# Using Food Science to Enhance STEM Education

by

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# Abstract

Student success in today's modern, technological world depends on a thorough understanding of Science, Technology, Engineering and Math. The US has made efforts to promote STEM education in recent years which has raised the international ranking of the United States students in STEM disciplines; however, more work is needed to make the US a leader in STEM education. Many methods have been used to help increase student interest and success in STEM disciplines. An integrated curriculum is one such method to heighten STEM education by using multiple subjects to support the content being taught.

Food Science can be used as a tool in integrated curricula to enhance STEM education. The universality, cultural importance, and scientific diversity of food make it a perfect fit to incorporate content from all STEM disciplines. Furthermore, exposing students to the complexity of the food chain, food safety, and food science at a young age sets them up to be informed and educated consumers throughout their lives.

The curriculum prototype developed for this report demonstrates the continuing promise of food science to enhance STEM education. This food-centric, project-based integrated curriculum encompasses all the standards required in fifth-grade science and math in the state of Tennessee with the added benefits of incorporating knowledge of food safety and the realities of the food chain. This curriculum is based on the essential question of how to use a community garden to bring nutrition to the people of Southern Asia. Through dissecting this problem, students learn about geographic diversity, plant growing conditions, food harvesting and preservation techniques, and cost implications to complex problems. Furthermore, the content required in 5$^{th}$ grade math and science in Tennessee is incorporated so that students learn the required content while solving a complex, real-world issue. The use of food science in integrated curricula provides students with hands-on experience in STEM subjects in a way that encourages independent learning, student engagement in the content, and real-world learning experiences.

For students to have success in the modern world, they need a clear understanding of how the material presented in STEM courses relates to their lives. Food science can be used to enhance STEM education in a way that engages students and highlights important learning principles in science, technology, engineering, and math. Food science can elevate STEM education, increase student interest in STEM, and cultivate an engaged and knowledgeable public.

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# List of Abbreviations

STEM- Science, Technology, Engineering, and Math

USDOC- U.S. Department of Commerce

TIMSS- Trends in International Mathematics and Science Study

FoodMASTER- Food, Math, and Science Teaching Enhancements Resources

FMI- FoodMASTER Intermediate Curriculum

NGSS- Next Generation Science Standards

IFT- Institute of Food Technologists

PBL- Project-Based Learning

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# Chapter 1 - The Need for STEM Education

Science, technology, engineering and math (STEM) are pervasive in society. Every person encounters these subjects on a daily basis from the chemical makeup of the food they eat for breakfast to the electricity in the light they turn off at night. Therefore, it is imperative that people have a working knowledge in areas of STEM to be successful in the modern age. However, most people are not trained with basic scientific understanding. Due to this, people are likely to be influenced by perception, opinion, and media reporting when they do not understand scientific principles. Elizabeth Marincola, former President of the Society for Science and the Public, noted that "as the pace of scientific research accelerates, the average citizen is faced increasingly with having to grapple with matters of science in his everyday life."[1]

Education in science, technology, engineering and math has been shown to be valuable to many modern professions.[3] Individuals with STEM knowledge can use their skills in many careers in STEM fields and beyond. Langdon, McKittrick, Beede, Khan, and Doms, economists from the U.S. Department of Commerce (USDOC), note, "Although still relatively small in number, the STEM workforce has an outsized impact on a nation's competitiveness, economic growth, and overall standard of living."[2] Critical thinking skills, which are acquired in STEM disciplines, are needed in today's increasingly technological workplace. STEM classes teach students to solve problems, evaluate facts, and interpret information.[3]

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[1] Elizabeth Marincola, "Why Is Public Science Education Important?," *Journal of Translational Medicine* 4, no. 7 (2006)., p. 1

[2] David Langdon et al., "STEM: Good Jobs Now and for the Future," no. 03-11 (2011). , p.6

[3] Economics & Statistics Administration, "STEM Jobs: 2017 Update," (2017).

In a 2015 review of STEM jobs, the USDOC noted that roughly 6% of all workers in the U.S. worked in STEM occupations. The USDOC considers STEM occupations to include the following career paths: computer and math, engineering and surveying, physical and life sciences, and STEM managerial occupations. Over the past 10 years, employment in STEM fields has grown 24.4% whereas growth in non-STEM fields has only grown by 4%.[3]

The USDOC has cited that STEM workers earned 29% more than their non-STEM peers in 2015. Furthermore, it has been shown that individuals with STEM degrees earn more than their non-STEM peers regardless of whether they work in STEM fields. From 2000-2010, STEM job growth was three times that of non-STEM job growth. STEM employment grew 7.9% during this time whereas non-STEM employment only grew 2.6%. Furthermore STEM workers are less likely to be jobless than their peers. This could be related to the fact that STEM workers have degrees and so are less likely to be jobless than those without degrees in general.[3]

According to the USDOC, STEM graduates earn 20% more than non-STEM majors who work in non-STEM jobs. Physical and life science careers have the highest educated workforce with 40% having graduate-level degrees. STEM fields include professionals and support positions which do not require 4-year degrees. In these roles, 23% have associate degrees, or some college experience; 9% have a high school diploma or less. This shows that opportunities do exist in STEM without advanced degrees.[3]

For women, in particular, pursuing STEM careers can be challenging. According to a report by the USDOC on women in STEM, women make up 47% of the U.S. workforce but only 25% of the STEM jobs. Slightly more than half of college educated workers are women, but only 25% of women pursue jobs in STEM. Women with degrees in STEM are less likely than their male counterparts to work in STEM fields but are more likely to work in education or healthcare. Despite the gender gap in STEM fields, there are lucrative opportunities for women in STEM. Women working in STEM earn 35% more than women working in non-STEM fields. There is also a smaller wage gap between men and women in STEM fields compared to other areas. Women working in STEM earn $0.84 to a man's $1.00 which is a wage gap of 16%. This is an improvement over the wage gap of 19% seen in non-STEM fields.[4]

Although it has been shown that individuals with degrees in STEM earn more and have more stable careers than those in non-STEM fields, education in STEM in the United States needs improvement to move from the fact-memorization methods currently in use to a more holistic approach to STEM education. Marincola argues that it is more important for students to learn broad scientific concepts, like the scientific method, than to memorize minute details. She argues, "Science education at all levels should focus on creating a society where well-educated adults are equipped to bring scientific thinking to bear on issues that affect them as citizens." [5] Marincola argues that when people are trained to think in a scientific way, they become better at their given fields whether they are in STEM or not.

Though it has been shown that STEM education is important for building a modern society, the United States has been trailing many other industrialized countries for decades in the area of STEM education. The Trends in International Mathematics and Science Study (TIMSS) measures how countries compare when it comes to STEM education. Countries are scored on a scale of 0 to 1000 with an average of 500 and a standard deviation of 100. The TIMSS measures aptitude in math and science for fourth and eighth graders in industrialized countries around the

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[4] Ryan Noonan, "Women in STEM: 2017 Update," no. 06-17 (2017).

[5] Marincola, "Why Is Public Science Education Important?."

world. TIMSS was created by the International Association for the Evaluation of Educational Achievement which is an international organization of research institutions and governmental agencies. The goal of the study is to show how well students have learned the concepts taught in math and science.[6]

In the 2015 study, 49 countries and 6 other education systems participated at the grade 4 level. Thirty-eight countries and 6 other educational systems participated at the 8th grade level. Countries are independent political entities. Other educational systems are not stand-alone entities but are sections of larger countries such as the Flemish community of Belgium, England. TIMSS evaluated students in specific areas within science and math at each grade level. For fourth graders, TIMSS tested students on the numbers, geometric shapes, measuring, and displaying data in the math section. It tested students on life science, physical science, and earth science in the science section. For eighth graders, it tested students on numbers, algebra, geometry, data, and probability in math as well as biology, chemistry, physics and earth science in the science section. Across grades and disciplines, TIMSS questioned students on knowing, applying and reasoning as well.[6]

[6] National Center for Education Statistics, "TIMSS 2015 in Brief."

**Table 1: Trends in International Mathematics and Science Study country rankings 2015**

| | 4th Grade | | 8th Grade | |
|---|---|---|---|---|
| **RANKING** | **Mathematics** | **Science** | **Mathematics** | **Science** |
| **1** | Singapore | Singapore | Singapore | Singapore |
| **2** | Hong Kong | Republic of Korea | Republic of Korea | Japan |
| **3** | Republic of Korea | Japan | Chinese Taipei | Chinese Taipei |
| **4** | Chinese Taipei | Russian Federation | Hong Kong | Republic of Korea |
| **5** | Japan | Hong Kong | Japan | Slovenia |
| **6** | Northern Ireland | Chinese Taipei | Russian Federation | Hong Kong |
| **7** | Russian Federation | Finland | Kazakhstan | Russian Federation |
| **8** | Norway | Kazakhstan | Canada | England |
| **9** | Ireland | Poland | Ireland | Kazakhstan |
| **10** | England | **United States** | **United States** | Ireland |
| **11** | Belgium | Slovenia | England | **United States** |
| **12** | Kazakhstan | Hungary | Slovenia | Hungary |
| **13** | Portugal | Sweden | Hungary | Canada |
| **14** | **United States** | Norway | Sweden | Sweden |

Information compiled from the Trends in International Mathematics and Science Study conducted in 2015.[7]

In the most recent study (2015), U.S. fourth graders ranked 14th and eighth graders ranked 10th in mathematics. The same year, fourth graders ranked 10th and eighth graders ranked 11th in science (Table 1). The encouraging news in this report is that U.S. students in fourth and eighth grade showed improvements in scores over previous years. Fourth graders scored an average of 539 points, which was an increase over the 1995, 2003, and 2007 scores. Eighth graders (with an average score of 518 points) increased their score over all previous years of the study (1995, 1999, 2003, 2007, and 2011).[7] These scores show that while the United States still has room to grow in advancements in STEM, improvements are being made to how U.S.

[7] This report gives detailed information of how the U.S. has ranked in each year the TIMSS study has been performed. "Selected Findings from TIMSS 2015," https://nces.ed.gov/timss/timss2015/findings.asp.

students learn STEM subjects.  The TIMSS shows that increased efforts in STEM education are paying off and that students are increasing their STEM acumen.  Though U.S. students' scores are improving, continued work is needed to bolster the STEM education system.  Work can be done to increase the ways in which students interact with STEM educational material.  These new approaches can be used to further elevate the progress the U.S. is making in STEM education.

# Chapter 2 - Overcoming Challenges in STEM Education

Many professionals in education agree that the current state of teaching STEM education needs to change if students are to be fully prepared to work in our increasingly technological world. Professor Yeping Li, Editor-in-Chief of the *International Journal of STEM Education,* said in an interview for an article entitled "Inspired Women in Science Take a Stand against Gender Inequality":

> "We all know that people often need to solve problems in real world that requires the use of integrated knowledge and skills from multiple disciplines. However, current school education is typically subject content-based education, and we simply leave the knowledge integration part to students themselves to manage in the future. There is an apparent gap between what and how school education provides and what and how students will likely need to use in the future."[8]

Researchers from the Department of Elementary Education and Middle Grades Education at East Carolina University understood this struggle to close the gap between classroom education and real-world experiences when they studied how afterschool programs in STEM can impact a student's interest in science. Many education professionals have noted that there is typically a decrease in student interest in STEM subjects in middle school. To combat this, the researchers from East Carolina University developed an afterschool program to engage K-7 students in STEM activities that brought learning out of the classroom and involved real-world experiences to underpin the lessons taught. Chittum et al. describe the results of the program in this way: "our findings may indicate that participation in problem-based afterschool science and

[8] Roberto Garbero, "Inspired Women in Science Take a Stand against Gender Inequality," in *SpringerOpen Blog* (2017).

engineering programs like Studio STEM can serve in assuaging the documented decline in science-based motivation perceptions many students experience during those academic years." [9]

Chittum et al. found that student-centered learning allowed students to make choices and take charge of their own learning. This led to empowerment of the students and increased their enjoyment of the program. Students found the program to be useful both in the classroom and in their lives beyond school. By using real-world applications, students were able to envision using the information they learned in other areas of their lives. Collaborating with teachers, undergraduate students and peers increased the students' feelings of success. This is especially important when dealing with more difficult tasks. Having a support structure that both enabled and pushed students to achieve helped the students feel more successful at the end of the program. Lasting interest in the subjects presented was sparked through a combination of enjoyment and repeated efforts in problem solving along with the ability to explore topics individually in a hands-on way while collaborating with others.[9] These findings highlight ways in which teachers can better engage with their students in order to increase their interest in STEM subjects. By increasing interest in STEM in middle school, teachers can increase the likelihood that students will maintain their motivation to learn STEM subjects and pursue careers in STEM fields.

[9] Jessica R. Chittum et al., "The Effects of an Afterschool STEM Program on Students' Motivation and Engagement," *International Journal of STEM Education* 4, no. 11 (2017).

## Overcoming Barriers for Teachers

Another reason for the struggle to prepare students fully in STEM is a lack of teacher preparation to teach STEM subjects. There are many causes for this stumbling block in STEM education. Teachers are not being properly prepared to teach STEM disciplines and often have negative associations with science from their past experiences with learning the subjects. When this is coupled with decreasing imagination in the classroom a decreased interest from students in STEM is expected. The lack of imagination in how teachers can teach subjects has led students to see scientific facts as disconnected from the real world making the subject unapproachable and distant. It has been shown that a child's understanding is directly tied with the quality of teaching they receive. One way to reach a higher level of teaching is to create a link between content taught in the classroom and student's lives and experiences outside the classroom. [10] John Stiles of the Institute for the Promotion of Teaching Science and Technology within the Ministry of Education in Bangkok, Thailand understands the struggle to get qualified teachers interested in engaging students in STEM learning. Through repeated interactions with teachers experiencing this challenge to bring interest to STEM learning, he has found that teachers and students need consistent and repeated experience with new methods and subjects before they can master them. Stiles has noted that "Schools around the globe continue to stubbornly cling to the notion that 'telling is teaching', and 'listening is learning', resisting the opportunity for students to learn ways to be independent learners, and develop critical thinking skills, problem-solving techniques and creative ways to apply knowledge to real world situations."[11] In order to move

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[10] Andrew Gilbert and Christie C. Byers, "Wonder as a Tool to Engage Preservice Elementary Teachers in Science Learning and Teaching," *Science Teacher Education* 101 (2017).

[11] John Stiles, R., "Skill Development Takes Time for Students (and Teachers!)," *K-12 STEM Education* 3, no. 4 (2017). P. 285

beyond the traditional approaches to teaching STEM, teachers have to engage with students in a new way which takes time and dedication on the part of the teachers, administration, and students.

Andrew Gilbert and Christie Byers, both of George Mason University, argue that teachers have had their natural sense of wonder diminished by traditional approaches to teaching science that put such a high value on reaching one correct answer within the content without going deeper into the scientific questions.  Teachers are also limited because they were taught to think of science in one specific way when they were in elementary school.  They teach from what they know, and they have not experienced science in a wondrous, uncaged way that allows for true scientific thought.  Gilbert and Byers claim that supporting STEM educators to see science through the lens of wonder and imagination will help them transfer the impression of science as approachable and fascinating to their students.[10]

As important as it is for educators to engage their sense of wonder in order to best engage students in STEM, it is equally important for educators to realize that young students have natural curiosity that, if directed properly, can be crafted naturally into scientific learning. Jiyoon Yoon from the Department of Curriculum and Instruction at the University of Texas, Arlington and Kyoung Jin Kim from the Department of Early Childhood Education at Wheelock College in Boston argue that even though young learners are natural scientists, they need direction to turn their natural curiosity into scientific learning.  They believe that "developmentally appropriate engagement with quality science learning experiences is vital to help children understand the world, organize information, apply and test ideas, and develop positive attitudes toward science that will provide a solid foundation for the development of scientific concepts that they will encounter in school settings."[12]

Young learners naturally use basic science skills including observation, communication, classification, measurement, inference, and prediction as they interact with and begin to understand the world around them.  However, Yoon and Kim have found that teachers may be ill-equipped to harness these natural skills in young learners.  They have found that low confidence or low interest from teachers may limit questioning, brainstorming, and discussions in the classroom.  These are all methods which help young learners transform their natural curiosity into true scientific understanding.  Therefore, due to teachers' lack of confidence in teaching STEM in a hands-on, collaborative way, they are missing an opportunity to engage with students at the youngest levels to start forming a natural interest in, and understanding of, STEM subjects.

[12] Jiyoon Yoon and Kyoung Jin Kim, "Science Song Project: Integration of Science, Technology, and Music to Learn Science and Process Skills," *K-12 STEM Education* 3, no. 3 (2017).  p. 236

## Current Approaches to Improve STEM Education: Integrated Curricula

One teaching method that many educators have found to be successful in engaging students and increasing comprehension is to use an integrated curriculum. This method is all about making connections between subjects, content, and skills. Drake and Burns identified three main approaches within this method that are typical in teachers' interpretations of integrated curricula. See Table 2 for a summary of these approaches. The first is a multidisciplinary approach in which standards from multiple disciplines are combined and organized around a single theme. The second approach is interdisciplinary in which the curriculum is organized around common areas across disciplines. Lastly, the transdisciplinary approach is centered on student's questions about the world and is developed around student's life skills. This curriculum is developed so that students solve a large-scale problem with real world implications as part of the learning process.[13]

[13] This book contains detailed information about how to design and implement an integrated curriculum. Susan Drake and Rebecca Crawford Burns, *Meeting Standards through Integrated Curriculum* (Alexandria, VA: Association for Supervision and Curriculum Development, 2004). P.183, p.14

Table 2. Descriptions of the qualities of Multidisciplinary, Interdisciplinary, and Transdisciplinary education.

| | Multidisciplinary | Interdisciplinary | Transdisciplinary |
|---|---|---|---|
| **Organization** | Education standards of multiple disciplines are organized around a theme | Common learnings across disciplines are organized together | Student-guided learning which uses real-life context to increase understanding |
| **Philosophy** | Knowledge is best learned through structure of traditional disciplines | Disciplines are connected by common concepts and skills | Knowledge from all subjects is interconnected and interdependent |
| **Role of Individual Subjects** | Each discipline is distinct and taught separately while centered around a common theme | Disciplines are distinct, but big picture skills like literacy, critical thinking, and numeracy are the focus | Disciplines are identified but not stressed as being individual. Real-life scenarios are the focus. |
| **Role of the Teacher** | Facilitator and specialist in the disciplines | Facilitator and specialist in the disciplines while also being a generalist about overarching topics | Co-planner, co-learner, specialist in the disciplines and generalist in overarching views |
| **Example** | Reading, writing, and oral communication are combined into the topic of language arts | Teaching math through the use of ingredient measurement and recipe design | Students work to improve their city image and while doing so learn critical thinking, problem solving, time management, and some information from individual disciplines |

Information compiled from text in *Meeting Standards through Integrated Curriculum*[13]

Several studies have shown the benefits of teaching using an integrated curriculum. There have been many approaches to integrating multiple subjects together to enhance the curriculum. One such example was completed by Yoon and Kim, who studied early elementary teachers who incorporated music into their teaching of science. They found that integrating music into their teaching allowed them to engage with students in a new way. They also found that the experience of taking subject material and transposing it into verse and rhythm helped them better understand the subjects and improved teachers attitudes toward science. It turned their perception of science from something difficult and intangible into something fun and engaging.[12] This shows how doing things in a different way or engaging new tactics to bring science into new avenues can help students learn while simultaneously increasing teacher interest in science.

Areas beyond music have been used to show the value of integrating STEM education into different educational streams. Tomovic, McKinney, and Berube, STEM education experts from Old Dominion and Hampton University, illustrated the value of using English Literature to teach STEM subjects and enhance skills needed for 21st century students. They hypothesized that English literacy and scientific literacy could go hand-in-hand through the use of English literature being the context for language instruction. According to the National Science Teachers Association, "students learn science best when it is integrated with other areas of the curriculum such as reading, language arts, and mathematics."[14] Tomovic, McKinney, and Berube believe that

> "an integrated approach to teaching would more accurately represent and reflect the highly integrated world in which we live today. Integrated teaching methods better reflect the highly integrated world in which we live today."[14]

## Current Approaches to Improve STEM Education: Project-Based Curricula

David Kanter, professor of Curriculum, Instruction, and Technology in Education at Temple University, believes that an integrated, project-based approach to teaching STEM courses can build meaningful understanding and lasting information retention. Kanter argues that "meaningful understanding of standards-based science does more than just address the goals of classroom accountability; it also addresses today's need to educate scientifically literate individuals, who can use what they know and build on that knowledge to make decisions in the

[14] Cynthia Tomovic, Sueanne McKinney, and Clair Berube, "Scientific Literacy Matters: Using Literature to Meet Next Generation Science Standards and 21st Century Skills," *K-12 STEM Education* 3, no. 2 (2017). P.180

face of uncertainty."[15] Kanter argues that the real-world implications of project-based learning can excite students and can increase class participation. Integrating useful experiential and problems-based learning into specific situations can enhance understanding. This is particularly important and useful when dealing with subjects that are notoriously difficult for students to understand. Drake and Burns agreed on the value of project-based curricula. Through their research on the topic they found that "studies of project-based programs show that students go far beyond the minimum effort, make connections among different subject areas to answer open-ended questions, retain what they have learned, apply learning to real-life problems, have fewer discipline problems, and have lower absenteeism."[13]

Kanter provides detail on how to design courses to best integrate project-based learning into a curriculum in order to increase long term understanding. He shows that in order for students to gain full mastery of concepts, they have to be motivated to learn the material. Part of designing an impactful project-based curriculum is to create demand for the knowledge that is being presented. The challenge here is to find a way to create demand for something when the student has never encountered it and cannot see how the information will be needed in real life. Simply telling students that they will need the information later is not sufficient to create meaningful learning of the material. Kanter shows that sometimes it is necessary to present new information in a round-about way that may not seem directly related to the final goal of the teaching so that the learner can apply the new topic to something they are already familiar with. Kanter describes three ways to handle this challenge to create demand when creating project-based curricula. One way is to "unpack the task" in which students are asked to do a large task

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[15] David E. Kanter, "Doing the Project and Learning the Content: Designing Project-Based Science Curricula for Meaningful Understanding," *Journal of Science Education* (2009). P. 526

or answer a complex question and then work backwards to unload this large problem into steps they already know. In the class, teachers and students work together on interactive examples that show each step. The students know that each of these mini steps will come together to answer the larger question that was presented.

Another method to create a demand for the information presented in a project-based design is to "highlight the incongruity." This approach is to present information to the students and then ask them which piece of information is not like the others, or which piece seems to contradict information they already know. When one scientific concept seems to contradict another, the students are asked to explore both concepts and learn why they do not actually contradict. A third approach is to "try to apply," where students are asked to complete a task or to apply knowledge about something they have not learned yet. After seeing that they did not know how to solve the new problem, they would do a lab or hands-on activity about the new information. The students know that the information in the lab would later be referenced to solve the original problem. This method is similar to learning by failure in which students are asked to apply knowledge they do not have yet. In failing to be able to complete the task, students learn where the gaps in their knowledge are and know that the subsequent lessons will help them fill these knowledge gaps.[15]

Kanter found that it is important when designing a project-based curriculum to include all the material required when creating the project that the class centers on. In project-based learning, students perform a large project, or series of projects that includes all the learning that is required in the subject. In his research, Kanter prepared a science class in which students were asked to find a way to measure the energy in food and the energy used up by doing activities and then redesign their school lunch and activity choices in order to balance these numbers. This project allows students to learn about the physics of potential energy, interconversions of energy, chemical changes that occur during combustion and respiration, and the properties of matter. It also taught students about how organs, tissues, and cells are organized, how organs work together in a system, how bodily systems work together, and how cellular respiration happens.[15] The project for this course, as discussed above, allows students to learn all of the required content while appreciating how the content from different subjects is interrelated. By allowing students to connect the dots between related content, and by giving students hands-on experience with each step in the learning process, students were able to retain the information much better than if they had been presented the information in a lecture format.

If the curricula is not designed to help the learners apply the content in a way that is meaningful to them, they are not likely to remember it and apply it in future applicable situations. Sometimes curricula can be altered slightly in order to achieve the desired result. One that Kanter presents around this topic is of a physics class that is tasked with designing a rocket that will go as high as possible. Instead of having students design a rocket to see how high it could go, the teacher could ask the students if a rocket will go higher if it is painted or unpainted, if it has 3 fins or 4, etcetera to guide the exploration into the reasons each of these scenarios would allow the rocket to go higher.[15]

Kanter found that the time the course takes make an impact on how much students truly learn and retain. Learning is hindered if too much time passes from the start where the question or project is presented to the end where the performance is completed. One common approach to teaching uses a capstone project that students complete to show how much they have learned through the course. The cognitive load theory shows that this approach is flawed because the student is not given the opportunity to apply the content; therefore, the student cannot integrate new information with prior knowledge in long-term memory. The student than will have a heavy working memory load which is hinders meaningful understanding of the material.[15] Teaching all the material up front at the start of the class, then having students apply the knowledge at the end of the class, several weeks later, can impede long term memory formation. To combat this, Kanter recommends that the material be broken into sections. This allows students to apply their knowledge as they go. Then as students continue in the class, new information can be presented and added to what was already learned. This allows teachers to build on what was learned and to keep reinforcing it while also introducing new material.[15]

# Chapter 3 - Using Food Science in the Classroom

Many professionals in the food industry and academia see the potential of food science to enhance student learning. Understanding the impact that education can have on fighting the obesity epidemic, many programs exist to teach nutrition to K-12 students in the United States. Other programs teach cooking skills to young students in order to get them interested in cooking. Some programs use gardens in schools and communities in order to increase fruit and vegetable consumption with the idea that if students work with fruits and vegetables they will be more likely to eat them. A few programs exist that bring math and science into food education. Many of those programs are covered in this chapter.

## Using Food Science in the Classroom: the FoodMASTER Approach

The Food, Math, and Science Teaching Enhancement Resources (FoodMASTER) Initiative was created in 2005 as a National Institute of Health Science Education Partnership Award Project. It was structured as a compilation of programs to use food as a tool to teach math and science. Creators of the program believe that education in science and math is imperative to stimulating interest in research careers and can empower children to be effective and productive citizens. They argue that interest in scientific careers can be formed as early as elementary school. Creators of the FoodMASTER program argue that food can be used as a teaching tool because students encounter it daily. Moreover, food can be used to teach science material and basic research methods. Their approach is to use food as a tool to encourage learning in microbiology, chemistry, biology, nutrition, health science and math. They use hands-on lessons that allow for interdisciplinary learning in STEM subjects.[16]

In 2004, Phillips, Durrin, and Geist, founders of the FoodMASTER program, developed a program called Kitchen Wizard: Food Science for Kids, which provided lessons in food science with the goal of teaching mathematical and scientific concepts. This project encouraged learning in science and math by using food and led to the development of the FoodMASTER program. Kitchen Wizard was a program for gifted 4th and 5th grade students that showed that when food was used in the appropriate way, it could be a tool to help students develop skills in science and math. Lessons were 2.5 hours long and the program lasted 14 weeks. Eight of the classes focused on food science and the remaining six focused on consumer science. During each lesson, students gathered data, took notes, formed hypotheses, and solved problems.[17]

The lessons covered many basic food concepts such as proper measuring technique, the effects of different processing methods, and the application of different ingredients. Students worked with fractions consistently in each class. Once they mastered the basic measurements (one whole, one half, and one quarter), they worked with smaller fractions by using a restricted number of measuring cups. This forced the students to convert the measurements into terms of each fraction. They created the same food many ways to see how ingredients affected the results. For example, students had to form a hypothesis around how using sifted and unsifted flour would affect a cake recipe. Then they created the recipes and came up with conclusions about the results. Students compared weight and volume by measuring one-half cup of shortening first in a cup and then through displacement with water. Students compared fresh,

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[16] M. W. Duffrin et al., "Using Food as a Tool to Teach Science to 3 Grade Students in Appalachian Ohio," *Journal of Food Science Education* 9, no. 2 (2010).

frozen, and canned vegetables for sensory characteristics. They also looked at how each preservation method affected the vegetable's nutrient loss by observing the color loss in the vegetables after processing. Students observed how boiling broccoli in different solutions (water, water plus baking soda, water plus cream of tartar) affected the vegetable. This showed how different preparation methods affect the cell structure by observing how mushy the broccoli became with each method. By the end of the program, students had a basic understanding of fundamental food science concepts and had used math and science in real-world contexts.[17]

In 2007-2008, the FoodMASTER program worked with 3rd grade teachers from Ohio to implement 45 hands-on lessons throughout the school year. They were looking, in part, to better understand the students' needs to be able to improve attitudes toward science and math. The lessons were each one hour long and the teachers implemented them as time allowed throughout the academic year. A content-based test was given at the end of each lesson. In addition, a science proficiency test was given at the beginning and the end of the program. In analyzing the pre-and-post program test data, researchers found that female students showed a significant difference from the control group to the test group in their attitude toward science by the end of the school year. This was not seen in the male students. In fact, some male students had worsened attitudes toward science in the post test versus the pre-test suggesting that this approach did not work well for this age group of male students. This could be due to gender differences in this age group about preferences regarding scientific topics. These negative results for male students in the testing did not line up with teachers' observations of these same students during the lessons. Teachers noted that most students, male and female, were very excited about

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[17] Sharon Phillips, Melani W. Durrin, and Eugene A. Geist, "Be a Food Scientist," *Science and Children* January (2004).

the lessons and became increasingly interested in the subjects over time. Teachers reported that students preferred these hands-on lessons to traditional textbook and lecture style classes. They also noted that the students were more engaged and excited about learning in the FoodMASTER lessons than any other lessons during the day. The disconnect between the test results and the observations may stem from students not relating the hands-on classes to science in the way they typically experienced it. Science for this age group is often received in a passive way while the FoodMASTER program was active learning.[18]

A similar research project was developed in Ohio and North Carolina in the 2009-2010 school year. This project looked to see how the FoodMASTER Intermediate Curriculum (FMI) could combine nutrition, science and math education by using hands-on lessons with food as the backbone of learning. The project involved 34 fourth-grade classes. Eighteen of the classes integrated the FMI curriculum into their existing curriculum throughout the year in 24 food-based lessons. The remaining 16 classes served as the control group. All 34 classes completed a test at the beginning and end of the school year to measure knowledge in nutrition, science and math. In all, 438 students participated in the beginning and end of year testing and their scores were analyzed to understand how nutrition, science, and math curricula can be integrated. Science and math knowledge were positively impacted by using food as a tool in the learning process. Nutrition knowledge increased as science knowledge increased, showing that science and nutrition integrate well together and can mutually bolster student achievement. The results showed that nutrition can be related to the Next Generation Science Standards for physical science and life science. Specifically, nutrition can be used to help teach the topics of energy transfer, chemical reactions, matter, energy and the organization of living systems. Nutrition

[18] Duffrin et al., "Using Food as a Tool to Teach Science to 3 Grade Students in Appalachian Ohio."

knowledge was also linked to mathematics knowledge but to a lesser extent than science knowledge. Nutrition education can be used to help students learn statistics, probability, proportions, measuring, converting units, problem solving, and collecting, organizing, describing, and displaying data. The test group of students showed a high association between nutrition knowledge and science and math knowledge. In the control group, end of the year nutrition knowledge was not seen to be impacted by their science and math knowledge, showing that using food as a tool helped students interrelate the three subjects and learn them all better than if they were taught separately. Using food to teach nutrition, science, and math led to strong associations between the three subjects within the test classes. The interaction between nutrition, science, and math learning shows that teachers can combine these subjects to some degree without losing time in teaching. With time resources being scarce, this data shows that integrating food and nutrition education into existing classes in math and science can help teach all three subjects without taking any additional class time. This study illustrated that integrating nutrition and food education into math and science classes can have a meaningful impact on learning in all three subject areas. It also showed the value of applying real-life situations to standard science and math classes. This study displayed that using a hands-on approach can prepare students in a better way to understand mathematics and science while simultaneously supporting a healthy lifestyle. [19]

[19] Virginia C. Stage et al., "Exploring the Associations among Nutrition, Science, and Mathematics Knowledge for an Integrative, Food-Based Curriculum," *Journal of School Health* 88, no. 1 (2018).

## Using Food Science in the Classroom: Integrating Math and Nutrition

Another project looked at integrating nutrition and math education. James and Adams, professors at the University of Florida, considered nutrition and math to be perfect pairs and apt for integration. The study of nutrition utilizes statistics, probability, estimation and proportion, which are all subjects that students frequently have difficulty understanding. James and Adams argue that math is often combined with science in integrated curricula, but not often other subjects. This limits the view that students get of math. In their project, James and Adams instructed elementary students using two activities. The first was called the "5 and 3 store" in which students would get $20 of pretend money to buy food at a grocery setup in the classroom. Students learned how to estimate purchase totals by adding and subtracting as well as how to make change and calculate sales tax. In the second activity, "supermarket challenge," students compared the nutrient content of foods, analyzed their cost, estimated their price, and then presented their results in picture graphs, line graphs, bar graphs, and circle graphs.[20] These activities allowed students to practice math in real-world situations. They were able to see the content as more than just material in a text book. By using real-world situations and hands-on learning, students were able to interact with the content in new ways and make new connections with the material.

[20] Delores C.S. James and Thomasenia Lott Adams, "Curriculum Integration in Nutrition and Mathematics," *Journal of School Health* 68, no. 1 (1998).

## Using Food Science in the Classroom: Public Engagement in Food Science Education

Harvard researchers, Rowat, Rosenberg, Hollar, and Stone, conducted a class to engage the public in learning food science. Their report shows how food science can be used to increase excitement for, and understanding of science in the public for individuals of all ages.[21] The researchers conducted an hour-long class on the science of pizza. The class was crafted to have content for learners as young as age 6 but to have information that was still engaging and interesting to adults and learners of all ages in between. They covered topics such as building molecules from atoms and small molecules, forming networks of molecules that are bonded together, the role that microbes play in the texture of food, and how digestion and enzymatic degradation work. The class was designed to be interactive to increase engagement. The researchers succeeded in this by asking the audience questions every 10 minutes to keep them engaged, using children to participate in role-playing segments to get them actively involved, and using tasting experiments to give all learners a way to interact with the material. The class was for parents and children because having the parents participate had the potential to create long-term changes in the family's behavior.[21] This project shows how food can be used to increase scientific understanding for learners of all ages. This material can be adapted to learners in particular age ranges and can be used to meet the National Science Education Standards. This

[21] This article goes into detail on how the Harvard researchers conducted their class, including the class material they used and how they structured each learning segment. Amy C. Rowat et al., "The Science of Pizza: The Molecular Origins of Cheese, Bread, and Digestion Using Interactive Activities for the General Public," *Journal of Food Science Education* 9 (2010).

is a good example of the role that food can play to support science learning in the public for learners of all ages.

## Using Food Science in the Classroom: The IFT Integrated Food Science Kit

The Institute of Food Technologists (IFT) recognized the value of introducing Food Science to high school students to increase their exposure to the subject and increase the number of students pursuing Food Science in college. To this end, they crafted food science kits that teachers could use to integrate food science into their classrooms. The kit included a DVD, poster, and experiment guide for high school teachers. The program that IFT implemented was a good way to get students exposed to, and interested in, food science but the scope of their program was limited to a few very specific topics. Expanding the program to a more holistic and integrated approach would allow for deeper understanding of the topics and full integration of the Food Science material into the standard science curriculum. It was discovered that to be successful, teachers needed training in order to feel comfortable performing the experiments. Therefore, IFT piloted a training workshop for teachers to address this. [22] Workshops like this are a great way to help teachers integrate food and Food Science into their curricula.

## Using Food Science in the Classroom: An Australian Approach using Kitchen Gardens

Another prime example of a program that used food and hands-on activities to enhance learning in a STEM subject is the kitchen garden project completed by the 5th and 6th grade students at Wooranna Park Primary School in Melbourne, Australia. In this experiential learning

[22] Barbara Schaich-Rogers, "Training Teachers to Use Food to Teach Science," *Journal of Food Science Education* 6 (2007).

project, students were involved in the design, construction, planting, and maintenance of a school garden. They were able to integrate mathematical concepts into their learning about plant systems and agriculture. Students designed the gardens following specific dimensional criteria to ensure maximum efficiency with the space given and the growing needs of the plants. During construction, students measured wood for the garden beds, calculated soil capacity, and ensured that the beds were level. Students worked with a water tank for the garden and with it practiced their skills in estimation, fraction terminology, and understanding of capacity. Students also measured the growth of the plants weekly and graphed the progress of their plantings. They created rain gauges and organic pesticides for use in the garden. Throughout the process, students journaled about their activities and progress. This allowed them to see the value of the mathematical concepts they were exploring and using in the garden. Even students who were typically disengaged in class fully participated in the activities due to the interest raised with experiential learning with real-world implications.[23] This example illustrates how an integrated curriculum following a transdisciplinary approach can enhance the learning and interest of students. Although this example is from a program in Australia, the implications hold true for students in many countries including the United States.

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[23] Anthony Lyon and Leicha Bragg, "Food for Thought: The Mathematics of the Kitchen Garden," *Australian Primary Mathematics Classroom* 16, no. 1 (2011).

# Chapter 4 - Food Project-Based Learning Curriculum Prototype that Complies with Tennessee Educational Standards

According to Vasquez, Sneider, and Comer in their book, *STEM Lesson Essentials*, project-based learning has three essential elements. The first is to develop an essential question which becomes the driver for student engagement throughout the year. Second is to create standards-based STEM learning objectives, which provide direction for the lessons. The third is to utilize students' previous experiences to individualize the curriculum. In project-based learning (PBL), it is important to start with the essential question and then break it down into manageable amounts of content through the use of lesson questions, curriculum framing questions, and content questions to guide learning throughout the year. Lesson questions can be used to help students break down the essential question into manageable pieces. Curriculum framing questions challenge students to connect real-world issues that drive the project and key concepts within the discipline. Lastly, content questions help students move forward on the project as they master vocabulary, concept knowledge, and skills. In PBL, the teacher crafts the essential question and guides the students through their breakdown of the material. The teacher provides content and support while the students pursue answers to the questions that lead them to solve the essential question. Students work in groups in which they can best utilize their individual talents. The groups can be assigned so that students of similar skill levels are together and can learn at the same pace.[24]

[24] Jo Anne Vasquez, Cary Sneider, and Michael Comer, *STEM Lesson Essentials: Integrating Science, Technology, Engineering, and Mathematics* (Portsmouth, NH: Heinemann, 2013).

When designing a project-based curriculum, it is important to design an essential question that facilitates learning in all the standards that students are required to learn during the course of the year. Since PBL is transdisciplinary, standards for multiple subjects can be met within one project. This transdisciplinary approach means that work on the project can occur over multiple subjects, which ties together material from math into science and history into art. It is a unique way to engage students in holistic learning in which they work to solve a meaningful problem in society.

The following example curriculum was designed following the approach to PBL laid out by Vasquez, Sneider, and Comer. It was designed to meet the standards for $5^{th}$ grade math and science within the Tennessee state curriculum.[25] [26] The $5^{th}$ grade was chosen due to the documented decrease in student motivation in STEM learning at this age. If students can engage meaningfully in STEM education in the middle-school years, they are more likely to have a positive view of STEM as they move forward in their academic career.[9]

**Table 3. Math Education Standards for 5th Grade in the state of Tennessee**

| Tennessee 5th Grade Math Standards | |
|---|---|
| **Domain/ Conceptual Category** | **Content** |
| Numbers and Operations Base 10 | Understand the place value system |
| | Perform operations with multi-digit whole numbers and with decimals to hundredths |
| Numbers and Operations-fractions | Using equivalent fractions as a strategy to add and subtract fractions |
| | Apply and extend previous understandings of multiplication and division to multiply and divide fractions |
| Operations and Algebraic Thinking | Write and interpret numerical expressions |
| | Analyze patterns and relationship |
| Geometry | Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition |
| | Graph point on the coordinate plane to solve real-world and mathematical problems |
| | Classify two-dimensional figures into categories based on their properties |
| Measurement and Data | Convert like measurement units within a given measurement system from a larger unit to a smaller unit |
| | Represent and interpret data |

Content derived from the Tennessee state 5th Grade Education Standards for Math[25]

[25] "Tennessee Math Standards," ed. Tennessee State Board of Education (2017).

**Table 4. Science Education Standards for 5$^{th}$ Grade in the state of Tennessee**

| Tennessee 5th Grade Science Standards | |
|---|---|
| **Domain/ Conceptual Category** | **Content** |
| Embedded Inquiry | Explore scientific phenomena by asking questions, making logical predictions, planning investigations, and recording data |
| | Select and use appropriate tools and simple equipment to conduct an investigation |
| | Organize data into appropriate tables, graphs, drawings, and diagrams |
| | Identify and interpret simple patterns of evidence to communicate the findings of multiple investigations |
| | Recognize that people may interpret the same results in different ways |
| | Compare the results of an investigation with what scientists ready accept about this question |
| Embedded Technology and engineering | Describe how tools, technology, and interventions help to answer questions and solve problems |
| | Recognize that new tools, technology, and inventions are always being developed |
| | Identify appropriate materials, tools, and machines that can extend or enhance the ability to solve a specified problem |
| | Recognize the connection between scientific advances, new knowledge, and the availability of new tools and technologies. |
| | Apply a creative design strategy to solve a particular problem generated by societal needs and wants |
| Life Science- Cells | Distinguish between the basic structures and functions of plant and animal cells |
| Life Science- Interdependence | Investigate different nutritional relationships among organisms in an ecosystem |
| | Explain how organisms interact through symbiotic, commensal, and parasitic relationships |
| | Establish the connections between human activities and natural disasters and their impact on the environment |
| Life Science- Flow of matter and energy | Demonstrate how all living things rely on the process of photosynthesis to obtain energy |
| Life Science- Heredity | Describe how genetic information is passed from parents to offspring during reproduction |
| | Recognize that some characteristics are inherited while others result from interactions with the environment |
| Life Science-Biodiversity and change | Investigate physical characteristics associated with different groups of animals |
| | Analyze fossils to demonstrate the connection between organisms and environments that existed in the past and currently |
| Life Science-The universe | Compare planets based on their known characteristics |
| | Recognize the charts can be used to locate and identify star patterns |
| Life Science-The Earth | Compare geologic events responsible for the earth's major geological features |
| Life Science-The Atmosphere | Analyze and predict how major landforms and bodies of water affect atmospheric conditions |

| | |
|---|---|
| Physical Science- Matter | Observe and measure the simple chemical properties of common substances |
| | Design and conduct an experiment to demonstrate how various types of matter freeze, melt, or evaporate |
| | Investigate factors that affect the rate at which various materials freeze, melt, or evaporate |
| Physical science- energy | Design an experiment to illustrate the difference between potential and kinetic energy |
| | Conduct experiments on the transfer of heat energy through conduction, convection, and radiation |
| Physical science- motion | Design and investigate, collect data, and draw conclusions about the relationship among mass, force, and distance traveled |
| Physical science- forces in nature | Recognize that the earth attracts objects without directly touching them |
| | Investigate how the shape of an object influences the way that it falls toward the earth |
| | Provide examples of how forces can act at a distance |

Content derived from the Tennessee state 5th grade Education standards for Science[26]

[26] "Grade 5 Science Standards," ed. Tennessee Department of Education (2016).

## Curriculum Prototype: The Essential Question

For this food project-based curriculum, the essential question was selected to be: How can the community garden model be used to bring nutrition to the malnourished people of Southern Asia? The Food and Agriculture Organization of the United Nations has noted that Southern Asia has the highest burden of hunger of any region in the world. Some 281 million people were recorded as malnourished in the 2015 State of Food Insecurity in the World report.[27] The essential question defined above has several educational benefits. First, it benefits society and so produces a worthwhile end product. Second, as will be shown in subsequent pages, researching and answering this question allows for the coverage of all the Tennessee 5th grade math and science standards and so fulfills the need to cover all necessary content.[15] Third, it is a complex topic that can foster engaging discussion and involvement for the students throughout the course of the year. While significant work is required by the teacher before the first year of this course, slight adaptations can be made with little additional effort in subsequent years. Different regions of the world or within the United States can be covered during different years to allow students to have unique experiences while providing a simple framework from which the teacher can work.

[27] This report outlines the progress various regions have made toward the 2015 Millennium Development Goals target of reducing the proportion of hungry people in the world by half by 2015. *State of Food Insecurity in the World 2015. Meeting the 2015 International Hunger Targets: Taking Stock of Uneven Progress*, ed. Food and Agriculture Organziation of the United Nations (Rome2015).

## Curriculum Prototype: Lesson Questions

The broad essential question of how to use community gardens to bring food to malnourished people in Southern Asia can be broken down into a series of lesson questions that lead students toward solving the essential question while learning, through hands-on experimentation, the standard content required.

First it is important to frame the essential question in the history and culture of Southern Asia to familiarize the students with the problem and to bring the work to life. The lesson question for this topic is: What are the foods, traditions, cooking methods, and preservation techniques common in this region? Students can research answers to this question in small groups and through hands-on learning activities. Multidisciplinary learning can occur through lectures and activities in history classes on this topic. A good way to introduce the topic in the start of the year is through having a cultural experience day for the students. They can taste the foods common to the region, see pictures of the area and go on a virtual walking tour of the region. Students can research in small groups what countries comprise Southern Asia and can fill in a map of the region with the appropriate countries. Students can listen to music from the region and can try on clothes popular in this region. This introduction brings the topic to life and shows the students that the project will be helping real people.

**Table 5. Student learning areas associated with the lesson question: What are the common foods, traditions, cooking methods, and preservation techniques in this region?**

| Lesson Question | Curriculum Framing Questions |
|---|---|
| What are the common foods, traditions, cooking methods, and preservation techniques common in this region? | What countries make up Southern Asia? |
| | What are common traditions of the people of Southern Asia? |
| | What are the common foods of Southern Asia? What are common fruits, vegetables, meats and dairy products of this area? How do people prepare food here? |
| | What are common clothes for people in this region? |
| | What is the musical tradition of this area? |

The second lesson question covers basic understanding of the environmental conditions of Southern Asia. Students can research the soil conditions, rainfall amounts and rainfall patterns of the area. They can learn about the differences seen in each country based on its geology. They can learn about the directness of the sun in this area, patterns of the seasons, geological features, and vulnerability to natural disasters. They can graph the average temperatures recorded each month, the average wind patterns seen in the area, and the typical rainfall each month. They can research historical natural disasters in the region to learn about how geological features effect an areas vulnerability to major weather events.

**Table 6. Student learning areas associated with the lesson question: What are the environmental conditions in Southern Asia?**

| Lesson Question | Curriculum Framing Questions | Tennessee Educational Standards Met |
|---|---|---|
| What is the environment in Southern Asia? | What are the soil conditions of Southern Asia? What is soil made of? What are minerals? | Science- Observe and measure the simple chemical properties of common substances |
| | How is the geology of each country in Southern Asia different? What effect does this have on the environmental conditions? | |
| | How direct is the sun in Southern Asia? Why are some places hotter than others? | Science- Conduct experiments on the transfer of heat energy through conduction, convection, and radiation |
| | How does the Earth move around the sun? What does this movement do for the directness of the sun in various places on Earth? | |
| | What are the rainfall amounts and patterns in this area? What is a rainy season and a dry season? What is a monsoon? | Science- Analyze and predict how major landforms and bodies of water affect atmospheric conditions |
| | What are the geological features of Southern Asia? Why do certain places on Earth have different geological features than others? | Science- Compare geologic events responsible for the earth's major geological features |
| | What are the seasons like in Southern Asia? What are the temperatures each month, and the wind, rain, and snow in each season? | |
| | What are rainfall amounts and patterns in Southern Asia? | Math- perform operations with multi-digit whole numbers and with decimals to hundredths |
| | How vulnerable is the area to natural disasters? What causes natural disasters? What makes an area more prone to natural disasters? | Science- Establish the connections between human activities and natural disasters and their impact on the environment |

The third lesson question covers what plants can be combined to create a balanced diet. Through answering this question, students learn about basic nutrition such as what an essential nutrient is and what vitamins and minerals do for the body. They learn why certain foods are important to the diet and why the body needs them. They can learn about how the body breaks down food into its basic building blocks which the cells use as energy. Through this question, students can also learn about what the growing needs of plants are. They can seek to understand if this region provides these growing conditions. Students can brainstorm what supplemental technology would allow these plants to be grown in this region. Through this they have an opportunity to learn how plants use photosynthesis to create energy to grow. They can also determine what combination of plants would lead to year-round food for the community.

**Table 7. Student learning areas associated with the lesson question: What plants can be combined to create a balanced diet?**

<table>
<tr><th>Lesson Question</th><th>Curriculum Framing Questions</th><th>Tennessee Educational Standards Met</th></tr>
<tr><td rowspan="10">How do plants grow?</td><td>Why do plants need the sun?</td><td rowspan="2">Science-Demonstrate how all living things rely on the process of photosynthesis to obtain energy</td></tr>
<tr><td>What is photosynthesis?</td></tr>
<tr><td>Why do plants need water?</td><td></td></tr>
<tr><td>Why do different plants have differing needs for water and sun?</td><td>Science-Investigate different nutritional relationships among organisms in an ecosystem</td></tr>
<tr><td>What happens during germination, growth, and reproduction?</td><td rowspan="6">Science-Describe how genetic information is passed from parents to offspring during reproduction<br><br>Science-Recognize that some characteristics are inherited while others result from interactions with the environment</td></tr>
<tr><td>What are cells made of?</td></tr>
<tr><td>What are the parts of a cell?</td></tr>
<tr><td>What do plant cells look like?</td></tr>
<tr><td>What is cell differentiation?</td></tr>
<tr><td>What is cell division?</td></tr>
<tr><td rowspan="3">What are the growing needs of the plants</td><td>Does the region provide these growing needs?</td><td></td></tr>
<tr><td>What supplemental technology would allow these plants to be grown in this region?</td><td>Science-Recognize that new tools, technology, and inventions are always being developed</td></tr>
<tr><td>What combination of plants would lead to year-round food for the community?</td><td>Science-Identify appropriate materials, tools, and machines that can extend or enhance the ability to solve a specified problem</td></tr>
<tr><td rowspan="7">What plants can be combined to create a balanced diet?</td><td>How do you create a balanced diet?</td><td></td></tr>
<tr><td>What are essential nutrients and why are they important to the body?</td><td>Science- Observe and measure the simple chemical properties of common substances</td></tr>
<tr><td>Why do different plants provide different nutrients?</td><td rowspan="4">Science- Distinguish between the basic structures and functions of plant and animal cells<br><br>Science- Investigate different nutritional relationships among organisms in an ecosystem</td></tr>
<tr><td>How do you combine various plants to create a balanced diet?</td></tr>
<tr><td>Why does the body need various nutrients?</td></tr>
<tr><td>How does the body break down food?</td></tr>
<tr><td>Are there any plants that do not grow well together?</td><td>Science- Explain how organisms interact through symbiotic, commensal, and parasitic relationships</td></tr>
</table>

Next, the students can seek to understand how many plants are needed to feed communities of various sizes. They can learn about plant yields and about how much of each food is needed to provide the necessary nutritional benefits needed to provide adequate nourishment. They can learn about the varying nutritional needs of people based on their age.

**Table 8. Student learning areas associated with the lesson question: How many plants are needed to feed communities of various sizes?**

| **Lesson Question** | **Curriculum Framing Questions** | **Tennessee Educational Standards Met** |
|---|---|---|
| How many plants are needed to feed communities of various sizes? | How much produce does each plant typically yield? | Math- Perform operations with multi-digit whole numbers and with decimals to hundredths |
| | How much of each food is needed to provide the necessary nutritional benefits to maintain a healthy body? | |
| | How do people's nutritional needs change with age? | |

The fourth lesson question answers the following: what is the best way to harvest the fruits and vegetables produced in the garden? Students can learn how to know when food is ripe. They can learn about how the growing season and ripeness effect the qualities of the plants and the nutritional makeup of the produce. They can learn about traditional harvesting techniques used by people of Southern Asia and compare these methods to those used in the United States. Students can investigate what technology is used in harvesting and what new technology could be used to make harvesting more efficient.

**Table 9. Student learning areas associated with the lesson question: What is the best way to harvest the fruits and vegetables produced in the garden?**

| Lesson Question | Curriculum Framing Questions | Tennessee Educational Standards Met |
|---|---|---|
| What is the best way to harvest these plants? | How do you know when produce is ripe? | Science- Observe and measure the simple chemical properties of common substances |
| | How does ripeness effect the nutrition of produce? | |
| | How does the growing season/ripeness effect the qualities of the plants? | |
| | What technologies are used to harvest these plants?<br><br>How can the plants be harvested safely? What food safety principles are important when harvesting crops? | Science- Design and investigate, collect data, and draw conclusions about the relationship among mass, force, and distance traveled.<br><br>Science- Provide examples of how forces can act at a distance.<br><br>Science- Investigate how the shape of an object influences the way that it falls toward the earth |
| | What is the growing season of each plant? | |

Subsequently, students can answer the lesson question: how can the produce be best prepared to preserve its nutritional qualities? Students can research preservation techniques common to the region. Through this work they can describe how tools, technology, and inventions help to answer questions and solve problems. They can work hands-on with various preservation techniques such as pickling, canning, baking, salting, refrigerating, and freezing to understand how different techniques produce different results. They can also work to understand how various cooking methods change how nutrients are preserved in the food. They can experiment with color loss of various vegetables during steaming and boiling to understanding how boiling leads to the loss of more nutrients as described in Phillips et al program.[17] Students can explore how heat transfer affects various foods differently. This leads to how each food conducts heat and how different heating methods affect how heat is transferred to the food. Through this topic, students can also learn the basics of food safety. They learn how preservation techniques reduce the microbial load of foods which makes them last longer. Through this they can learn about cells and how to distinguish between the basic structures and functions of plant and animal cells. Similarly, students can learn about the microbial breakdown of plant material that happens during decomposition. They can learn about composting and how nutrients transfer from the decaying plant matter back into the soil and how this brings nutritional qualities to subsequent plantings. Along with understanding how produce can be preserved, students can learn about how to preserve seeds for subsequent years of planting. They can estimate how many seeds are needed to provide food for various population sizes.

**Table 10. Student learning areas associated with the lesson question: how can the produce be best prepared to preserve its nutritional qualities?**

| Lesson Question | Curriculum Framing Questions | Tennessee Educational Standards Met |
|---|---|---|
| How can the produce be best prepared to preserve its nutritional qualities? | What preservation techniques common to the region? | Science- Describe how tools, technology, and interventions help to answer questions and solve problems.<br><br>Science- Design and conduct an experiment to demonstrate how various types of matter freeze, melt, or evaporate |
| | How do various cooking methods change how nutrients are preserved in a food?<br><br>How does heat transfer through various foods differently? How do foods conduct heat? How do different heating methods affect how heat is transferred to food? | Science- Recognize that new tools, technology, and inventions are always being developed<br><br>Science- Identify appropriate materials, tools, and machines that can extend or enhance the ability to solve a specified problem<br><br>Science- Recognize the connection between scientific advances, new knowledge, and the availability of new tools and technologies.<br><br>Science- Investigate factors that affect the rate at which various materials freeze, melt, or evaporate |
| | How do you make sure food is safe to eat? How can you reduce the microbial load of the foods to make them last longer? | Science- Recognize the connection between scientific advances, new knowledge, and the availability of new tools and technologies. |
| | How are foods broken down by the environment? What role do microbes play in the decomposition of food? How do nutrients transfer from decaying plant matter back into the soil? What qualities does this brings to soil for subsequent plantings? | Science- Analyze fossils to demonstrate the connection between organisms and environments that existed in the past and those that currently exist |
| | How are seeds preserved? | |
| | How many seeds needed for each population size to provide enough food to combat the food insecurity of this region? | |

Students can complete the lesson question: how can the garden container be designed to be most efficient? Students can investigate different garden containers. Each small group can create their own garden design that they feel optimizes the space allowed with the resources available. They can learn about hydroponic plants and evaluate their value over traditional planting. They can learn how to test soil for various attributes and how to adapt the soil to make it the best for the specific plants chosen. Students can investigate how much space each plant needs to grow efficiently. They can learn that different plants have different needs in terms of growing space. The students can graph the daily or weekly measurements of plant growth and compare the growth of the plants to one another to understand that different plants have different needs.

**Table 11. Student learning areas associated with the lesson question: how can the garden container be designed to be most efficient?**

| Lesson Question | Curriculum Framing Questions | Tennessee Educational Standards Met |
|---|---|---|
| How can the container be designed to be most efficient? | How much space do these plants need? | Math- Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition |
| | What volume of soil is needed by each plant and total for the garden? | Math-Graph point on the coordinate plane to solve real-world and mathematical problems |
| | What garden design is the most efficient in its use of space and water? | Math-Classify two-dimensional figures into categories based on their properties |

As a culminating exercise, students can learn about the costs of the gardens they create. Students can research the costs of materials for their garden designs and can create an itemized list of these costs. They can add the costs of each material which allows students to work on understanding the place value system and performing operations with multi-digit whole numbers and numbers with decimals to the hundredths. At the end of the project, student groups can present their garden designs to the rest of the class. The class can discuss the pros and cons of each design and determine a final design to pursue further.

**Table 12. Student learning areas associated with the lesson question: What are the costs of the garden?**

<table>
<tr><th>Lesson Question</th><th>Curriculum Framing Questions</th><th>Tennessee Educational Standards Met</th></tr>
<tr><td rowspan="5">How much would the garden cost?</td><td>What are the costs of materials to make the garden kits?</td><td rowspan="5">Math-Understand the place value system<br><br>Math- Perform operations with multi-digit whole numbers and with decimals to hundredths<br><br>Math-Using equivalent fractions as a strategy to add and subtract fractions<br><br>Math-Apply and extend previous understandings of multiplication and division to multiply and divide fractions<br><br>Math-Write and interpret numerical expressions</td></tr>
<tr><td>What labor will be needed to create the gardens?</td></tr>
<tr><td>How much will the gardens cost to maintain? What daily, weekly, and monthly work will need to be done in the garden?</td></tr>
<tr><td>What is the cost of shipping and packaging the garden kids to Southern Asia?</td></tr>
<tr><td>How much will it cost to manufacturing the container?</td></tr>
</table>

Ideally, at the end of the year as the project is completed, students can present their work to local organizations, companies, and officials who might be able to make the gardens a reality. This would offer students a chance to impact change with their work and feel a sense ownership over the project. This food-centric project-based curriculum offers many opportunities for students to learn the course material in a hands-on way. Centering the content around a real-world scenario allows students to utilize their learning in real situations which will help them retain the information.

Over subsequent years, the teacher can direct the project around any number of regions so that after a few years, students could look to past projects for inspiration. In this way students can learn from each other over time and can build on the past experiences of former students. This extends the real-world feel of the project since, in real life situations, previous work is often considered and analyzed at the start of new projects.

By utilizing a transdisciplinary approach, students can learn the content in a holistic manner. Students can bring their individual skills to the table and can practice new skills in a safe environment of learning. Students can learn at different paces depending on their abilities and can learn from one another. Students can experience work in a group setting and can build their communication and presentation skills as well. Through this project students will be enveloped in the course material each day in a way that builds on previous learning. In this way students can naturally move from one subject to another or from one topic to another with the foundation of learning supporting them as they take on new information. This will help them retain the material and will reinforce their learning of similar content in other subjects. By taking a transdisciplinary approach, students will begin to see how all subjects are interrelated. Since work in the real world is not segmented into single-subject tasks, this will help prepare students for their future careers. This also has the potential to help students build connections between subjects so that if they are not as strong in one area, they can relate to the similar learning in a related subject which can help them learn both sets of content more efficiently.

There are many benefits to using food in the curriculum. Centering the content around food helps keep the students engaged and interested in the material. Since food is central in all cultures, it is a simple way to connect students to people in other parts of the world. Moreover, food is simple to use in hands-on experimentation and can be adapted to virtually any class activity to help support the content of the lesson. Since Food Science incorporates most basic scientific principles, it can be used to teach areas of biology, chemistry, anatomy, physical science, and earth science. With food security and obesity both being major problems in the world today, it is important for students to understand the food chain, food practices, and food safety in order to help solve these global problems. Students who are engaged in the food they eat are more likely to think deeply about their food choices and the nutrition they consume than students are not exposed to this information. Helping students understand where food comes from and how it is prepared makes students more educated consumers and prepares them for independent life. Exposing students to the complex problems facing the world in relation to food, such as malnutrition in Southern Asia, can help them grasp the scope of the problems facing the world in which they are living. It can also help students prepare to face and solve these global challenges as they continue their education and live independent lives.

While there are many challenges to designing a project-based curriculum, the benefits far outweigh the time and resources required. The biggest obstacle for educators seeking to take on this style of curriculum is getting school boards and administration on board with this style of learning, especially if they are not familiar with it. Support from outside resources would be essential to help schools understand the need and the benefits of this type of education. Furthermore, resources would need to be allocated to make this style of curricula successful. Through partnerships with nonprofits and local organizations, teachers can work to create a network of support to bring food-centric project-based learning to their classrooms. Another large hurdle would be teacher training in this method of instruction. Classes, workshops, and seminars are all good ways to introduce this type of learning to teachers and ongoing support would be needed to help teachers be successful. Networks of teachers utilizing this method of instruction could be created to allow teachers to work together to craft food-centric project-based curricula. Teachers from schools in similar regions could work together to share resources, experience, and ideas. Though these challenges are significant, the benefits to bringing food-centric project-based curricula to students is worth the effort.

A food-centric project-based curriculum is a great tool to create a STEM educational environment that will foster deep learning and information retention. This curriculum style prepares students to think critically about complex problems in a way that will prepare them for future careers in STEM and non-STEM fields. This style of learning can elevate students' perceptions of STEM material and can encourage them to pursue work in STEM fields later in life. There are many opportunities to craft food-centric project-based curricula for learners of all ages. These curricula would give students the tools they need to be prepared for life after school and to be informed and engaged citizens throughout their lives.

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