by maintaining agendas for committee reports, they facilitated accountability and mutual input in the sessions. As reported in the previous chapter and shown in Figure 5.1 (p. 297), the establishment of collaborative decision-making processes played a large part in the success of this partnership.

#### *Mutual Resources Committed*

The Vision Lead team also carefully guided members to both articulate and commit resources to the partnership. The school district committed the resources for the external facilitators to help guide the strategic planning. The university dedicated a half-time salary for the scientist-educator coordinator. Since the new satellite campus had no office space, the school district dedicated an office and technology for the coordinator to use. In these ways, both institutions were invested in the human capital needed to make the partnership work. As projects unfolded, the facilitators continued to guide participants to articulate and document the additional resources committed: people, materials, technology, and equipment. The fact that both institutions committed resources to the partnership, equity and mutuality was further established.

#### *Establish Relationships and Structures*

Kanter (1994) reports that the relationships and structures important in effective partnerships often develop over time through real experience of working together, and the best agreements between partner organizations often involve undertaking a small "specific joint activity, a first-step venture or project" since it "makes the relationship real in practice, helps the partners learn to work together, and provides a basis for measuring performance" (p. 103). Carline and Patterson (2003) also found that starting with small projects was important to the success of partnerships.

The Vision Lead team helped participants in the MWU-VSD partnership to identify just these kinds of small projects to build experience and success together. The career fair, summer camps, and community conversation projects all served as small ventures that helped cement the relationships and establish communication patterns. In addition, the Senior Biotechnology Project also provided a tangible opportunity in the first year to establish the partnership while working closely with students and scientists. These activities were informative for future work together in the partnership as a whole, and specifically in curriculum program development.

Under the facilitation of the Vision Lead team, ongoing assessment of progress was made and members felt accountable other simply because they reported in these meetings to each other. Such small initial ventures proved very valuable for "testing the waters" of the partnership, gaining confidence in how partners worked together, and establishing a record of success together. Taking such bite-sized steps together is highly recommended for new partners establishing a collaborative relationship.

***Caveat Regarding Third Party Involvement***

The MWU-VSD science education partnership studied here benefitted from the engagement of third parties, both in its genesis and in its early days of establishment. It is important to note that neither the City of Vista nor the Vision Lead facilitators imposed their own will on the nature of the partnership or on the actual decisions made by the collaborating institutions. While they were not exactly disinterested parties, both the city and the facilitation team brokered the collaboration according to their own professional best practices. They did not impose their own wishes on the partner organizations as to the details of their collaboration. In fact, the third parties helped ensure a great deal of freedom and respect for those engaged in actually envisioning and implementing the partnership to do so using their own best professional judgment.

Third party engagement under those conditions of neutrality was incredibly effective in fostering success in this case study, and can be recommended for other partnerships. Such engagement can prevent subtle and unconscious forms of power inequities to arise, which in the case of scientist-educator partnerships usually means that scientists' expertise is given more weight than educators' expertise. Even in this case study in which members were well aware of some of the natural power inequities between university scientists and K-12 educators, and who maintained the very best intentions of equity and respect, such inequities in power and influence were perceived at times. The example of the teacher deferring to the scientist in the classroom illustrates how easy it can be for very subtle nuances to develop. In the MWU-VSD partnership, the external facilitators helped ensure that in the heady excitement of the early days of collaboration, procedures and patterns of communication were established that protected the balance of power of both partners.

If neutrality does not exist, however, a third party can hamper such a free exchange, and can even be detrimental. Examples of such problematic involvement by third parties can be found in the movement for corporate involvement in school reform (Gelberg, 2007; Kumashiro, 2012; Sawicky, 1997). One of the strongest critiques leveled at involving the business community in public education is that businesses are in fact usually not neutral, and they project a business model of organization onto educational organizations, ignoring the professionalism of teachers, failing to recognize the complex contexts of learning, and rejecting the scientific basis of many educational practices. The same critiques can often be made about government involvement in education (Banilower, Smith, Weiss, & Pasley, 2006; Southerland et al., 2007). The important point here is that *neutral* third party involvement can be very valuable in brokering science education partnerships.

### *Infrastructure and Processes that Help Integrate Resources and Efforts*

As successful partnerships progress, structures and processes put in place tend to be those that allow practical integration of resources for active collaboration (Scherer, 2008). Kanter asserts that successful partnerships involve authentic collaboration, "creating new value together," rather than mere exchange of "getting something back for what you put in" (1994, p. 97). While the Vision Lead facilitators helped establish a climate of authentic collaboration, after the first year of the MWU-VSD partnership they were no longer involved. The maintenance of the processes and dynamics shown in the model in Figure 5.1 (p.297) continued to create a supportive climate for partnership members to work in and helped foster an evolving common vision together. The structures and processes that helped integrate the organizational efforts will be discussed in this section.

Even though establishing some structures are important in the functionality of partnerships, Kanter (1994) warns against having external organizational structures dictate too much of the partnership dynamics. Rather, active collaborations are based on a blend of strong relationships between people as well as developing mechanisms natural to both organizations "for bridging organizational and interpersonal differences and achieving real value from the partnership" (Kanter, 1994, p. 105). Indeed, the findings from this case study support this premise by establishing that the MWU-VSD partnership was based primarily on relationships (see Figure 5.1, p. 297).

Kanter (1994) identifies five levels of integration in the most productive organizational partnerships: 1) *strategic integration*, which involves continuing contact among top leaders in each institution; 2) *tactical integration*, which involves middle managers and professionals in developing specific projects or joint activities and instill processes to effectively achieve this; 3) *operational integration*, which involves people carrying out the day-to-day work to accomplish their tasks; 4) *interpersonal integration*, which involves developing strong interpersonal relationships among many people between organizations; and 5) *cultural integration*, which involves participants to be both teachers and learners and requires "communication skills and cultural awareness to bridge their differences" (p. 106). Using this model, I will discuss the levels and means of integration between partner organizations in this case study.

This partnership relied on a relatively small number of people from each institution, and many of them attended the strategic, tactical, *and* operational meetings. Because of this overlap, and because of the progression over time of their frequency, I will treat the first three levels of integration together.

***Maintain Strategic, Tactical, and Operational Integration Through Appropriate Meetings***

The MWU-VSD partnership progressed in time from having a greater number of strategic planning meetings that involved leaders and staff from both institutions at the beginning, to having more tactical meetings and side-by-side operational teamwork in its third year. During the first year, basic infrastructure was established, consisting of allocating staff, dedicating a coordinator position, creating budget lines within both institutions, and establishment of communication and reporting patterns. Collaborative decision-making procedures were well established in all levels of meetings. Even as tactical and operational meetings increased, the large group still gathered once a quarter for strategic integration.

A common threat to partnerships can be that staff in positions other than those who initiated the partnership, yet are instrumental to its fulfillment, are not as dedicated as the initiators (Granger, 2004; Kanter, 1994). In this case study, the individuals on the ground implementing it were enthusiastic and dedicated, while the challenge was keeping top institutional leaders informed and committed. The school district maintained internal horizontal and vertical alignment during all three years by communicating with teachers, principals, administrators, superintendent, the school board of directors, and parents. Such communication has been shown to be important in university-school partnerships (Carline & Patterson, 2003; Granger, 2004). As two district administrators noted, it was important to keep the district board of education informed and enthusiastic about it, since they were the ones who ultimately made funding decisions.

As long as Susan Rasmussen was at MWU, vertical and horizontal alignment also occurred internally in the university, both with staff and leaders at the MWU-Vista campus and with faculty and the provost on the main campus. She had meetings with other university faculty, district leaders and teachers, and the coordinator. After her departure, however, such communication and commitment within the university waned significantly. Not only did the coordinator of the partnership lose connections within the university, university faculty reported the same loss of communication at the university. During the interviews, district administrators worried about the lack of integration with university leaders at that point, and feared the institutional commitment was waning. Although the lack of strategic integration did not result in a collapse of the partnership during the time frame of the study, the fear that it could was certainly expressed by participants. The fears expressed, however, a growing lack of confidence in the strategic integration of the university. Such fears threatened to upset the collaborative decision-making model.

Over time, it is appropriate in a university-school science education partnership for the majority of meetings to occur among individuals tending to the tactical and operational aspects of the collaboration, the "boots on the ground" people. Yet, Carline and Patterson (2003) note, "While weekly informal communication might be needed between staff conducting programs, formal meetings of partnership councils might take place only every six months to review general policy or renew institutional commitment" (p. 480). The MWU-VSD partnership provides evidence that weaknesses or perceived weaknesses in the partnership can occur without annual or semi-annual meetings among key institutional leaders to evaluate and revitalize the collaboration.

### *Encourage Interpersonal Integration Through Rich Networks of Relationships*

The participants involved in the MWU-VSD partnership experienced the tension between two seemingly conflicting principles: 1) trying to develop infrastructure to support the partnership so it was not based on personalities, and 2) recognizing that the success of the partnership was inextricably linked to personal relationships. Kanter in fact reports that partnerships "cannot be 'controlled' by formal systems but require a dense web of interpersonal connections and internal infrastructures that enhance learning" (1994, p. 97). Carline and Patterson (2003) similarly found that relationships and the qualities of the people involved are the two most positive influences of successful partnerships. Indeed, in the MWU-VSD case study, people were overwhelmingly recognized as the most important resource for the collaboration. And for the first two of the three years studied in the case, a high degree of *interpersonal integration* was achieved. Interpersonal integration between institutions means there is a strong and complex, even "messy" network of personal relationships between individuals across institutions.

> Broad synergies born on paper do not develop in practice until many people in both organizations know one another personally and become willing to make the effort to exchange technology, refer clients, or participate on joint teams. (Kanter, 1994, p. 106)

In order for inter-organizational partnerships to be successful, the quality of these relationships is important. They need to be respectful, with much listening and reflection; they need to be inspiring and synergetic in which staff members are productive together; and decisions need to be made collaboratively, often through consensus (Carline & Patterson, 2003; Cole, 2005; Magolda, 2001; Scherer, 2008). These characteristics were present in the MWU-VSD case, with participants attributing the partnership's success to these types of relationships. Similarly, they recognized that the clarity and degree of communication was paramount. As with other science education partnerships, the transparency and free flow of information not only led to a climate conducive to collaborating but also to participant satisfaction with a sense of equity, trust and understanding (Carline & Patterson, 2003; Drayton & Falk, 2006; Logan et al., 2010). The active and dynamic quality of relationships contributed to a sense of the MWU-VSD partnership as a living, breathing and evolving entity, much as Kanter describes partnerships as "living systems that evolve progressively in their possibilities. Beyond the immediate reasons they have for entering into a relationship, the connection offers the parties an option on the future, opening new doors and unforeseen opportunities" (Kanter, 1994, p. 97). Often, having "the right person at the right time … was an important factor in beginning and sustaining partnership activities" (Carline & Patterson, 2003, p. 479), and this proved to be important in program development within the MWU-VSD case.

Flexibility of participants also means that members can keep a pulse on issues that needed to be dealt with, and when challenges arise, they can be amicably resolved. Carline and Patterson (2003) found successful partnerships to not only embody "clarity of goals, but flexibility of design to respond to opportunities and challenges" (p. 479). Flexibility was one of the major characteristics of the MWU-VSD partnership that participants identified as valuable. Kanter reports: "Flexibility and openness bring particular advantages at business frontiers – in rapidly changing or new markets or in new technology fields" (1994, p. 108). Indeed, she points to the fact that in successful partnerships, smaller side projects often grow to be significant ones. The MWU-VSD partnership had an original large focused goal of creating an Animal Health Twenty-First Century Program. After its launch, the side projects of the Field Research Camp, the Lab Techniques Course, and the developing online course became central foci of the partnership activities. While they augmented the Animal Health Program, they also created stand-alone modules that could be disseminated in the university's work with other districts.

***Invest in Cultural Integration by Committing to Mutual Learning***

Because participants in the MWU-VSD partnership were committed from the beginning to mutual learning through their differences, the partnership achieved a high degree of *cultural integration*. Susan described the partnership as "transformative" for her and other scientists in the degree that they learned from the pedagogical culture of the district. The district educators learned a great deal about the university culture and how they could integrate their students with it, and the teachers learned and incorporated practices and principles of professional science into school science programs. As coordinator and scientist-educator, I was so integrated into the school culture that one teacher did not even consider me part of the university. Kanter (1994) notes that in business partnerships, "Companies that are good at partnering take the time to learn about the differences early and take them into account as events unfold" (p. 105), and these steps were taken and maintained in the MWU-VSD partnership. Again, however, when Susan's departure resulted in fewer individuals involved, the cultural integration between institutions waned in the last year studied.

One quality of successful partnerships, and an indicator of cultural integration, is the degree that each institution has influenced and changed the other (Kanter, 1994; Scherer, 2008; Tanner et al., 2003). For instance, in a simultaneous renewal model of a professional development school partnership, not only are school district curricula and teacher professional development influenced by university input, but also the university curriculum, coursework and planning are influenced by teacher input (Darling-Hammond, 2010; Scharmann, 2007; Shroyer et al., 2007). In the MWU-VSD partnership, the district curriculum was changed due to the university's engagement in that a new Twenty-First Century Program was designed and implemented, and a number of complementary offerings were instituted that aligned with scientific practice. The MWU scientists reported to have been personally transformed through the partnership as they learned about pedagogy and program development in precollege settings. The new MWU-Vista campus was changed in that the partnership helped establish credibility to build larger collaborations throughout the region. Many scholars involved in science education partnerships note that an important change in universities that would encourage greater involvement with precollege institutions would be adjusting the reward criteria for tenure and promotion among scientist faculty (Dolan & Tanner, 2005; Granger, 2004; Tanner et al., 2003). Although the job description of the Chief Academic Officer and then the Associate Dean included oversight of the partnership, such changes had not yet occurred for other faculty at MWU. As the new MWU-Vista campus develops, however, that may change since one of their missions is to be engaged in K-12 education as well as graduate education.

### *Dedicate a Scientist-Educator Coordinator as Formal Integrator*

Integration between institutions takes a dedicated effort and usually a dedicated coordinator whose prime responsibility is the partnership itself (Bellamy, 2005; Granger, 2004; Kanter, 1994). In the case of the MWU-VSD science education partnership, dedicating not only a coordinator position but also someone who was a scientist-educator with experience both in scientific research and as a secondary was critical for the success of the partnership.

Kanter (1994) considers a partnership coordinator as playing a critical *formal integrator* role whose job involves diplomacy, negotiation and communication, and who helps achieve all levels of integration. In a study of partnerships between medical schools, public schools and community-based organizations, researchers learned it was important for coordinators to “identify, understand, and maneuver within these (multiple) organizational structures” (Carline & Patterson, 2003, p. 473). In the case of science education partnerships, scholars advocate the importance of scientist-educators who have experience in both scientific research and pre-college teaching in order to expertly coordinate between the organizations and cultures (Dolan & Tanner, 2005; Tanner et al., 2003), what Sussman calls “a new breed of hybrid professionals” (Sussman, 1993, p. 14).

The MWU-VSD case study provides evidence of the multiple roles played by the scientist-educator coordinator, and how these roles contributed to institutional integration between the partners. The study identifies three roles of the scientist-educator coordinator: 1) coordinator; 2) mediator; and 3) scientist-educator.

The role of “coordinator” helped to achieve the *strategic, operational and tactical integration* between organizations by playing largely an administrative role. This person was responsible for the day-to-day management of the partnership by helping keep all parties engaged, on track, and on task, by helping to channel resources to the partnership, and by helping to solve problems as they arose. The primary means of achieving these levels of integration was communication, communication and more communication. “More communication than anyone anticipated is necessary” (Kanter, 1994, p. 105). This required formal and informal communication, written and oral communication, and a great deal of administrative skills.

The role identified as “mediator” helped facilitate *interpersonal integration*. This meant assessing and understanding partner needs and connecting people to meet those needs. The scientist-educator coordinator translated cultural differences to help fostering understanding so that common vision could be maintained. This role also required a great deal of communication and listening.

Finally, the role identified as “scientist-educator” helped catalyze *cultural integration* in the partnership so that the mutual learning and program and curriculum development could occur. Having a scientist-educator in a coordinator position meant often having “the right person at the right time” who could actually teach and conduct research as needed, and who understood the trajectory of science education both in the high schools and at the university. The scientist-educator moved freely in the schools as well as the university, and served as a scientist role model and mentor to students, a source of informal professional development for teachers.

Finally, the scientist-educator coordinator helped cultivate additional scientist-educators through helping scientists and educators understand each other's work through mutual learning.

Tanner and colleagues (2003) suggest that scientist-educators can help scientists and educators find common ground by: promoting mutual teaching and learning; possessing expertise on collaboration; understanding the K-20+ science education continuum; being communication specialists; cultivating evidence-based analysis; serving as boundary workers; and being recognized as a professional (see Figure 2.2 in this document, p.83). The results of the MWU-VSD partnership case study demonstrate that these roles were indeed enacted by the scientist-educator coordinator. The activity Tanner and colleagues recognize as cultivating evidence-based analysis was accomplished in the MWU-VSD case by the scientist-educator coordinator conducting this dissertation research project on the partnership. The members of the partnership recognized the professional role of the scientist-educator coordinator not only in their acknowledgement of these roles in the interviews, but also through establishing the position itself with sustainable funds.

Both institutions were initially invested in this position, with the university underwriting the salary. This is in accord with Granger (2004) who urges such a coordinator position in science education partnerships be dedicated through permanent operational funding rather than "soft" grant money: "'Hard money' positions take the load off scientists who want to be involved in science outreach but do not have the time to do all of the work that designing and administering a program requires. … Permanent positions not provided by grant funding also improve the chances of recruiting excellent employees who want job security" (p. 49). Pitman (2003) underscores the imperative that the coordinator has unhindered movement in both institutions, which was true also in the MWU-VSD partnership.

This study provides strong evidence that scientist-educator coordinators play a vital role in the success of science education partnerships involving university scientists and K-12 schools. Further, this study details the different roles of coordinator, mediator, and scientist-educator enacted by such a person. A scientist-educator coordinator serves a formal integrator between organizations in a science education partnership, and the position should be funded with permanent institutional funding.

### *Evaluate the Partnership*

Evaluation of the partnership did not occur in formal ways in this case study due to budget cutbacks, and members recognized the loss. Yet they made a concerted effort to informally evaluate the partnership, the programs created within it, and the processes involved. They naturally tended to assess their own work and want to improve. Formal evaluation would have strengthened and likely legitimized their insights and reinforced the value of their joint efforts. It also can point to new ventures and goals the partnership can commit itself to.

## *Additional Considerations for Fostering Collaboration*

### *Resilience During the Great Recession*

The partnership, though conceived of earlier, began in earnest just as the economic downturn started in 2008. Along with the rest of the nation, individuals involved in the partnership slowly began to realize the growing impact of the recession on the economy at large, the diminished tax base, and its impact on both institutions that depended on tax dollars. Not only were there some hard years that followed, but it appears likely that the entire economic foundation of the nation had dramatically shifted for the foreseeable future. In other words, high levels of economic growth that prevailed in recent decades likely would not be regained again. The recession affected all public institutions across the country, with similar cascades of budget cuts, loss of staff, and institutional reorganization.

While all participants in the case study admitted that the reduced funding and institutional reorganization meant paring back goals and reprioritizing what was feasible to do within certain timelines, the partnership actually provided resiliency for each institution in the face of the economic downturn. A major benefit of partnerships is that together the organizations can do more than either could alone. In this case, targeting funding among them to leverage the greatest gain meant that students were engaged to a greater degree when the institutions worked together, and greater student needs during that time were actually met to a greater degree due to the partnership.

### *The Importance of Leaders*

Whether through an economic crisis or other reasons, one of the greatest threats to partnerships found through research on them is due to loss of key leaders and staff turnover

(Kanter, 1994; Logan et al., 2010; Shepherd, 2008). "It is not clear whether, or at what point in its history, a partnership can endure the departure of a successful leader" (Carline & Patterson, 2003, p. 479), although the degree of integration between institutions *sensu* Kanter (1994) as described above could likely provide a buffer to the loss of a key leader. In addition, multiple staff losses due to either turnover or reorganization, as occurred in the MWU-VSD partnership, increases the magnitude of the challenges (Carline & Patterson, 2003). The loss of key individuals can also lead to significant loss of institutional integration, such as what occurred at MWU after Susan Rasmussen's departure (Granger, 2004).

One factor that likely buffered the impact of Susan's departure was that the partnership had grown increasingly reliant on the scientist-educator coordinator to enact the actual collaboration. The coordinator moved easily into district classrooms and university offices and labs alike and was increasingly the one relied on for face-to-face engagement. In the last year, the coordinator worked shoulder-to-shoulder with the teacher of the Introduction to Lab Techniques Course, designed and taught the Field Study course, and was designing and preparing to teach the online course. The coordinator could access university resources and expertise to a degree to accomplish these things, and when other university staff needed to be involved, it came through the coordinator. However, this was ultimately unsustainable for a true partnership to continue, and the diminished *strategic integration* after Susan's loss caused concern for partnership members about its long-term sustainability.

Kanter's model of the various levels of integration within partnerships is revealing in this light. It is clear that it is not enough for true organizational partnerships to be sustained only on the strength of tactical and operational relationships. The MWU-VSD partnership points to the importance of leaders. Not only were the key leaders, Susan and Alice, important drivers at the formation of the partnership due to their innovative and strategic natures, but each of their departures also inform what is important in the maintenance and continual evolution of a partnership. Kanter (1994) indicates that successful partnerships between organizations maintain strategic integration throughout the life of the partnership, with top leaders meeting to renew and revitalize the institutional commitments to collaborating. While MWU may very well have been committed to the partnership in the long-run, the fact that top leaders had not met since Susan's departure created a sense of unease among some district participants.

On the other hand, after Alice retired as district superintendent, the new superintendent and his associates in the district maintained a strong and public commitment to the partnership, strategically planning a public presentation to the board of education to renew commitment. The case studied here underscores the importance not only of capable and skilled staff being positioned to coordinate and implement the day-to-day work of the collaboration, but also that engagement from informed top leaders is necessary for a strong partnership between organizations to be maintained.

### *Recommendations for Establishing and Maintaining Science Education Partnerships*

While the science education partnership literature describes the importance of moving to a partnership model rather than an outreach model, and a mutual learning model rather than a one-way learning model (Dolan & Tanner, 2005; Tanner et al., 2003; Tomanek, 2005), it does not say much about *how* to create such a partnership based on the valued traits of respect, equity, and mutuality and trust (but see Cole, 2005). The MWU-VSD science education partnership met the criteria set out by Dolan and Tanner (2005) that collaborations between scientists and educators include "1) the adoption of a mutual learning model of partnership, 2) the integration of partnership into the training of scientists, and 3) the development of sustained infrastructures for partnership" (p. 35). Further, it provides evidence for identifying the specific means of moving beyond the traditional outreach model to an authentic science education partnership model. These include:

- Establish mutuality and equity in the partnership:
    - Create mutual investment in each other
    - Have a deliberate conversation: "Is collaboration a good idea?"
    - Base strategic planning on collaborative decisions
    - Mutually commit resources to the partnership
    - Start with small joint projects to establish relationships and structures
    - Engage a neutral third party facilitator that can initially help establish collaborative practices and equity
- Institute ongoing structures and processes that help integrate resources and efforts:

    - Maintain strategic, tactical, and operational integration through appropriate meetings
    - Encourage interpersonal integration through rich networks of relationships
    - Invest in cultural integration by committing to mutual learning
    - Dedicate a scientist-educator coordinator as a formal integrator
    - Evaluate the partnership
- Additional considerations
    - Partnerships can be synergistic when resources are stretched
    - The loss of key leaders necessitates the renewal of strategic integration

## Growing Scientists Through Twenty-First Century Science Education Partnerships

With increasing volume, the calls to improve the quality of science education in the United States in light of twenty-first century skills today are multiplying (Bybee & Fuchs, 2006; National Academy of Sciences, 2010; National Research Council, 2010, 2012b). Amid strong international competition in science and technology fields, growing health and national security issues, and increased globalization, appeals for twenty-first century science education reform emphasize learning science and technology in the context of real-world applications (Bybee & Fuchs, 2006; National Research Council, 2010). Accordingly, a new set of national science standards are being developed at the time of this writing emphasizing:

- Science and engineering practices
- Crosscutting concepts that unify the study of science and engineering through common application across fields
- Core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of sciences (National Research Council, 2012a, p. 2)

Interestingly, such calls for developing twenty-first century skills for workforce development take place at a time when the K-12 science curriculum has narrowed due to the increased standards and assessments implemented for over a decade due to No Child Left Behind legislation (Griffith & Scharmann, 2008; Southerland et al., 2007; Taylor et al., 2008). In addition, due to the economic downturn that started in 2008, public schools have suffered massive state budget cuts, and so are being asked to do far more with much less (Darling-Hammond, 2010; Kanter, 2011; National Research Council, 2012b).

Schools across the country will need to garner resources to implement the new standards, and one of those resources is recognized as universities that can partner with school districts (Council on Competitiveness, 2005; National Academy of Sciences, 2010; National Research Council, 2012b). Further, to develop twenty-first century skills, schools are also encouraged to partner with the business community in order for students to gain first-hand experience of real-world applications (Bybee & Fuchs, 2006; National Academy of Sciences, 2010). In fact, business leaders increasingly involve themselves with schools, emphasizing their interests in developing a meaningful workforce, with offers for support and partnerships with schools (Aikenhead, 2005; Bybee et al., 2009; Council on Competitiveness, 2005; Fensham, 2009; National Academy of Sciences, 2007b). Universities and businesses alike recognize that cultivating interest in science in precollege environments is critical to their success.

Given this context of increasing emphasis on science education for workforce development and national competition in a global marketplace, and the severely reduced revenue sources on which public schools depend, schools are by necessity being forced to be creative and innovative in programming. Further, given the growing interest and recommendations to universities and businesses to partner with K-12 institutions, science education partnerships hold the promise to provide meaningful real-world and career-development opportunities for students while strengthening all organizations involved (Council on Competitiveness, 2005; Kanter, 2009; National Academy of Sciences, 2010; National Research Council, 2012b).

The MWU-VSD science education partnership specifically formed in the context of developing twenty-first century skills, and it also involved fostering business and industry connections. As such, the findings from this instrumental case study offer insight and recommendations for science education partnerships in the light of twenty-first century science education reform.

### *District's Twenty-First Century Programs Provided Targeted Educational Interface*

The district's Twenty-First Century Programs were an innovative way to address VSD's commitment to educating students in twenty-first century skills. These programs were situated within comprehensive high schools, and the Twenty-First Century Program students had many of their classes with students outside of their program. The Twenty-First Century Programs emphasized careers and practical applications, yet they also required rigorous science and math coursework. They were inclusive in that they did not require selective criteria for admission; however, due to the rigorous curriculum, students did self-select.

In short, the Twenty-First Century Programs embodied the school structures that studies have found to be the most successful: 1) small learning communities that allow for personalization and strong relationships; 2) intellectually challenging and relevant instruction with a coherent set of standards and curriculum; 3) performance-based assessment; 4) highly competent teachers who collaborate in planning and problem-solving; 5) adequate instruction time; and 5) equal access to high-quality learning opportunities (Darling-Hammond, 2010; National Research Council, 2011)

A hallmark of the Twenty-First Century Programs was the strong relationships students formed with the program, their peers within it, and their program facilitator. With rigorous program content, these encouraged strong cohort relationships among students, and engaging the broader local community in learning opportunities for students. The programs relied on student, teacher and community engagement in their design, with the vision of the teacher as facilitator or coach of student learning.

The Twenty-First Century programs proved to be nimble and flexible in the context of the partnership: innovative programming developed through intense collaboration between scientists and educators. To a large degree, programs were actually developed *as* they were being implemented, and could "turn on a dime to reorganize" when necessary. The programs targeted student needs, university interests, and community workforce needs. The programs interfaced with regional colleges and engaged the local community of animal health businesses who were interested in cultivating a talented and skilled local workforce of scientists. The fact that the Vista School District had a few years' experience creating and implementing other Twenty-First Century Programs was a tremendous asset for the partnership as it created a well-polished crucible for innovation with the new content that MWU could bring.

Students in this case study reported that their experiences engaging with MWU scientists in research were interesting, satisfying, and inspiring, and the way the university scientists and district educators interfaced in these programs excelled at giving students such research opportunities.  These included class research projects engaging the scientist-educator coordinator in students' ninth and tenth grades, and a capstone research experiences in their senior year.  A National Research Council study noted that "students who had research experiences in high school, who undertook an apprenticed mentorship or internship, and whose teachers connected the content across different STEM courses were more likely to complete a STEM major than their peers who did not report these experiences" (NRC, 2011, p. 9).  The student interviews in this case study confirm the difference these opportunities made for them in planning a career.

### *Twenty-First Century Programs Helped Address Science for All*

One of the difficult charges school districts face regarding science education is the often conflicting purposes of educating students in science in order to train future scientists while also educating all students for a citizenry generally literate in science (Fensham, 2009; Millar & Osborne, 1998; Roberts, 2007).  When educating all students takes precedence, the highly motivated and advanced students can be held up by those not so interested in science.  When educating students for the purpose of training future scientists, those students not interested in such a career can be left behind.  Especially with fewer resources to commit to education, meeting this call for *Science for All Americans* (American Association for the Advancement of Science, 1990) can be a somewhat intractable problem for schools.

The Vista School District's Twenty-First Century Programs helped solve this problem. Students could choose and even transfer to the high school offering a particular science program. At the same time, students who did not choose such a program remained in the comprehensive high school program that still required students to take science courses.  In fact, the comprehensive school programs still offered Advanced Placement science courses, so students did not have to be enrolled in a Twenty-First Century Program to take advanced science courses. However those that did choose one of the Twenty-First Century Programs also had the benefit of a curriculum focused on particular careers, with community members from higher education and businesses involved in the development of the curriculum and engaged in helping create a real-world context for the content area.

Another challenge in meeting the goals of Science for All relates to teaching science to a diverse population, not only to educate those who will not pursue science as a career but also to encourage students who might not otherwise be interested in science to pursue the subject, to actually recruit and train future scientists (Lazarowitz, 2007; Lee & Luykx, 2007). By not having specific requirements for students to apply to the Twenty-First Century Programs, district educators encouraged even those who had perhaps not done so well in school in the past but could do well in the future to enroll. The rigor of the science programs did tend to have a self-selecting impact in students. Students with diverse academic backgrounds, racial, cultural and linguistic backgrounds, and socio-economic backgrounds who wanted to pursue science careers enrolled in the science-focused Twenty-First Century Programs.

The partnership engaged three science-focused Twenty-First Century Programs in the high school with the largest diversity in the district, including the highest poverty level. As such, the partnership intentionally tried to provide science opportunities to a diversity of students, "not just those with means." Of those three students engaged in the partnership who continued to MWU, two were females of color who both were accepted into the Developing Scholars program at the university designed to help foster scientific research interests and procure places in research labs for them to work as undergraduates. The one of these two that was interviewed for this study credited the experience with the partnership for sparking her interest in scientific research, for opening her eyes to the possibilities of pursuing a research career, and for helping to facilitate the pathways to realize that. This is a powerful testament to the role university-school district partnerships can play in turning under-represented students on to a career in science, and helping them pursue education and training to become scientists.

Seven of the ten students who were still in high school could definitively imagine themselves as scientists, and five of those seven credited the partnership programs for influencing this view. When they described what scientists do, they overwhelmingly described the passion and curiosity scientists employ as well as their systematic reliance on evidence. The fact that they described so many positive personality traits of scientists suggests they had first-hand experience with interacting with actual scientists, and were inspired by them. These kinds of experiences could be provided to a diverse population of students through the district's Twenty-First Century Programs. In effect, the partnership with scientists and educators collaborating in the context of the Twenty-First Century Programs provided programming that not only helped "grow our own scientists," but also grow a diverse group of scientists.

Linda Darling-Hammond (2010) documents how educational inequality, especially for low-income students and students of color, presents the United States with a formidable challenge.  She posits that the educational crises in this country will not be addressed until educational equality for these populations of students is achieved.  The science education partnership between MWU and VSD provides an example of how such partnerships can help address the disparities.  By creating a focuses Twenty-First Century Program that appealed to students' interests and passions, and by housing the program in a high-diversity, high-needs school, the partnership was able to help diverse student populations find pathways into science careers.

### *University Expertise Informed Leading Edge Content Perspectives*

Creating a Twenty-First Century Program focused on animal health provided an innovative way to attract and recruit students into science fields.  As one of the scientists noted in the study, "Animals are popular, so if you can use animals as a way to engage students in science and technology education and math, it's a good thing" (see page 147 of this document).  Students in the Animal Health Twenty-First Century Program often were attracted to the program by their affection for animals and a general wish to work with them, likely as a veterinarian, only to realize how very many diverse opportunities to pursue careers in animal health there were. While students had yet to graduate from this program during data collection for this study, future studies on this program can clarify the impact it had on recruiting students into science.  This study indicates that the program has had a large impact with over sixty-five students at the time enrolled in the program, and the capacity for one hundred in subsequent years.  Further, the program meets a need for the regional area in workforce development for its large animal health industry in training well-educated scientists.

The animal health focus of the science education content created through the teamwork appears to be relatively unique in high school settings.  While a number of well-known and successful science education partnerships exist between medical universities and schools (Carline & Patterson, 2003; Logan et al., 2010; Siegel et al., 2005), the MWU-VSD partnership is the only one to my knowledge that focuses on animal health.  Further, while outreach programs recruiting students into schools of veterinary medicine exist, the perspective of the scientists in this partnership was one in which animal health, human health and environmental health were seen as inextricably linked through a "One Health" perspective (One Health Initiative, 2012).  This perspective informed program development through the partnership in that the integration of environmental and human health perspectives were encouraged by the scientists.  For instance, in the Senior Biotechnology Project, not only was the research focused on the effects of non-steroidal anti-inflammatory drugs on animal tissue, but also implications for human health were made explicit.  Also, in the Animal Health Twenty-First Century Program, the incorporation of environmental and ecological perspectives through the Student Naturalists class and Field Research Camp was highly encouraged by the scientist advisors.

### *The Role of Innovation in Science Education Partnerships*

In a bold statement inspiring one of the leaders of the partnership, the Council on Competitiveness (Council on Competitiveness, 2005) proposed that "innovation will be the single most important factor in determining America's success through the twenty-first century" (p. 7).  Leaders from both the university and school district in this case study were committed to innovation to find new solutions to today's challenges.  The university's new satellite campus in the metropolitan area was driven by a mission to support innovation, to combine graduate education with industry research to spur and incubate new services and products.  This was understood to explicitly involve partnering with industry collaborators.  It also positioned itself to create innovations through educational partnerships, including those with local school districts with the foundation laid in the partnership with the Vista School District.  The school district created its Twenty-First Century Programs recognizing the need to create educational and career development opportunities for students interested in particular fields such as culinary arts, biotechnology, engineering, and electronic communications.  They developed a model of partnering with regional industry leaders as advisors for program content and to help provide internship opportunities for students.  Each institution was already partnering with the local business community before they formalized their partnership with each other, and the school district valued the new connections the university could provide to the animal health industry.

Innovation is commonly considered the purview of the business world since new innovations drive the national and indeed the global economy, and innovation in the market place is seen as the way a business or even a nation keeps a competitive edge over others (Kanter, 2009; Merx-Chermin & Nijhof, 2005; National Academy of Sciences, 2007a). However innovation is also recognized in the field of education as creating solutions for ineffective or problematic practices, what is often termed educational reform (National Research

Council, 2012b; O'Banion, Weidner, & Wilson, 2011). Indeed, Hannon (2010) asserts that in education, “the language of *improvement* and *reform* has given way to the language of *transformation* and *radical innovation*” (p. 25).

In order to understand the context of innovation in science education partnerships, it is helpful to examine the role of innovation in partnerships and in education.

***Partnerships Foster Innovation***

What is innovation, and what is needed for it to work? Since innovation has primarily been studied in the context of the marketplace, a brief look at this literature is helpful. Merx-Chermin and Nijhof (2005) claim innovation is an applied learning process “in which valuable ideas are transformed into new forms of added value for the organization, customers, employees and stakeholders” (p. 137). They relate the concepts of creativity and innovation in this way: creativity may be thought of in terms of an individual, whereas innovation is generated when groups of individuals work together in creative ways, requiring a “fine-tuning between individual and collective transformation” (Merx-Chermin & Nijhof, 2005, p. 137).

Kanter (2010) points out that the very nature of organizations with their structures, roles, job descriptions and reporting structures tend to inhibit internal innovation. However, it takes “thinking outside the box,” or even “thinking outside the building” to facilitate change, to identify emerging problems, to expand the field of possible solutions and new learning (Kanter, 2010). Innovation implies a “first on the market” quality, and this can be supported through organizational communication and collaboration as well as simplifying logistics and bureaucracy (Kanter, 2010; National Academy of Sciences, 2007a). Resources need to be committed to innovation with expectations that not every idea will bear fruit, and not every innovation will change the world (Kanter, 2006).

Interestingly, the research on collaborations between organizations shows that *partnerships not only tend to foster innovation, but also an organizational culture that nurtures innovation tends to be very similar to one that fosters partnerships* (Council on Competitiveness, 2005; Kanter, 2011). The nature of partnerships requires being open to different cultures, different ways of thinking, different views on familiar topics. These very elements set the stage for the new applied learning in synergistic groups that comprises innovation.

### *The Role of Innovation in Education*

Innovation in pre-college and higher educational organizations share many qualities with those of business organizations, and similar practices that support innovation in business are also reported in (Hannon, 2010; O'Banion et al., 2011). Hannon (2010) distils the processes of innovation in education down to five elements: 1) collaboration; 2) support and challenge; 3) learning; 4) creativity; and 5) action. She also reports that it is often through teachers forming partnerships with others that breakthroughs are achieved, and she proposes that education innovation is accomplished by practitioners: “It is in the crucibles of practice that significant new approaches are being developed” rather than in think tanks separate from the classroom (Hannon, 2010, p. 25). This principle is similar to Doyle and Ponder’s (1977-78) premise that educational change must take into account the “practicality ethic” of teachers if it is to be effective. In fact, empowering teachers to design programs in teams with other educators and scientific experts provided a powerful force for innovation in the MWU-VSD partnership that met the needs of students teachers saw every day.

Educational innovation is seen today as a critical component to cultivating a skilled and competent society in a time when public funding for education is decreasing at an alarming rate so that ways can be found to do more with less, especially since the economic downturn in 2008.

> Across the world, the resources supporting public services are diminishing. The assumption of everlasting growth and investment has received a nasty shock, and it is increasingly understood that the options are stark: either reductions in service quality and reach or radically new ways of working. (Hannon, 2010, p. 25)

As science practice and technology continues to advance at an increasing rate, it is difficult for textbook-based curricula to keep pace. And in a time of decreasing financial resources for books and an increasing reliance on web-based resources, educators are learning to innovate to bring relevant and leading-edge learning to their students (Hannon, 2010).

Public K-12 schools are not the only institutions suffering from such severe budget cuts. A recent report from the National Research Council (2012b) addressed the challenges American research universities currently face with regard to “unstable revenue streams, demographic shifts in the U.S. population, changes in the organization and scale of research, and shifting relationships between research universities, government, and industry” (p. 2). The report offers recommendations to not only revitalize partnerships between research universities, government, and industry, but also to help invest in creating "America's pipeline of future talent" through partnering with K-12 schools (National Research Council, 2012b, p. 4). Again, partnerships between universities and K-12 schools are recommended to serve common goals in education.

### ***Mutual Learning in Partnerships Is Key to Innovation in Science Education***

The efforts to interface the two cultures of university scientists and K-12 educators in the MWU-VSD partnership indeed proved to be the "crucible of practice" that allowed new science education approaches to be developed. Mutual learning required that both educators and scientists acknowledged that neither side had all the answers and that each had something to learn from the other. It was also accomplished by hiring a coordinator for the partnership who was familiar with both cultures and could help interface them.

If creativity is the purview of individuals, and innovation the purview of groups dedicated to creating new value in something, how is innovation fostered in science education partnerships? When individuals express interest in each other's area of expertise, with educators wanting to learn about the leading edge science practices, and scientists wanting to learn about education, all within the context of the school and actual students, a dynamic of inspiration and synergy ensues. When each participant listens carefully to the perspectives, needs and ideas of the other, and each offers their own particular talents and skills, unique solutions are generated, developed and implemented together that can be "more than the sum of the parts." Transforming disciplinary science content into school science requires deep appreciation, respect, and creativity from both sides.

Partnerships form when groups of people with complementary differences join together to collaborate. However, the culture of innovation is not automatic, and likely will not happen unless both partners are invested in creating value together through their differences. A partnership culture that embodies elements similar to those modeled in Figure 5.1 (p.297) is critical to an environment that fosters innovation. The sense of trust, respect, equity, understanding, dedication and flexibility were key to fostering the mutual learning required in innovation.

The fact that the curriculum and programs developed through the MWU-VSD partnership were done so in the context of the school itself underscored that this case study was one that measured up to Dolan and Tanner's (2005) definition of a science education partnership rather than outreach. This was not a venture that was planned and created in university labs or offices and distributed to willing classrooms. Nor was it a response to a single teacher asking for advice from a valued scientist. Rather, the partnership created contextually relevant and sustainable programming that served to inspire and connect students to science careers by scientists and educators working together.

The students gained in experiencing their teachers interacting with university scientists. It helped create a "seamless interface between secondary schools and higher education" with students having direct interaction with scientists, on the university campus and in the district classrooms. This alignment and seamless interface had a positive impact on students in that the majority of them reported the programs helped change their perspective to being able to imagine themselves as scientists (Table 4.14, p. 294). While most were still in high school, two of them were already progressing in their undergraduate careers with plans for graduate school in animal health careers.

The flip side to innovation in K-12 science education contexts is also the enterprise of changing the practices within universities. Lederman and Gess-Newsome (1999) note that until university science education is transformed, high school teachers will continue to teach in ways they learned at universities. By engaging in this scientist-educator partnership, scientists learned pedagogical skills that they could take back to the university and use. Further, in intense partnerships that involve program and curriculum development, scientists also engage in the philosophies, the dilemmas, and the principles of learning science content. They returned to their educational work in universities having a deeper understanding of how to facilitate learning and how to achieve important goals in curriculum and program development.

### *Student Perspectives in Partnerships*

Somewhat surprisingly, the scholarly literature on science education partnerships contains very little in terms of their impact on students, and even less on student perspectives in partnership programs (but see Eberbach & Crowley, 2009). Rather, studies tend to focus on impacts on partner organizations and the quality of partnering. Scherer (2008) discusses the reasons why it may be so difficult to investigate long-term outcomes and impacts on constituents such as students in partnerships. Essentially, the reasons have to do with partnership complexity such as extraneous variables, hazy definitions of collaborations, the evolving nature of partnerships, and the difficulties in studying long-term effects.

By interviewing students involved in partnership programs, this study elucidated the perspective of the beneficiaries of the partnerships, that is, the perspective of students. They described the programs as changing their perspectives on career planning, exposing them to careers they never thought of before but that still met their interests. They also communicated how the programs motivated them to be self-starters, set goals and achieve them. They discussed their various research experiences through the programs, and how these impacted their own decisions to pursue or not pursue certain paths. They described science and science research as an enthusiastic and curiosity-driven enterprise with scientists passionately engaged in learning, with scientists trying to understand "what basically makes the world click." The described the processes of gathering evidence and basing conclusions on such evidence. The older students had a broader sense of specific career opportunities, and could describe the greater impacts the programs had on them.

Through student interviews, the impacts that the partnership programs had on their lives and their perspectives were illuminated. While it may not be easy to draw a clear causal link to the impact that the programs directly had on their perspectives, such interviews do provide evidence of the general influence of these programs. Student interviews show promise in clarifying the impacts of science education partnerships.

### *Implications for Growing Scientists Through Twenty-First Century Education Partnerships*

Partnerships between educators and scientists can help maximize resources and goals to provide meaningful learning in a K-20+ context that embraces the best in science and pedagogical practice and that also recruits, educates, and trains a diverse new generation of scientists. Based on the findings of this case study as discussed above, the following are important factors to consider in science education partnerships in the twenty-first century:

- Successful school structures such as those embodied in VSD's Twenty-First Century Programs provide:
    - Flexible and nimble contexts for universities to impact science curriculum.
    - Opportunities for recruitment of diverse students into science careers.

- Animal-focused curriculum can help recruit diverse students to science.
- Scientists can inform programs of leading edge practices and perspectives not only in classroom practice but also in curriculum and program development.
- Science education partnerships tend to foster innovation when:
    - A dynamic culture supporting mutual learning is enacted; and
    - Practitioners are engaged in the innovations.
- Innovations in science education partnerships can allow partners "to do more with less"

By engaging in local partnerships, respectful relationships can be forged that provide the flexibility to meet changing needs in a local environment, that provide students with mentors they can relate to and bridges to higher education and career development. Further, science education partnerships have the potential through creating educational innovations of impacting science education curriculum along a continuum of pre-college through graduate school, in effect, "growing scientists" in a meaningful context.

## Insights into Teaching and Learning Through Science Education Partnerships

Studying the intense collaboration of scientists and educators in the MWU-VSD case provided a unique perspective on understanding teaching and learning. Studies in curriculum and pedagogy are often concerned with how disciplinary knowledge of a particular field can be taught in schools. With scientific experts interacting with pedagogical experts in this partnership, there was an opportunity to observe the process of transforming disciplinary knowledge into school science.

### *Focus on Pedagogical Content Knowledge*

Each program initiated through the partnership provided varied opportunities for partnership members to interact through its development and implementation. Such teamwork largely focused on transforming the science content scientists thought important into learning for students. This is commonly referred to in the scholarly literature as developing pedagogical content knowledge (PCK). Although there are nuanced differences among researchers as to exact definitions of PCK (VanDriel & Berry, 2010), "at the center of those various definitions is the idea that the transformation of subject matter knowledge for the purposes of teaching is the heart of PCK" (Park, Jang, Chen, & Jung, 2011, p. 248). Abell (2007) offers a working model that synthesizes a number of scholarly perspectives (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999). According to Abell's model, PCK is a synthesis of a teacher's subject matter knowledge, general pedagogical knowledge, and knowledge of the learning context. Pedagogical content knowledge includes: 1) orientations toward teaching science; 2) knowledge of the science learners (students); 3) knowledge of the science curriculum; 4) knowledge of science instructional strategies; and 5) knowledge of science assessment (Abell, 2007). In comparing these elements of PCK with the subthemes of program and curriculum development voiced by participants in this case study listed in Table 4.6 (p. 210), there is general congruence of the elements. This suggests that a primary focus of the program and curriculum teamwork centered on constructing PCK.

That this primary focus of PCK would be present in a partnership with school district educators is not surprising, since PCK is concerned with "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). In first coining the term *pedagogical content knowledge*, Shulman (1986) intended to empower "teachers as professionals by creating awareness of the special forms of knowledge they possess," especially in contrast to discipline professionals such as scientists (Park et al., 2011, p. 246). Park and Oliver (2008) expand on Abell's PCK model include teacher efficacy as a sixth element, with processes of reflection-in-action and integration involved to synthesize the various elements.

In the MWU-VSD partnership case study, not only did teachers develop PCK in ways consistent with these models, but so did scientists in that they learned a great deal about teaching their own science content through the pedagogical expertise of the teachers. This was clearly possible because of the commitment from university scientists at the outset to mutual learning. By sharing and learning from each other, they together created courses, projects and curricula to bring cutting edge science to students. The equity and mutual learning in the context of program development is not always seen in the literature in scientist-educator partnerships. Rather, it is frequently reported that in scientist-teacher partnerships, teachers defer to scientists as the main expert in the room and fail to bring their own necessary expertise to the table (Bellamy, 2005; Tanner et al., 2003). While there were instances of teachers holding back a little in this case study (in the cases of Michael and Steve), equity in each situation was quickly restored by their perspectives being valued and emphasized by colleagues, including the scientists.

Somewhat surprisingly, PCK is not emphasized in the scholarly literature on scientist-school partnerships; rather the differences in institutional cultures are highlighted. It may be valuable, however, to focus on PCK in the context of scientist-educator partnerships. By doing so, the expertise of educators could be edified and relationships could be equalized as expertise from both partners is recognized and valued. Scientists and teachers could develop purposeful ways of working together through conceptualizing the translation of science subject matter knowledge into meaningful learning. Further, since scientists and educators actually embody distinct areas of expertise (e.g., content experts, pedagogical experts) in this enterprise, partnerships such as these could offer unique settings for inquiry into the processes of cultivating PCK.

The development and application of PCK clearly occurs in rich and varied contexts. At times as teachers learned new science content, they also developed ways of teaching it while simultaneously mentoring scientists in the same endeavor. Groups of experts helped develop and teach programs, and individuals or pairs did the same. The fact that programs developed in the learning contexts themselves with students present, rather than in a university for the purposes of outreach, helped create contextual meaning and sustainable infrastructure for the programs. Further, such programs developed with direct teacher participation provided confidence that the programs were practical and effective. Elgin and colleagues (2005) reminds us that “Developing curriculum materials is of no practical value if teachers cannot implement them …” (p. 33). Doyle and Ponder (1977-78) underscore this point in recognizing teachers are the most important element of implementing any education reform.

### *Partnership Revealed Relationship Between Pedagogy and Curriculum*

Pedagogical content knowledge is typically described as being related to classroom teaching. However, in this study, participants also pointed to the development of curriculum and programmatic infrastructure as integral to transforming science content into student learning in the classroom. This element in Table 4.6 (p. 210) is listed as developing programmatic infrastructure. Yet developing such infrastructure is not congruent with Abell’s (2007) model of

PCK, but rather represents a discrepancy. One needs to look to the literature on curriculum development to locate this element in the scholarly literature (Doyle, 1992; Schwab, 1973).

The nature of the partnership was such that administrators, teachers and university scientists worked together to create science programs for specific purposes, and this included creating infrastructure to support them. Infrastructure included budget lines, staffing, lab equipment, coursework and curricula to foster the collaborations in the school context. Understanding the science pedagogical content and context was important in creating – and justifying in especially lean economic times – such infrastructure. Yet much of this infrastructure is recognized as part of curriculum development. When teachers directly participate in such development, however, in the immediate context of classroom implementation, it is unclear where "curriculum development" begins and "pedagogical development" ends.

These findings suggest a blurring of the lines between PCK and "curricular knowledge" (Shulman, 1986), or the need for integrating the concepts of pedagogy and curriculum as suggested by Doyle (1992). Similarly, the findings in this study support Deng's (2007) premise that "transforming the subject matter is not only a pedagogical but also a complex curricular task in terms of developing a school subject or a course of study" (p. 279). Recalling the traditions of Schwab, Bruner and Dewey, Deng argues that transforming subject matter to facilitate student learning in schools "requires the participation or involvement of a body of expertise – including curriculum theorists or specialists, subject matter experts, and classroom teachers" (Deng, 2007, p. 280).

Interestingly, concepts of curriculum development can also be seen as a matter of translating subject content into appropriate materials to support student learning in schools and classrooms (Doyle, 1992; Jackson, 1992; Schwab, 1973). Doyle (1992) argues that there are multiple levels of curriculum making, from working at an institutional level, a program level, and a classroom level. In identifying these, he is suggesting the existence of a continuum between ideal curriculum development and pedagogical implementation.

One can see that in the case of the MWU-VSD partnership, these of curriculum development and program implementation occurred at times simultaneously, or nearly so. Indeed, members often referred to "building the plane as it's flying." This is not to deny that a great deal of curriculum development at the district level occurs in relation to state standards and district goals, purely outside of the partnership. However, given the infrastructure the Vista School District already had in place, the curricula and programs generated through the partnership were developed through specialized student learning communities focusing on twenty-first century skills and real-world experience in a professional content area; hence a great deal of flexibility existed to innovate, plan and improvise. Face-to-face interactions were important in these processes, and the programs developed in unique contexts that could be nimbly adjusted as needed.

### *Implications for Pedagogical and Curriculum Studies*

The intense collaboration among teachers, scientists, education administrators, scientist-educator coordinator and the students in forming programs was reminiscent of Schwab's (1973) imperative that curricula be developed within the context of these multiple perspectives (or "commonplaces") being represented. Interestingly, he also advocated for the importance of the "curriculum specialist" who chairs and facilitates the group and ensures the equality of all individuals without any one view overwhelming the others (Schwab, 1973). In the MWU-VSD case study, this role was originally carried out by the Vision Lead external facilitators, and then after the patterns were established, it was carried out by various individuals, including key leaders, and the scientist-educator coordinator. Schwab (1973) describes the process of curriculum development as being deliberative with consideration of many viewpoints and incorporating formative assessments of curriculum "bits" along the way to create a whole curriculum. "The method begins with an intertwining of two radically different strands: information and soul searching" (Schwab, 1973, p. 518).

The processes Schwab describes were seen taking place in this partnership, supporting Deng's argument that transforming subject matter is both a curricular and a pedagogical task, especially when science content is transformed into school learning in the context of reform-based programs such as the Twenty-First Century Programs studied here. Pedagogical content knowledge and curricular knowledge likely describe similar things but from different perspectives on a continuum – from a classroom enactment perspective, and from a conceptual programmatic perspective, respectively. Indeed, experts developing a national geoscience curriculum in Australia employed a tool designed to assess pedagogical content knowledge to guide their process (Loughran, Mulhall, & Berry, 2004; Moore & Woolnough, 2012). This suggests that pedagogical studies and curricular studies could be more closely aligned than they tend to be.

The activity of involving multiple perspectives in curriculum and pedagogical development was critical to the MWU-VSD partnership, and such engagement is highly recommended for science education partnerships as well as science curriculum development. In fact, science education partnerships that focus on interfacing university science and K-12 science can be the focal point in which dynamics of innovative science curriculum and pedagogy development can be studied. Such collaborations should be supported and studied for the benefit of understanding new and innovative best practices in education.

"Seamless interfaces" between secondary schools and higher education are not always possible. Practices in universities are not always appropriate in precollege education. Concepts need to be formed over time, and the way an expert conceives of and works with a subject is vastly different from how a novice conceives of and works with it (National Research Council, 2000). Appropriate pedagogical principles of learning influence the secondary school curriculum, and Deng (2007) argues that school subjects should not be conflated with their academic disciplines, and that the content in school subjects should be a matter for inquiry, reflection and discussion. He urges "teacher educators to go beyond the mere discussion of subject matter framed in terms of academic disciplines to a broader conversation enhanced and enriched by curriculum theories and discourse, with a particular attention to the formation of school subjects" (Deng, 2007, p. 291). The results of this case study support this premise. Such conversations among educators and scientists formed the heart of translating science content as practiced in the university and in industry into school science.

One issue that should continue to be addressed by science education researchers, and that should also include student perspectives, is the myth of a single rigid scientific method as it is often taught in schools (Barstow, 1997; Osborne, 2007; Rowbottom & Aiston, 2006; Rudolph, 2005a). While an experimental method is what is usually indicated as "the scientific method" in schools, it is important to place this is its appropriate context and also educate students about the multiplicity of approaches used in science. Unless changes are made in the school culture, intelligent and curious students will continue to be turned off to pursuing science when they do not initially relate to the parameters of the experimental method.

The approach used in this partnership to characterize science research as "curiosity-driven and evidence-based" seemed to generally appeal to students' sensibilities based on their interviews, and it seemed to inspire them to pursue science. They provided rich descriptions of scientific exploration engaging passion, curiosity, patience, and wonder. Further, students described their satisfaction and joy in making sense of data they collected, interpreting the data and thinking about the meaning of their results. In a critique on common misconceptions of science transferred through teaching approaches, titled "License to Wonder," evolutionary biologist Olivia Judson states that "in reality, while some scientific work does involve the plodding, brick-by-brick accumulation of evidence, much of it requires leaps of imagination and daring speculation" (Judson, 2009). Aligning the actual practices and dispositions of scientists with how science is presented in schools can have a great bearing on how students are attracted to and recruited into the field.

## Implications for Future Science Education Partnerships

### *A Similar Model*

The MWU-VSD partnership had extraordinarily unique drivers in its inception. The only example of a partnership with similar drivers I have found is in the new venture in New York City in which the city granted Cornell University, another land grant university, land on Roosevelt Island in order to create a satellite campus focused on technology innovation. Also like the MWU-Vista campus, the Cornell NYC Tech campus will focus on graduate rather than undergraduate education aimed at regional workforce development (Cornell University, 2012; National Public Radio, 2012). New York City Mayor Bloomberg stated in an interview, "We need a better educated workforce, and we need people educated in the businesses that we're going to grow and create jobs, and they tend to be technological in this day and age" (National Public Radio, 2012). In July 2011 the city's economic development office issued a request for proposals "seeking a university, institution or consortium to develop and operate a new or expanded campus in the City in exchange for City capital, access to City-owned land … and the full support and partnership of the Bloomberg Administration" (Cornell University, 2012). Cornell University's proposal was selected in December 2011. Mayor Bloomberg spoke about this decision, emphasizing Cornell's commitment to STEM education in the metropolitan region:

> Cornell won it. They were the right ones to win it. They were so far better than anybody else in terms of coming up with a proposal that fit the needs of the city. Without even asking, they said, well, of course we're going to train two hundred science and math teachers in the public school system every year. Of course we're going to train ten thousand kids. Of course we're going to have a venture capital fund. (National Public Radio, 2012)

Cornell is being provided land on Roosevelt Island and $100 million from the city, and plans to build a $2 billion, 2 million-square foot campus that will house approximately two thousand full-time graduate students (Cornell University, 2012).

Similar to the MWU-Vista partnership but on a far grander scale, the partnership between Cornell and New York City involves a tangible investment on the city's part in exchange for vitalization of the metropolitan region in terms of work force development and industry innovation. Also similar, Cornell is committed to working with the public school system in New York City. The details of these collaborations in New York City are still developing, and the findings of this MWU-VSD partnership case study may in fact be informative to the Cornell-New York City's plans for engagement with local schools.

Given the multitude of calls for greater collaboration among civic, educational, and business sectors, this type of model may be one that will be increasingly common. That said, many traditional drivers such as grants, required outreach, curriculum development, and straight-forward requests for collaboration will bring scientists and educators together in partnerships. Based on the MWU-VSD case study presented here, what further recommendations for future science education partnerships can be made?

### *Recruiting New Generations of Diverse Scientists*

Many of the calls for investing more in science and technology education in the United States stem from the recognition that other countries have surpassed us in research, innovation and development in these fields. Other countries' achievements in science and technology also correlate with their success in STEM education (National Academy of Sciences, 2010). Our national standing in these and other fields, however, requires addressing the growing student diversity in the United States and creating opportunities for all students to succeed. Darling-

Hammond (Darling-Hammond, 2010) states that until students in urban schools can get the same quality education that students in suburban schools get, the nation will not rise in global prominence in science and technology.

The programs developed in the science-education partnership established between MWU and VSD were focused in the high school representing the highest levels of diversity and poverty in the district. However, the district was a suburban district, and was still able to raise school bonds through tax initiatives approved by citizens throughout the whole city. Inequitable school funding between urban and suburban districts are often due to such inequities in local investment. These inequities affect teacher salaries, teacher quality, infrastructure investment, and other factors that impact school quality.

While the partnership presented in this case study made inroads in recruiting diverse students into science, more can and must be done by directing future partnership efforts also to urban schools.

### *Starting Younger*

School partnerships that directly involve university scientists can easily focus on high school programs, as was done in the MWU-VSD partnership. However, even by high school, students have often already made career decisions if only because they identify with certain subjects over others. The school science curricula across the nation has significantly narrowed over the last decade with the increased emphasis on standardized testing to the point that science is even non-existent in some elementary schools (Griffith & Scharmann, 2008). In addition to the standardized testing pressures, elementary teachers are often not confident in teaching science (National Academy of Sciences, 2007b). In efforts to grow diverse new generations of scientists, and help support the teachers that influence them, partnerships can extend their influence beyond just secondary school science and also develop programs in middle and elementary schools.

### *The Importance of Partners to Respect Educational Expertise*

In the MWU-VSD partnership, much of the success was due to both partners respecting each other's areas of expertise. Societal values as reflected in the study often meant that scientists were respected and deferred to more often than educators. Yet the anomalies did not become the norm, and overall balance in power was maintained through respect. The same lessons should apply when businesses engage in partnerships with K-12 schools.

With all the calls for greater collaboration among organizations in the economic, government and service sectors (Council on Competitiveness, 2005; National Academy of Sciences, 2007a; National Research Council, 2010, 2012b), there must be more motivation for businesses to collaborate and innovate than the economic bottom line. Kanter's (2008, 2009, 2011) extensive research with businesses, large and small, reveals that successful businesses are in fact invested in more than just the bottom line; they are also committed to values that improve the quality of their own employees' lives and of those that live in their communities. Accordingly, they invest in law enforcement, hospitals, schools and universities. Increasingly, companies are stepping up to underwrite community services after natural disasters and other crises. They see that their long-term bottom line is enhanced when they do so, for instance when they make their own community more appealing for experts to visit and live in, and when they gain loyalty from customers who share their values. Further, they help invest in their own workforce development when they partner with educational institutions, and enhance their products and services through collaborating on research (Kanter, 2008, 2012).

In the MWU-VSD case study, businesses were included within the model of Twenty-First Century Programs. They were asked to help support some of the Animal Health Program activities, and they were venues for field trips to show students real-world applications, and internships to give students experience working in the field. The university was engaged with the animal health industry in the region and helped provide business contacts to the schools.

Yet corporate involvement in education has its critics. Gelberg (2007) notes that throughout the last century, "the stated impetus for the business community's involvement in the education establishment has been securing America's preeminence in an era of fierce international economic competition," and that "criticisms of student achievement leveled by the business community … reveal tremendous ignorance of the complexity of schools, of the challenges facing children and teachers every day in classes across the nation, of the nature of the work of teaching and learning" (p. 45). She criticizes the premise that education's main purpose is for workforce development, while cultivating thoughtful, responsible citizens is often neglected. She notes that business demands "to get students 'work ready' may not be synonymous with providing the best educational experience for their students" (p. 46).

Overwhelmingly, studies show the negative results when businesses engage with K-12 schools yet fail to honor the professional expertise of educators, and the scientific basis of learning theory that many educational practices are based on (Gelberg, 2007; Kumashiro, 2012; Sawicky, 1997). Even when businesses partner with higher education yet fail to respect faculty autonomy, results can be detrimental (Baines & Chiarelott, 2010). A recipe for disaster in public / private partnerships includes lack of respect and understanding by businesses for service organizations.

If businesses engaged in partnerships with educational institutions, however, with a commitment of respect and even mutual learning, the potential exists for businesses to not only help schools do what they do best, but they could also learn a great deal about improving their own practice. For instance, because businesses tend to rely on innovation to succeed, and innovation requires new learning, businesses could learn a great deal about learning from educational experts. In fact, Senge and colleagues (1999) assert that successful organizations are those that are good at learning. Building on this premise, Merx-Chermin and Nijhof (2005) offer a model that situates innovation within a cycle of knowledge creation and learning within organizations.

Many of the elements in these studies of learning in business organizations parallel elements in social constructivist theory of learning. In keeping with a mutual learning model of partnerships, businesses could learn a great deal from educational institutions to improve their practice. Since universities are experts at knowledge creation, and pre-college educators are experts at facilitating learning, they have expertise that could help businesses learn how to become learning organizations and foster innovation. However, such potential benefit would require a genuine mutual learning premise. At minimum, in order for businesses to successfully partner with educational institutions, they need to respect the expertise of educators and not impose their own organizational values on the school organization.

## Conclusion

This science education partnership case studied here could be considered a true partnership as it met with Dolan and Tanner's (2005) criteria of adopting a mutual learning model, integrating the training of scientists, and developing sustained infrastructures for partnering. It went further as well in providing insights into the role of such partnerships in science education reform and innovation, and in pedagogical and curriculum studies. This partnership also addressed a potentially new model of investing in science education partnerships by city leaders as well as university scientists and K-12 educators for workforce development and innovation. This study served to identify means of fostering successful collaborations in science education partnerships.

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# Appendix A - Informed Consent Forms

**Curriculum and Instruction**
College of Education
261 Bluemont Hall
1100 Mid-Campus Drive
Manhattan, KS 66506
785-532-5550

**Informed Consent to be Interviewed**
**Research Study of a Science Education Partnership**

**The Study and Your Participation**
You are being asked to participate in a 45 to 90 minute interview to assist in a research project by providing insights based on your unique perspective and involvement in an educational partnership between a school district and a university. This case study is specifically designed to try to understand ways of fostering successful collaborations in science education partnerships between universities and school districts.

The research study is being conducted by Teresa Woods, doctoral candidate in the College of Education at Kansas State University. This research will be used for her dissertation, and scholarly presentations and papers.

**What to Expect**
You will be asked several questions about the partnership in general, as well as specific programs you have been, or are, involved with. Questions will relate to how the partnership and programs evolved in time, the nature of them, how challenges have been met and how success is fostered. The interview will be digitally recorded and transcribed for accuracy. Your name will not appear in the transcribed files. The digital files will be deleted upon completion of the study.

**Potential Risks**
There are no known risks to participating in this study. Your identity will remain confidential as outlined below. Further, you may withhold information or withdraw from the study prior to publication as described below.

**Confidentiality**
Every attempt will be made to protect the confidentiality of your identity in relation to the content of your interview. In order to maintain authenticity in reporting the findings of this research study, extensive quotes may be used in the final publication without identifying you as the source, either by name or by inference. You will have the right to review and withhold any material you have provided through this interview prior to publication.

**Right to Withdraw**
You have the right to withdraw completely from the study any time during or after the interview, and before publication of the results, with absolutely no penalty or loss of benefits.

**Contact Information**
If you have any questions regarding this study, you may contact:

Dr. Jeong-Hee Kim, Faculty Researcher
Bluemont Hall 357
Kansas State University
Manhattan, KS 66506
(785) 532-6976

Rick Scheidt, Chair
Committee on Research Involving Human Subjects
203 Fairchild Hall
Kansas State University
Manhattan, KS 66506
(785) 532-3224

I understand this project is research, and that my participation is completely voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and they my signature acknowledges that I have received a signed and dated copy of this consent form.

______________________________________ ____________________
Participant Signature Date

______________________________________
Printed Name of Participant

**Curriculum and Instruction**
College of Education
261 Bluemont Hall
1100 Mid-Campus Drive
Manhattan, KS 66506
785-532-5550

**PARENTAL LETTER OF CONSENT FOR MINORS**
**Research Study of a Science Education Partnership**

Dear Parent or Guardian:

I am a doctoral candidate and researcher working under the direction of Dr. Jeong-Hee Kim, Assistant Professor in the College of Education at Kansas State University. I am conducting a research study to learn about a partnership between a university and a school district. Your child participated in at least one program resulting from this partnership.

We are requesting your child's participation in this research study, which will involve one interview with your child between October 2010 and June 2011. The interview will be conducted by Teresa Woods on the property of your child's school. The interview will be audio-recorded, your child's name will not appear in the transcribed files, and the digital files will be deleted upon completion of the study. Your child's participation in this study is voluntary. If you choose not to have your child participate or to withdraw your child from the study at any time, there will be no penalty such as affecting your child's grade. Likewise, if your child chooses not to participate or to withdraw from the study at any time, there will be no penalty. The results of the research study may be published, but your child's name will not be used.

If you have any questions concerning the research study or your child's participation in this study, please call Teresa Woods at 913-269-8512, or Dr. Jeong-Hee Kim at 785-532-6976.

Sincerely,

Teresa M. Woods

Doctoral Candidate and Researcher
K-State Olathe Innovation Campus
18001 W. 106th St., Suite 130
Olathe, KS 66061
Phone: 913-269-8512

Dr. Jeong-Hee Kim

Assistant Professor
Department of Secondary Education
Kansas State University
Phone: 785-532-6976

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By signing below, you are giving consent for your child, ____________________________________,
to participate in the above study.

____________________________ ________________________ __________
Signature Printed Name Date

If you have any questions about your or your child's rights as a participant in this research, or if you feel you or your child have been placed at risk because of the participation, you can contact the Chair of the Human Subjects Institutional Review Board, Rick Scheidt, at 785-532-3224.

# Appendix B - Interview Questions

## Adult – Whole Partnership

1. General questions
    a. How would you describe this partnership?
    b. What are the goals of the partnership?
    c. How do you experience the partnership in your own work?
    d. What exists, or what things happen, that wouldn't without the partnership?
    e. How is the partnership different today than what you originally envisioned?
    f. What resources does each institution contribute to the partnership?
    g. What does each institution gain from the partnership?

2. How has the partnership evolved?
    a. From your perspective, how did the partnership come into being?
    b. What were some important decisions and agreements made at the beginning of the partnership?
    c. How were these decisions and agreements made?
    d. How were decisions and agreements carried out?
    e. What has contributed to the development of the partnership?
    f. How has the partnership changed over time?

3. What are the emerging issues of the partnership?
    a. What would a perfectly successful partnership look like?
    b. In what ways is the partnership currently successful?
    c. What might success for the partnership look like in the future?
    d. What challenges has the partnership faced?
    e. How have challenges in the partnership been dealt with?
    f. What helps you to engage successfully in the partnership?
    g. What do you do to help foster the success of the partnership?
    h. What do you see others do to foster success?
    i. How do these strategies foster success?

4. How have multiple constituents experienced the partnership?
    a. How would you describe your professional role?
    b. How well do you feel other partnership members understand, or don't understand, your professional role? Please describe.
    c. How well do you feel you understand, or don't understand, the professional roles of other partnership members? Please describe.
    d. How well do you feel other partnership members respect your professional role?
    e. What would you like to share with other partnership members that might be beneficial?
    f. What would you like to learn or experience from other partnership members that might be beneficial?

## Adult – Embedded Program(s)

5. General questions
    a. How would you describe this program?
    b. What are the goals of the program?
    c. How do you experience the partnership in your own work with this program?
    d. What exists, or what things happen in this program, that wouldn't without the partnership?
    e. How is the program different today than what you originally envisioned?
    f. What resources does each institution contribute to the program?
    g. What does each institution gain from the program?

6. How has the program evolved?
    a. From your perspective, how did the program come into being?
    b. What were some important decisions and agreements made at the beginning of the program?
    c. How were these decisions and agreements made?
    d. How were decisions and agreements carried out?
    e. What has contributed to the development of the program?
    f. How has the program changed over time?

7. What are the emerging issues of the partnership within this program?
    a. What would a perfectly successful partnership look like in relation to this program?
    b. In what ways is the partnership currently successful in relation to this program?
    c. What might success for the program look like in the future?
    d. What challenges has the program faced?
    e. How have challenges in the program been dealt with?
    f. What helps you to engage successfully in the partnership in relation to this program?
    g. What do you do to help foster the success of the partnership in relation to this program?
    h. What do you see others do to foster success?
    i. How do these strategies foster success?

## Student – Embedded Program(s)

1. General questions
    a. How would you describe this program?
    b. What do you think are the goals of the program?
    c. How do you personally experience the program?
    d. Are you aware this program involves a partnership with Kansas State University? If so, how?
    e. What do you think may exist in this program that wouldn't without the partnership?

2. What are the emerging issues of the partnership?
    a. How would you describe a scientist?
    b. How would you describe science?
    c. How would you describe scientific research?
    d. Can you imagine yourself being a scientist? Why or why not?
    e. Has your perspective changed as a result of this program? How?
    f. What helps you to engage successfully in the program?
    g. What do you do to foster success?
    h. What do you see others do to foster success of the program?
    i. How do these things foster success?

3. How have multiple constituents experienced the partnership?
    a. How did you experience the program at the beginning?
    b. What did you particularly like and not like about the program?
    c. What was easy and what was challenging?
    d. How were challenges dealt with?
    e. Did the program turn out different than what you originally expected? If so, how?
    f. What have you learned by being part of the program?
    g. How do you think your responses may be different from how others experienced it?