# Influences on faculty uptake from a faculty learning community

by

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# Abstract

Professional development is a tool that faculty members can use to become more knowledgeable about certain fields of study, or to develop a wide variety of skills. One way that college faculty use professional development is to learn how to become better teachers. We investigate what influences affect the ways in which faculty take up ideas from professional development programs. By employing the framework of Pedagogical Reasoning and Action, we investigate how faculty take up ideas from a particular Faculty Learning Community (the STEM Teaching & Learning Fellowship) and the factors that influence their instructional and material design choices. Influences affecting faculty were examined in three different cases. From these cases, we constructed themes, and examined those themes across all cases using a cross-case analysis. In this multiple case study we find that alignment between assessment and instruction and participation in departmental practices correspond to the extent in which faculty bring new teaching ideas and practices into the classroom. These findings can be leveraged to help influence the ways in which developers should design and improve programs as well as inform researchers on future avenues of research.

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# Dedication

This work is dedicated to my science teachers, Mr. William Johnson and Mr. Russell Rupp. Thank you for encouraging and nurturing my passion for science.

AND

In memory of my Grandmother, Eleanore Bender, who lived her life using her talents for the benefit of others.

# Chapter 1

# Introduction

Recently, there has been a movement to improve STEM education. Efforts that aim to better this field focus on increasing retention rates, and preparing students for careers in STEM[1–3]. Teachers at the post-secondary level play a large role in increasing STEM literacy among their students. As new practices and pedagogies are created to increase student outcomes, it becomes their responsibility to learn and apply these techniques to their classrooms. One way that faculty can develop new skills, techniques, and knowledge is through professional development[4].

This paper examines faculty members participating in a STEM Teaching & Learning Fellowship henceforth referred to as the Fellowship. The Fellowship focuses on bringing Three-Dimensional Learning into undergraduate STEM classrooms in order to provide students with meaningful and transferable knowledge. During their participation, Fellows are asked to design material for a unit of their class using ideas from the Fellowship. The material that they create and the process in which that occurs allows us to investigate how faculty take up their ideas from the Fellowship and apply it to their classrooms.

The Fellowship is part of a larger project that involves bringing Three-Dimensional Learning to undergraduate physics classes. Other research that has been conducted by this group has focused on assessment[5–7], instruction[8], course transformation[9], and principles of Three-Dimensional Learning[10]. The Fellowship provides us with the space to investigate different

avenues of research within the same context including research on the program itself.

There has been a lot of research done to help understand professional development as a resource for faculty learning. Research on professional development includes the design of programs[11–13], program effectiveness[14–19] , and effects of programs on student outcomes[20;21]. Review of the literature also reveals that there is a desire to conduct research about faculty during their participation in programs[22–24]. Findings from such research would allow us to explore and improve design of professional development programs on faculty learning. Finding ways to help faculty practice new pedagogies would also aid in the efforts to improve student outcomes. The Fellowship provides us with the opportunity to investigate faculty participation within the program.

Our research views faculty as talented educators with good ideas and the appropriate skills to implement them. Because we want faculty to carry out their ideas, it is essential to investigate the influences that affect their use. Moreover, by identifying influences that affect the ways in which faculty take up ideas from a program we are able to pinpoint features of program design that support faculty in implementing new ideas and practices.

Through the course of this paper, we review the literature pertaining to professional development, faculty learning communities, and faculty uptake in Section 2. In Sections 3 & 5 we explore the structure and design of the STEM Teaching & Learning Fellowship, and describe how we employed Pedagogical Reasoning and Action[25] to investigate influences on the design choices of faculty. Using case studies, we examine three faculty members, Ron, Charlie, and Molly (pseudonyms), and look for similarities within each case as well as across those cases with a cross-case analysis in Sections 6-8. We found that the alignment between assessment and instruction, and the departmental culture directly influence the ways faculty design an implement classroom and instructional material as found in Sections 9 & 10.

# Chapter 2

# Literature Review

## 2.1 Professional Development

Professional Development is a popular method used by instructors to develop new skills and techniques that can be applied to increase student learning in their classrooms[4]. Professional development programs use different formats such as workshops[14;21;26;27], seminars[28;29], mentoring programs[26;27;30], and faculty learning communities[31] to learn about content and techniques. The content that programs focus on can be anything from teaching practices to integrating technology into the classroom (e.g.[32–34]).

Although professional development is a tool commonly used by K-12 teachers, it is a less common practice for faculty in higher education[28;35;36]. This is not to say that higher-ed faculty do not participate in professional development, but their participation is generally centered around their research interests[37]. Additionally, there are other factors affecting participation in professional development. Most faculty have not formally studied education and have not received support when adopting new curriculum and teaching practices[14;26;38]. Professional development is not seen as part of their job description[35], and is subsequently seen as an inconvenience[36], or a distraction from other activities faculty normally focus on, such as conducting research, submitting publications, and writing grants[39]. Finally, in a physics department, dialogue about teaching is uncommon[40].

## 2.2 Approaches to Professional Development

Professional development programs are designed to evoke change and include several different approaches. Broadly, professional development can be split into two different categories, top-down and bottom-up. A top-down approach occurs when a facilitator comes to teach a group of faculty members about a set of specific information over a short period of time[41]. A common example of this would be a workshop focused on delivering a specific set of ideas to faculty in a way that allows no time for reflection or little say from the faculty attending. Overall this approach has been found to be demotivating[42] and inefficient because the nature of the approach is imposed on teachers[41] and does not value teacher's contextual and professional knowledge[43;44].

A bottom-up approach is built from needs of the faculty[41] by allowing them to be involved in decisions about program content[42]. The change that comes from bottom-up structures has the ability to not only change participating faculty but can also spread throughout the institution to which they are involved in[45]. Bottom-up approaches have the ability to create second-order change[46] by providing participants the means to engage in collaboration[47] and supports continuous professional development[48]. This approach allows participants to think about and discuss items such as the culture of their university. This addresses the needs for professional development to take the culture of the department and university into account[49].

Furthermore, professional development can be categorized beyond top-down and bottom-up approaches. Henderson, Beach, and Finkelstein conducted a meta analysis of 191 journal articles that focused on promoting change[24]. Review of these articles revealed four change categories that can be distinguished along two axes. One axis describes what the program intends to change (individuals vs. environments and structures) while the other axis describe who has control over the purpose of the program (prescribed vs. emergent). Together these two axes can be used to describe professional development programs. Professional development that would fall under "Individual" would focus on instructor's beliefs and behaviors[24]. A common ex- ample of this would be promoting different strategies to use when asking students questions. On the other hand, professional development that belongs to "Environment"

focuses on changing environments that would then influence instructional choices[24]. This could be a workshop promoting the change of table set up to promote student collaboration. The remaining axis is categorized as either "Prescribed" and "Emergent". Programs that are considered "Prescribed" are led by an individual separate from the participants that comes into the program to teach a predetermined set of ideas. Typically these programs would be considered to have a top-down approach due to ideas coming from one person and trickling down to faculty. "Emergent" programs do not begin with predetermined set of ideas. Instead the content and delivery are driven by the participants' needs. This could also be defined as a bottom-up approach.

Henderson, Beach, and Finkelstein find that strategies that align with the change beliefs of instructors over an extended amount of time tend to be most successful[24]. Programs that align with these beliefs take an asset-based approach to faculty learning and are concerned a bottom-up approach[50]. An asset based view of faculty would see them as experts of their own local contexts, knowledge, values, and tools[51]. It also celebrates and builds upon the diverse group of faculty participants[52]. These approaches also seek to leverage the ideas and skills of faculty members and ultimately develops faculty to become change agents[46;51]. One way that professional development can take an asset-based approach is through the use of Faculty Learning Communities.

## 2.3 Faculty Learning Communities

Faculty Learning Communities (FLCs) are a type of professional development that incorporates different levels of faculty participation and ownership[23;53] through the use of a community of faculty who support each other[54]. FLCs occur over extended amounts of time, where faculty and facilitators come together to investigate and discuss different teaching practices and concepts[31;54;55]. They also provide faculty with the space and time to reflect on their teaching[55;56]. FLCs can range from formal communities to more informal communities. For example, meeting a coworker for coffee to talk about work would be considered an independent learning community[57;58].

One common feature of FLCs is that participants often have varying levels of teaching experience and come from different disciplinary backgrounds[31;59]. These features have the ability to instill confidence in younger colleagues[55], and the interdisciplinary feature of FLCs provide faculty with the opportunity to interact with new colleagues and talk about similar problems and share their different approaches to solving those problems[55]. The FLC also gives them the platform to develop a community of colleagues with whom they can discuss professional and personal topics outside of the FLC[55].

More formal FLCs are often led by facilitators. FLCs are focused on participants' ideas and needs, the role of the facilitator is to create a productive space for the community, keep a focus on the big picture, and practice organizational skills[56]. The facilitator can also take on the responsibility of training faculty to use a certain tool or resource[60].

FLCs take many different forms in order to account for the different types of faculty participating within them. Two common types of FLCs are Faculty Online Learning Communities (FOLC)[61;62] and University-affiliated faculty learning communities (UFLC)[57]. FOLCs occur online and can extend over multiple institutions, this allows for a more narrow focus on professional development because faculty who are interested in a specific topic can join the community virtually[61]. UFLCs are composed of faculty that all come from the same university, and tend to participate in a more structured way than an independent learning community.

## 2.4 Faculty Uptake of Pedagogical Practices

Faculty use of practices and skills after participation in professional development programs has been the subject of research. Some research looks into how faculty report on their use of materials[14;63;64], others look at influences of discontinuation of use after participation in professional development[39;65–67], and others investigate faculty's selection and use of new practices[68;69]

Henderson, Dancy, and Niewiadomska-Bugaj found that professional development does a good job of making faculty aware of current research-based instructional strategies (RBIS)[65].

This study also identified factors such as attending teaching related professional development, reading teaching journals, interest in RBIS, and gender having an effect on the continued use of RBIS[65]. Other studies have found that the lack of local support[66;67], student responses[67], and time[67;70] have an effect on the continued use of new teaching practices. Research of this caliber has suggested professional development programs should provide support and feedback during implementation[65;71], and spend time addressing situational barriers[39]

Another study has also looked at the different ways in which faculty decide to use and choose to continue with new pedagogical practices[68;69]. Zohrabi finds that collecting student feedback and intuition benefit faculty in their continued use of practices while departmental and classroom practices, student engagement, and the use of classroom materials are all factors that influence how new practices are applied to their teaching[68]. Overall, this study finds that faculty view the process of implementing pedagogical change as a positive experience that becomes easier over time[68]. Another study conducted by Turpen, Dancy and Henderson find that factors such as using personal experience to gauge effectiveness and encouragement from their community and department as influences on adoption and continued use of a new pedagogical practice[69].

# Chapter 3

# Context

## 3.1 Three-Dimensional Learning

3DL is the foundation of the Next Generation Science Standards[2] and is largely focused on integrating scientific practices, crosscutting concepts, and core ideas into the classroom. Integration of these dimensions into the classroom helps create scientific literate citizens that possess skills needed to start their careers[2]. In order to provide students with the necessary skills and knowledge 3DL focuses on three dimensions: core ideas, scientific practices, and crosscutting concepts. Core ideas are fundamental ideas that are unique to each STEM discipline. In the case of physics these would include but are not limited to the ideas of energy conservation, forces and interactions, or waves[2]. Unlike core ideas, scientific practices and crosscutting concepts are not unique to specific disciplines. Scientific practices are the different ways that scientists engage in scientific problem solving. Scientific practices that are commonly used in physics are developing models, using mathematics and computational thinking, or constructing explanations[2]. Crosscutting concepts are lenses used by scientists across disciplines to inform how they engage in scientific practice[10]. Some examples of these would be scale, cause and effect, or proportion and quantity[2]. The integration of all three dimensions into all modes of instruction and assessment provides students with deep and meaningful scientific knowledge.

## 3.2 Learning Goals Driven Design

Learning-Goals-Driven Design (LGDD) is model for developing classroom materials that was created as a way to address the need for integrating science standards and pedagogical approaches into the curriculum[72]. The principles of learning goals driven design (LGDD) are modeled after Wiggins & McTighe's model of backward design that asks teachers to sequentially identify desired end results, determine the acceptable evidence, and plan learning experiences and instruction[73]. Drawing upon Backward Design, LGDD was designed to be a scientific specific model that focuses on three stages: articulating learning goals, creating the material, and collecting feedback[72]. In order to articulate learning goals, faculty need to understand what standards are important to address and what learning performances they would like their students to achieve[72]. By combining the standards and learning performances we create learning goals that tell us what we want students to know but also how they should use that knowledge. The next stage in LGDD is creating the material. In this stage focus is placed on aligning the learning tasks, instructional sequence, assessment, and rubrics together[72]. The last stage of LGDD is feedback. Feedback can come from a lot of different sources (e.g. student artifacts, classroom interactions, exams, etc) and is used to revise material[72].

## 3.3 Fellowship

Our research focuses on faculty participating in the STEM Teaching & Learning Fellowship. The Fellowship was created as a way to support the efforts to bring 3DL into college classrooms. The Fellowship started at Michigan State University (MSU) in 2013, but has since expanded to include three more universities: Florida International University (FIU), Grand Valley State University (GVSU), and Kansas State University (KSU). Since 2013 the Fellowship has had four cohorts of faculty, each with approximately 10-20 Fellows. The first two cohorts consisted of faculty only at MSU, and the last two cohorts consisted of faculty from all four institutions. Each cohort consisted of faculty from different STEM disciplinary

backgrounds (Biology, Chemistry, Physics, Math). A description of each cohort and the participating faculty can be seen in Table 3.1.

**Table 3.1**: *Description of each Cohort in the STEM Teaching & Learning Fellowship. Each Cohort consists of Fellows from all four disciplines (Mathematics, Physics, Chemistry, and Biology)*

| Cohort | Year | Participants | Institutions |
|---|---|---|---|
| 1 | 2014 - 2016 | 9 Fellows | Single site |
| 2 | 2016 - 2018 | 14 Fellows | Single site |
| 3 | 2018 - 2020 | 20 Fellows | Multiple sites |
| 4 | 2019 - 2021 | 12 Fellows | Multiple sites |

The Fellowship is led by a group of Three-Dimensional Learning (3DL) experts from all four institutions. These experts meet every week to discuss different types of resources (readings, activities, question prompts, etc.) that would be useful for the Fellows. These leaders are also available to provide feedback or help for Fellows as they participate in the Fellowship

The Fellowship is comprised of different types of activities. These activities are facilitator led presentations, faculty led presentations, small group discussions either between similar disciplines or institutions, readings, and reflections. The topics of these activities are typically selected by the needs of the Fellows. A large portion of the Fellowship is focused on giving Fellows the time and space to reflect on their teaching. Participating Fellows met virtually once a month for ninety minutes over the course of two academic years, this amounts to approximately 16 meetings and 24 hours of professional development.

Discussions and activities presented in the Fellowship are centered around the idea that assessment drives change in instruction[74]. In order to change assessment and align that to instruction the LGDD model is presented and discussed. As part of learning about LGDD, a significant amount of time and attention is given to creating learning objectives and assessment that align with the 3DL framework. Several meetings are spent discussing how to articulate what it is that instructors want their students to be able to do, and how those objectives would be assessed. After creating 3DL learning outcomes, time is spent creating assessment items that can produce evidence of achieved learning goals, and instructional

materials that align with those assessment items. More specifically time is spent reflecting on their own assessment practices and utilizing the Three-Dimensional Learning Assessment Protocol[7] to align exam problems with 3DL.

During the Fellowship the Fellows are asked to participate in discussions, activities, and reflections. One of the largest and non-trivial task that is given to Fellows asks them to create a 3DL unit for their classrooms using the principles of LGDD. The 3DL unit contained learning objectives, classroom activities/materials, and an assessment item. The application and design of the 3DL unit serves as the focus of our research.

# Chapter 4

# Research Questions

In order to investigate the influences on how faculty take up ideas from a FLC, we focus on the ways in which Fellows develop and implement their 3DL unit. In particular, we are interested in the following research questions:

1. What are the influences that Fellows encounter outside of the Fellowship that affect material design?

2. What are the influences that affect Fellows' plan for the continued use of 3DL?

3. How does the FLC support faculty in their adoption and plan for the continued use of 3DL?

The first research question focuses on influences that Fellows face outside of the Fellowship, and the ways in which these influences affect their material design. The last two research questions focus on the plan for the continued use of 3DL, and the influences that affect the decisions to adopt new practices. For this study, 'continued use' is defined as the process of faculty continuing to implement their new ideas and practices in their teaching.

Exploration of these questions allows us to look at common mechanisms that influence faculty who are involved in different departmental, institutional, and social contexts. Identification of these mechanisms allow us to look at design features of FLCs, and the ways in which they can be used to support faculty.

# Chapter 5

# Theoretical Framework

## 5.1 Pedagogical Reasoning and Action

For this study we used Pedagogical Reasoning and Action (PR&A) to investigate each Fellow's process of material design. PR&A is a framework proposed by Shulman to explain a teacher's development of classroom material and instruction from their content knowledge[75].

PR&A is particularly useful for faculty talking about their thoughts behind design decisions. Shulman (1987) states, "The following conception of pedagogical reasoning and action is taken from the point of view of the teacher, who is presented with the challenge of taking what he or she understands and making it ready for effective instruction.[25]" Stroupe takes on the following definition of PR&A, "the purposeful coordination of ideas, information, and values about subject matter, curriculum, learners, and instructional context to plan for, enact, and reflect on instructional practice.[76]" For our research we also take on this definition as it will help us examine what influences affect the design choices of our Fellow's 3DL unit. Research that has used this framework investigates the choices of beginning teachers[76], the significance of content knowledge[77], and uses/choices of technology[78–82].

Since PR&A places significance on the process of thinking about instruction and not solely on the observable acts of teaching[25], we can explore material design from the point of view of the faculty members, focusing on their talents, ideas, and practices. Furthermore, it

allows us to examine their reasoning as an educator and as a subject matter specialist[83].

PR&A occurs in five stages and ends with faculty creating new comprehension from their experience creating and applying their material in the classroom[25]. These stages do not occur in any order, and include comprehension, transformation, instruction, evaluation, and reflection[25].

*Comprehension* involves faculty thinking about the set of ideas they want to teach, and how those ideas connect to the educational purposes of the class[25] and comprehension is attained "when teachers understand what they are going to teach[82]". As experts in their fields our faculty are knowledgeable in physics content; therefore, in our research we focused on their comprehension of 3DL, and the ways that it intersects with the educational purposes of their class. The information that is learned from their experience implementing the material forms their *New comprehension*, and then this becomes part of their comprehension base as they move forward creating more and new materials.

In this study, the *Transformation* stage broadly focuses on how faculty turn their 3D design ideas into instructional material. This occurs in five substages: preparation, representation, instructional selections, adaptation, and tailoring[25]. These five substages broadly focus on selecting what is to be taught, representation of ideas, making sure materials are in an instructional format, and modifying ideas so that they are suitable for the students in their classroom. Ultimately this "result[s] in a plan, or set of strategies, to present a lesson, unit, or course"[25].

The next stage of PR&A is *Instruction*, this stage focuses on the observable acts of instruction[25]. Examples of these observable acts would be classroom management, presentation of material, and interactions with students[82]. In our research we were unable to observe instruction of Fellow's 3DL unit; therefore, faculty were asked to recall and describe their instruction of the unit as part of an interview.

*Evaluation* is centered around ways faculty choose to evaluate student understanding inside of the classroom as well as formally testing their understanding. Inside of the classroom, faculty may choose to use clicker questions or reflections to test student understanding of material during class time whereas formal evaluation may look like end of unit exams.

In our study the *Reflection* stage is focused on how Fellows felt their 3DL unit went, and what they learned from implementation. This includes but is not limited to recalling impressions and feelings of their teaching and overall experience of their material[82].

## 5.2 Situated Perspective

Initially, our research was concerned with faculty's understanding of 3DL as well as the influences on material design. In order to understand their perceptions of 3DL and the influences that affected their comprehension we used the situative perspective.

The situative perspective was advanced by Greeno and comes from both cognitivist and sociocultural perspectives[84]. The situative perspective allows us to look at learning as participation in ones surroundings[85;86]. The situative perspective also gives us the ability to take faculty's various situations into consideration when investigating faculty learning[86]. This gets away from a deficit model of thinking by allowing us to take their surroundings, situations, and experiences into account (understanding will look different for different people).

By employing this perspective we view learning/participation as being situated, social, and distributed[86]. It is situated in physical and social contexts where the learning takes place[86]. In other words, the situation in which a person learns becomes a fundamental part of what is learned. In terms of our research learning would be situated within the physical context of the Fellowship and their classrooms. Interaction with a community and the people in it makes up the social aspect of this perspective. For the Fellows, their participation in social contexts could include, but are not limited to, their interactions with other Fellows, site leaders, or students. Finally, learning is distributed across different resources, tools, and people[86]. Common tools and resources available to the Fellows in the Fellowship are readings, the 3D-LAP[7], assignments, and their 3DL unit.

One of our initial research questions that aimed to investigate the Fellows' understanding and perceptions of 3DL. In order to investigate this the situative perspective tells us where learning about 3DL occurs, and the parts of the Fellowship that contribute to the Fellow's perception of 3DL. This perspective also allows us to understand what areas of the Fellowship

contribute to Fellow's knowledge about 3DL.

The situative perspective also informed parts of our interview protocol. In the protocol Fellow's were asked about their time in the Fellowship, social interactions, and resources that they used in efforts to identify where the influences occurred.

Ultimately the use of this theory was thrown out as our interest in identifying the influences outweighed the interest in identifying where they took place. Furthermore, this change in interest allowed us to devote more time investigating the influences in order to understand the effect those influences have and the underlying mechanism between them.

# Chapter 6

# Methodology

## 6.1 Case Study

In this paper, we use a case study approach, which allows us to deeply explore a phenomenon with its context[87]. This is typically done through the use of multiple sources of data in order to produce case-based themes[87]. For our study, a case is confined to the experience of a Fellow participating in the Fellowship.

In order to explore the different ways in which faculty take up ideas from the Fellowship we selected three different cases. By exploring each case separately, we are able to gain a thorough insight into their participation in the Fellowship, design of their 3DL unit, the Fellowship itself, and the ways in which these aspects influence their PR&A and hence their design choices.

These cases are then cross analyzed to complete a multiple case study. A multiple case study gives us the opportunity to explore similar themes in more than one Fellow's experience. Moreover, comparing multiple cases and their case-based themes together allows us to explore both the similarities and differences in themes and explore possible underlying mechanisms.

## 6.2 Case selection

We chose to explore the experiences of three Fellows: Ron, Charlie, and Molly. We chose these cases based on our informal understanding of their attitudes toward 3DL and the Fellowship. Our cases encompass a range of attitudes. Our first Fellow Ron is excited about 3DL, our second Fellow Charlie feels skeptical about it, and our final Fellow Molly is familiar with 3DL as she already uses principles of 3DL in her teaching.

Our cases are also composed of faculty with different levels of experience teaching and teach in different classroom formats. Finally, these cases also use a range of different tools and resources that affect the way that they participate in different categories of PR&A. A more comprehensive background of each of the Fellows can be found in Table 6.1.

**Table 6.1**: *A summary of the three selected cases*

| | Cohort | Academic Level | Classroom Format | Attitude Towards 3DL |
|---|---|---|---|---|
| Ron | Later cohort | Pre-Tenure | Lecture | Excited about 3DL |
| Charlie | Later cohort | Post-Tenure | Lecture, Lab, Recitation | Skeptical about the use of 3DL |
| Molly | Earlier cohort | Pre-Tenure | Studio | Already uses principles of 3DL |

## 6.3 Data Collection

In order to gain a deep understanding of our Fellows, we collected data from interviews, homework assignments, Fellowship meetings, and forum discussions.

The interview was semi-structured, lasted for approximately 45 minutes, and occurred either online or in person. Ron and Charlie were interviewed after their first year in the Fellowship and Molly was interviewed one year after she completed the Fellowship. The interview was focused on the design of 3D material and was constructed to specifically address all five stages of PR&A. The interview provided Fellows with an opportunity to vocalize their understanding and thoughts about 3DL, their experience in the Fellowship, and the choices they make when designing material. In order to anchor the conversation around their 3DL material, we used stimulated recall techniques. Stimulated recall techniques are

used to "prompt participants to recall thoughts they had while performing a task[88]." We applied this principle by introducing the material they designed during the Fellowship into the interview.

The homework assignments that were collected were posted to a faculty forum and included an end of the year survey, reading reflections, and other prompts that Fellows were asked to respond to as part of the Fellowship. The end of the year survey focused on each Fellow's personal goals and accomplishments. It asked them to talk about how the Fellowship supported their use of 3DL, and the supports that they needed. Other prompts that Fellows were asked to reflect on included their thoughts on how principles of 3DL fit within their discipline and classroom, their use of formative assessment, and their current approach to instruction. As well as collecting assignments, the discussions that occurred in the comment section of the forum were also collected.

The meeting recordings that were collected were from disciplinary Fellowship meetings. Fellows that attended these meetings were from different institutions but belonged to the same STEM discipline These meetings focused on each Fellows 3DL unit and served as a way for Fellows to share ideas and receive feedback in a smaller, more intentional way.

## 6.4 Data Analysis

Data analysis occurred in three separate stages: sorting and coding, single case analysis, and cross case analysis.

We began by pulling every response and comment that Fellows made within the data set. Then each quote was read and categorized into the stage of PR&A that they belong. Due to the sometimes long nature of the quotes, quotes were sorted in to stage of PR&A in which the majority of the quotes was focused on. In order to understand the definition of each code please see Appendix B. Quotes that did not belong to a stage of PR&A were given a code of N/A, and were used to provide more details about the case (i.e. motivation to join the Fellowship).

Initially, these quotes were then categorized into of of components of the situative per-

spective (situated, social, or distributed). The additional step of categorizing the data into the different components the situative perspective only occurred within one of our cases, Ron. It was after this analysis that we decided to focus our efforts on understanding influences that effect material design and not on where these influences exist. We removed these extra codings for Ron's case and proceeded to analyze Charlie and Molly's cases without the use of the situative perspective. From there we looked for themes across each case, and then for themes across all three cases.

Themes across a singular case were constructed by focusing on each stage of PR&A and the ways in which these stages relate to their 3D unit. During the analysis of each category we paid close attention to Fellow's ideas of 3DL, the structure and management of their class, features of their context that Fellows note as helping or hindering them, and how these influences connect to the design of the Fellowship. Influences that were noted as effecting a Fellow's PR&A were written down. Once each stage of PR&A was looked at individually, we looked for repeating factors that influence multiple stages of PR&A. Influences that were prominent across multiple stages of PR&A formed our themes for each case.

Next, we looked for themes that were occurring across all three of our cases. This process began by synthesizing the themes in each case and thinking about how these themes are present in the other cases. The process of comparing and contrasting Fellows' experiences with similar influences helped form the basis of our cross-case themes. Exploring these themes further allow us to identify and explore the ways in which these influences effect all of our Fellows.

# Chapter 7

# Cases

Our research used various sources of data, in order to distinguish one data source from the other the presented data will end with [I] to signify an interview, [M] for a Fellowship/disciplinary meeting, and [F] for forum discussion and homework assignments.

Our data analysis revealed three themes that were influencing all three of our Fellows. These themes include Motivation/Ability to change assessment practices, material placement and participation in instruction, and engagement in social interactions. These themes are present in multiple places of our Fellow's PR&A, and their location can be found in Table 7.1.

**Table 7.1**: *A summary of the three themes present in the cases, and where they present themselves in each Fellow's PR&A. Here T stands for the Transformation stage, I is for the instruction stage, E is for evaluation, and R is for Reflection.*

| Themes | Ron | Charlie | Molly |
|---|---|---|---|
| Motivation/Ability to change assessment practices | T, E, R | T, E, R | T, E |
| Material placement and participation in instruction | T, I, R | T, I, R | T, I |
| Social interactions | T, E, R | T, E, R | T, E |

## 7.1 Ron

Ron is a pre-tenure Physics professor teaching a lecture-only introductory physics class. Ron joined the Fellowship to "meet like-minded people" and to learn how to prepare lectures using

"evidence-based approaches." Throughout his experience Ron is very open to discussing and trying new ideas.

Ron created his 3DL unit with two other Fellows. Ron's idea for the 3DL unit was to create an interactive lecture activity that would focus on the photoelectric effect. In order to do this, Ron wanted to utilize clicker questions and a PhET simulation[89].

Due to his participation in the Fellowship, Ron has thought about how he can integrate 3DL into his advanced lab class that he co-teaches. His ideas for his advanced lab course involve finding places in lecture and lab reports to connect to 3DL.

Looking throughout Ron's stages of PR&A we find that Ron's stages of transformation, instruction, evaluation, and reflection contribute to our three themes. The location of these themes within Ron's PR&A can be found in Table 7.1.

### 7.1.1 Pedagogical Reasoning and Action

#### Comprehension

When it comes to the ideas of 3DL and using it in the classroom Ron feels positive that 3DL aligns with his educational goals for his class. When asked about his learning goals for his class, Ron responds, "What I've internalized as my goal for the class is to help them learn problem solving skills [I]." More specifically Ron wants his "students to do [every scientific practice] in the classroom, [...] it doesn't matter if they are K through 12 or college age or 50 physics majors or not physics majors. These are the practices that I'd like to see my students do [I]." These learning goals also extend to students in his advanced lab course. When talking about his advanced lab course Ron states, "I mean, there's just so much of 3D that you should be doing [I]." Overall, Ron believes the principles of 3DL, specifically how it teaches scientific practices, aligns well with what he wants students to learn.

#### Transformation

Ron's process of material design is defined by his experience using already constructed classroom material, the use of clicker questions, the limited availability of time and content,

and the different types of interactions that he has with colleagues inside and outside of the Fellowship.

Ron's process of material design was influenced by the interactions with other faculty at the beginning of his career. This influences the way that Ron approached design of his 3DL unit. As a new faculty member Ron was given the following strategy: "as junior faculty, I was just given all this course material. And so the advice I was given was just to go with what we have [I]." When it comes to the 3DL unit, Ron starts by "think[ing] of questions that were in the vein of some of the examples we had seen earlier in the Fellowship [I]." From there Ron looked at the questions "And then we're trying to think of, you know, what sort of category [of 3DL] does [the material] fit into [I]?" In order to help him decide what category of 3DL that material fit into, Ron created a "cheat sheet with all the cross-cutting ideas and practices and stuff[I]." These sheets allow Ron to ask himself, "does the you know, does this question match one of these things? And if not, how can we restate this question so it actually follows 3DL [I]?" Another way that Ron refined his material was by thinking about the "common misconceptions about the photoelectric effect [I]."

Ron felt stuck designing 3DL material for a lecture, but identifies clicker questions as one way he felt he could integrate 3DL into his classroom. The class that Ron teaches is a large lecture setting, and this type of format is challenging for Ron. In an end of the year survey Ron writes, "[Developing material that gets students to engage in 3DL] was challenging because of the "pull" of the traditional lecture style is surprisingly hard to resist [F]." Although the "pull" of the lecture is hard to resist Ron creates a class activity for his 3DL unit. One way Ron felt like he could accomplish this is through the use of clicker questions. In the interview Ron says, "there are ways that you can design clicker questions better, that allow them to actually use those scientific practices, even in answering a clicker question. So that's a place where I have more freedom in terms of how I run my class [I]." When talking about the instructional selections of his material design, Ron also mentions the course management system that his department uses. He mentions that he "[doesn't] know what fraction of the instruction still needs to [incorporate the course management system] these days, especially now that it seems like we know a lot more about how to more

effectively instruct students [I]."

When it comes to content, Ron notices that in order to integrate 3DL into his classroom material, time and the amount of content is going to be an issue. Ron lists three barriers to implementing crosscutting concepts and scientific practices, "Cutting content/lectures would be necessary. Project based two-way discussions would be great with adequate time for feedback. Material for the students to review before coming to lecture [sic] [F]."

The content that he chose for his 3DL unit was based on timing and other available resources. For his 3DL unit Ron picked the subject of the photoelectric effect because he was "trying to squeeze something into the semester [I]" although he notes the topic as "rich [M]" and "connect[ing] to a lot of other things [M]." He also notes the availability of a PhET photoelectric effect app[89] as a positive, "there was this applet that existed to work with it, so we could actually do something a little bit more interactive in class [I]."

A lot of the ideas Ron used to create this material came from interaction with other Fellows, these interactions are very different from the interactions that Ron has with faculty who do not participate in the Fellowship. When talking about interactions with other Fellows Ron describes it as being "very helpful because it's certainly opened my eyes to what could be done in the large lecture room [I]." This is contrasted by the way Ron talks about interactions with non-Fellows, Ron describes these faculty as tending "to have a more old school perspective on the teaching is just, there's some lecture slides, just give a good performance, the students are going to do how they do and this is really out of your control. And this is kind of the feedback that I get outside the Fellowship, to be honest [I]." These types of interactions have stopped Ron from talking about his ideas to change features of his advanced lab course that he co-teaches. When asked about talking to his co-instructor about integrating his ideas of 3DL into the advanced lab classroom Ron responds, "Uh, no, I probably should ... I should give him, I should give the benefit of the doubt... [I]" Overall, Ron feels supported by his colleagues in the Fellowship, but having a hard time finding support from other colleagues outside of the Fellowship.

Overall, we see that the design of Ron's materials relies heavily on tools that are readily available or commonly used within the department. Ron's sees his colleagues inside the

department that also participate in the Fellowship as positive additions to the design process while he sees colleagues that are not participants in the Fellowship as more skeptical about Ron's new ideas. Ron views time and content as limiting factors to designing his 3DL unit.

### Instruction

Students were presented with "three activities [M]" followed by "discussion questions [M]" these were done "in class mostly on by [sic] themselves and if they had any questions they could ask [M]." For these activities, Ron "had the students use the app with some sort of guidance of what settings to use [M]." Before the third activity there was "a small lecture component [M]" where Ron introduced the work function. Overall, the three activities focused on the "current and wavelength relationship [M]", "threshold and target material", and "us[ing] the conservation of energy to make sense of the work function [M]."

For the instruction of the 3DL unit, Ron deviated from his typical instruction. During the instruction of Ron's 3DL unit he was not the only instructor. Ron explains the instruction of the unit as the following: "when we did this in the lecture room, [my colleagues] and I were all three of us were there, plus the TA for the class, plus the three LAs for the class [I]." The role of the instructors for this unit focused mostly on classroom organization and group facilitation by "walking around the outside [I]" to check on students. This deviates greatly from Ron's typical approach which is "just straight lecturing [I]." In order to organize the class, instructors "gave [students] a heads up [M]" and "organize[d] the students that didn't have partners [M]." Overall, due to the format of the 3DL activity Ron's instruction had to change from lecturing to group facilitation.

### Evaluation

Ron's approach to formative evaluation involves clicker questions. When it comes to his formal assessment Ron feels confined to multiple choice exams, and although he feels positively about integrating 3DL into his exams, other factors such as a commonly used course management system and interactions with colleagues create difficulties for Ron.

Before the Fellowship Ron used experiences that he had "overhearing the conversations students we having, and also just my own conversations with the students [I]" as ways to evaluate his own teaching. Ron talks about this experience as "disappointing", and he found that "it was clear that whatever I was doing was pretty ineffective [I]."

During class Ron utilizes clicker questions as a way to evaluate his students; although his use of the clicker questions has evolved. Normally the clicker questions were used as "a review of the most recent lecture slide [F]" where "most students get it right and collect their bonus points for being in that class [F]." Ron wants to move away from using clicker questions for participation points and move towards using them as an aid to student learning and understanding. Ron moves on from his previous statements to say, "I would much rather use it as a way to test their outside class study as well as to set up the next set of lecture slides so that they are motivated to find out the answer [F]." In order to provide more formative assessments, Ron also encourages his "students to play around with the PHET simulations on their own time. [...] I was hoping that they would use it do/check their homework problems [F]."

When it comes to the structure of his formal exams, Ron feels limited to using a multiple choice format. His formal exams are typically multiple-choice questions and "similar to the homework [I]." Ron wants to move away from the way that exams are typically done, but struggles to do so. One reason for this is because "we use [a course management system]. And it's really, really well-suited, well-designed for multiple choice problems [I]" this makes Ron feel restricted to using multiple choice formats. Another factor is that Ron does not get the impression that he could make 3D questions to put on his exam. In his interview he brings up, "At least from going through the Fellowship so far, I didn't get the impression that it was... It was easy to have something that you could just have like four or five multiple choice questions that you could have as a 3D assessment [I]." Ron even notes needing help creating 3D material in the end of the year survey, "I would like to learn how to write 3DL assessments within a [course management system] framework. This will help me design new exam questions [F]."

The way Ron feels about 3D exams also changes depending on who he is talking to.

In particular, Ron is "very comfortable [giving a 3D exam] [I]" if he was talking to other Fellows, but Ron knows that his colleagues outside of the Fellowship "would recommend against it."

Ron's issues with 3D exams has nothing to do with his students' capabilities but more with its alignment in the course. When asked about his students, Ron notes, "In terms of my students I think it would be great for them to do it and I think they would rise to the occasion [I]." Lastly, Ron also thinks about how his exams align with instruction, and the fact that they don't currently align causes Ron to doubt the effectiveness of bringing 3DL into his classroom. Ron brings up in the interview, "it's all fine and good if you have examples in class and if you give the homework like that, but if it's not, if its also not an exam question, then the students aren't going to really invest themselves in learning how to do those kinds of problems [I]."

Ron wants to change some aspects of his assessment, but the structure of the class, resources used by the department, and interactions with others factor into the ways in which Ron thinks about his evaluation.

**Reflection**

After reflecting upon how the implementation of the 3DL unit went, Ron notes how there was a "palpable difference [F]" in the room. He also talks about his experience teaching the new material. He describes it as "very interesting to walk around and just listen to the stuff his students think their way through the problem [M]." He goes on to mention that the students "were really engaged [M]." In his interview Ron states, "I know that [feeling] shouldn't be the gauge [. . . ] but putting that aside, they certainly seem to enjoy it more and we enjoyed it as well [I]."

Ron was also able to reflect on certain aspects of the unit that he would like to change for the future. In particular, Ron felt that he needs to keep participating in these types of instructional activities. Upon reflection Ron explains his thoughts, "This was just one opportunity for the students to engage with material in this way and then they didn't see it

in this format again on the homework or the exam and I think it would really drive it home [I]." He also notes that, "the assessment didn't directly assess the activities that they did [...] so we either have to change the assessment, which I think was our consensus that we had, or change the activity so that the two match better [M]."

Ron also talks briefly about continuing his use of 3DL materials. He mentions that "I certainly when I teach classes like [making activities is] something I'll engage in more myself [I]."

All in all, Ron enjoyed how the unit went and believes that students enjoyed themselves also, but he believes he needs to integrate more material into the classroom for this to become more useful for students.

### 7.1.2 Themes

#### Motivation/Ability to change assessment practices

Ron uses a course management system that is commonly used by his department. Use of this system influences the way that he can design assessment and instructional items. In particular, it limits Ron to creating multiple-choice problems. Ron views the course management as a constraint and a barrier that he needs to overcome in order to align his instruction with assessment, and design the problems that he wants to make.

#### Material placement and participation in instruction

Ron created an activity for his lecture style class using a PhET[89] animation and other educational resources. Ron was present for instruction of the material that he created, and he was able to reflect upon his students' reaction to the activity. The positive impression that he formed from his students' reactions and his own personal feelings about how the material went are a main motivating factor for his continued use of 3DL.

#### Social interactions

Ron is influenced by the social interactions with his colleagues inside the Fellowship, outside of the Fellowship, and with his students. His interactions with Fellows give him new ideas that he can implement in his classroom. Outside of the Fellowship, Ron's social interactions discourage the use of his new ideas, and even start to negatively impact how he interacts with his co-instructor. Social interactions that influence him also extend to his students. His interactions with his students also served as his motivation to join the Fellowship and continue with 3DL material.

## 7.2 Charlie

Charlie is a tenured physics faculty member teaching an intro physics class for non-physics science majors. Every couple of semesters Charlie tries to find new ways he can improve his teaching and this served as his motivation to join the Fellowship. Throughout the Fellowship, Charlie participates in conversations and brings a lot of discussions to the table.

Charlie's idea for his 3DL unit was to create a unit that could also be used in a class his colleague teaches. This led him to creating a unit that focuses on the idea of electrostatic potentials by using the core idea of energy conservation. Charlie also chose to challenge himself by choosing a scientific practice that was not "using mathematics and computational thinking."

By examining Charlie's PR&A, we find that Charlie thinks a lot about his alignment and instructional materials, his current assessment practices, and the time he has available. All of these factors contribute to the themes that we have found influencing all of our Fellows. In Table 7.1 we can find where these themes present themselves in Charlie's case.

### 7.2.1 Pedagogical Reasoning and Action

#### Comprehension

Charlie interprets 3DL as a way for students to learn science while simultaneously teaching them how to be a scientist. These principles align closely to the educational goals Charlie has for his classroom, but he still holds on to some reservations of 3DL.

Charlie likes 3DL because it teaches students how to be scientists while also teaching the content of the course. Charlie describes this as, "three dimensional learning is this goal that science classes should, you know, one teach the skills necessary to be a scientist and two, you know, weave in these concepts to connect the various fields of science together, while at the same time teaching this specific branch of physics that is on the title of the class [I]."

In his class, Charlie has multiple educational goals that align with 3DL principles. First, Charlie wants students to "try and you know, make that connection between the physics that is the, the, you know, the primary goal of that class, and the scientific field that most of my students are interested in [I]." He would also like his students to "have a feel for, you know, a little bit of a physical intuition about the world. [I]." He also wants his students to be able to synthesize information from different areas and bring them together to solve a problem. Charlie states, "it's a physics class and so we do you know, there's a lot of problems worked out and so that I think those are good for, you know, being able to solve problems by synthesizing information in different areas. In this case information with different areas would be, you know, taking multiple equations that grab different concepts and putting them together [I]" Charlie also mentions that he wants his students to understand "model building [...] physical intuition and problem solving, However, time constraints mean that I ultimately had to cut models from my lectures [F]." His classroom goals are different than previous instructors who solely focused on "problem solving [I]", Charlie has "shifted the focus more toward the conceptual [I]." Overall, we see that Charlie's educational goals of his class is to get students to be able to connect physics to their primary field of study as well as real world scenarios that they encounter.

Although Charlie does like some ideas of 3DL he also has his reservations. His reserva-

tion is about "how much these proposals [of cross-cutting concepts and scientific practices] diverged from the teaching that actually occurs in the classroom [F]." This has Charlie thinking that there are two different questions we could be answering in the classroom. Charlie writes, "I believe the answer lies in what we want to accomplish in our curriculum. Are we trying to create a scientifically literate population, or one that is able to think like scientists [F]?" He also believes the questions could be answered on a "course-by-course [F]" basis. Overall, Charlie's reservations about 3DL revolve around the purpose of the class.

In summary, Charlie feels 3DL aligns with the educational goals of connecting physics to other fields of study as well as many real world scenarios, but he struggles with deciding whether his introductory physics class should strive to create a scientifically literate population or create students that are able to think like scientists.

### Transformation

When it comes to designing new material Charlie is used to designing material from scratch. When creating his 3DL unit, Charlie was focused on making it a collaborative experience that his colleague could also adapt for his class, challenging himself to use scientific practices that aren't commonly used in 3DL, and selecting where 3DL material should appear within the structure of his class.

Charlie has always created his own material from the beginning of his teaching career, and although this took effort he wanted to make sure the material was targeting what he wanted to target. Since then Charlie has tried adapting problems to fit into his class. This resulted in his class content changing slightly every year. Upon reflection, Charlie states that "other help wasn't offered. And and I guess, you know, now I would, I would ask for it [I]." He then would adapt the material "one slide per year [I]" until lectures are where he wants them to be. Some problems that Charlie felt like he had to (or would have to) write from scratch because other professors put "more emphasis on the problem solving and less on the concepts [I]." The material that he borrows from online learning websites usually do not get students to engage with the content that Charlie wants them to. In the interview Charlie

says, “I’ve gone into some of the online homework systems to steal multiple choice questions. And by and large, I don’t like those, [. . . ] those ones that have been that were borrowed or stolen or modified tend to rank low on the ones that I like [I].” Since creating his initial body of work, each one of Charlie’s “lecture[s] [improve] by one slide per year. And after five years that’s a lot that adds up [I].” Additionally, Charlie improves these slides by asking himself ”What were the places that [the students]] struggle or the test questions, they struggle? How can I tweak you know, the material in order to target those in order to get these concepts through? [I].” For his 3DL unit Charlie chose to work with another Fellow. He reflects on working with other Fellows recalling that ”working with, with the other people and the other Fellows, and that’s been a far more enjoyable experience [I].” The collaboration that Charlie has with his colleague looks different from his typical interactions. He describes these interactions as, ”a little bit of an exchange of ideas on and, you know, we’ve talked about them, you know, after the rollout and after they’ve been implemented and get feedback from each other [I].”

Charlie does comment on the process of design. In particular he found learning about backward design and being able to ”[say] this is how you build up to material. That was very illuminating...you know, identifying things like, you know, learning objectives as distinct from just like I want them to be able to handle this question [I].”

A lot of the design decisions that went into creating his 3DL unit came from working with another Fellow. While creating his 3DL unit Charlie picked the content of the unit so it could be a collective effort with a colleague. Charlie describes this process as, “so we figured that these are very similar concepts. And so we could put together a teachable unit that can be used with minor modifications in both, both contexts [F].” The larger concept that they chose to focus on was energy conservation. Charlie makes the conceptual connection between gravitational potential energy and electric potential energy. He describes his students needing to, ”realize that this is electrical potential energy instead of say gravitational potential energy, which they’re, they’re more used to [M].”

Other dimensions of 3DL were picked because they would challenge both Charlie and his colleague out of the physics “comfort zone.” He talks about his selection of dimensions as,

“so devising something like this, you know, it sort of seemed like the challenge of it for us was implicitly make something that doesn't involve as much math [I].” Ultimately Charlie and his colleague chose to create a unit that would use a scientific practice that they typically do not integrate into their classroom material.

Due to the structure of the class, Charlie also had to decide where he would like to introduce 3DL into the classroom. Charlie sees “time is at a, at a real premium [I]”, and because of this “spending, you know, 15 minutes, even 15 minutes doing the lecture activity would have been brutal [I].” Presenting a 3D activity in the recitation seemed to make the most sense because of the nature of the class. Charlie goes on to say, “The recitation seems like the ideal place to put the sort of thing that's the time where the students really have time to, you know, get involved and, and get their hands dirty [I].” Charlie does mention that ”if [his]lecture time doubled or increased by 50%, I think that I would work hard [to put activities there]. I think it'd be better to use that time to you know, get the concepts across and to give that practice [I].” Ultimately, We see 3DL appearing within the recitation component of Charlie's class due to the problem-solving environment that the class provides.

When it came to thinking about how the material should be taught, Charlie feels he did not put much thought into how the material would be taught because he spent more time figuring how to represent the problem to students. This is because creating the material was “a challenging enough of a task, that, you know, trying to, you know, just the formulation of the question is seems more difficult than, you know, even trying to teach it [I].” We see time, that time spent designing activities has an affect on the amount of time that Charlie can spend thinking about other aspects of the 3DL unit. In order to make more material Charlie asks for a ”bank of materials [M]” because ”developing these materials is too time consuming to be realistically implemented [M].” In a forum post, the importance of time is also something Charlie notes as a barrier to implementing scientific practices and crosscutting concepts into his class.

In summary, several factors influenced the way Charlie approached transforming his ideas into usable material these include: working with his colleague, selection of scientific practices, the structure of his class, and time.

### Instruction

For the 3DL unit, students were exposed to 3DL material in the lecture and recitation. In the lecture students were given a series of clicker questions that were used to "show the conversion between you know, kinetic energy and potential energy using a video [I]. After that was done Charlie went through the idea of energy conversion: "this time the electrostatic context where I've got a charge and I'm moving it against electric field now instead of a gravitational field [M]." The recitation was the "very next day [M]" and students were presented with a screenshot of the video they saw in lecture and were asked to "[fill] in the chart for you know, all these different stages throughout the video [M]."

Charlie relied on other instructors and their choice of classroom management and content delivery for the 3DL unit. Charlie was present for the instruction of his 3D material in the lecture and he "really like how this fit into the lecture [I]", but he was not able to be present for the instruction of the 3D recitation material. During the recitation different instructors are responsible for teaching the 3D material. In recitation, instructors give students a "problem to work out [...] usually in teams of four and [...] they've got a secondary instructor roaming the room to and hopefully an LA but not this semester roaming the room to [...] help them through that [M]." During the 3D unit, instructors decided to encourage "a bit of a divide and conquer approach [M]" this was mainly done to "make things go more efficiently [M]." The instructor also had to point was "the total energy column [...], many of the groups didn't even notice that until an instructor came around and said, hey, look, she's got the same number for four times in a row [M]." Charlie was able to get this feedback from his recitation instructor, although he typically doesn't "feel like [he] need[s] to check in [I]." Overall, Charlie had to rely on the recitation instructor for the instruction of his material.

### Evaluation

Charlie's evaluation includes clicker questions and unit exams. Charlie has a difficult time wanting to align his unit exams to 3DL. More specifically, Charlie takes a lot of pride in the current status of his exams and the way that he feels that they assess student understanding.

In order to check his students' understanding during lecture, Charlie employs clicker questions. During lecture Charlie uses "clickers a lot [I]" to help "bringing the scores up of those, those tricky multiple choice questions [I]." Charlie wants to give his students the chance to "see more of the types of logic that I want them to be able to do when they get in front of a test [I]." We see that clicker questions provide Charlie with the opportunity to test his students understanding as well as give students practice for his formal exams.

Charlie's formal exams are composed of "physics written problems [I]" and "multiple choice questions [..] designed to test concepts [I]." When it comes to formal exams Charlie has a harder time integrating 3DL. One reason for this is because he "take[s] a fair amount of pride [I]" in his assessment questions. More specifically, he "like[s] the concepts they target", and "like[s] that, the way that I think they make the students think [I]."

Charlie also likes the concepts his test questions cover and thinks his instruction and assessment complement each other nicely. He states, "I have been orienting my class, I know what questions I like to ask [I]." Charlie comes to the conclusion that "my default probably ought to be to show them questions and recitations that more closely connects to types of test questions [I]." Overall Charlie thinks it is best if all of his instructional material aligns with his exams, he does not think that his 3DL recitation achieves this due to the type of questions that are asked in recitation.

At the beginning of Charlie's teaching exams "[were] just a disaster, you know, because there was very little alignment between the teaching material, and [...] the exams that I gave. After [...] I tried to write my exams first, and then go back and, you know, build the lectures up to do that, to match it [I]." When it comes to creating 3DL exams, Charlie also notes that creating new 3DL classroom material takes so much effort that the assessment becomes an afterthought. When speaking about assessing his recitation problem he mentions, "we spent so much time and effort on [the recitation] that it never turned into an exam problem [I]." He goes on to say "integrating the three dimensions into the test questions is significantly difficult and challenging, that it almost decouples the test from the teaching is that it sort of breaks that connection there [I]." Ultimately, he sees creating the assessment as an "afterthought [I]."

The way that Charlie chooses to evaluate his students in his class relies on in-class clicker questions and unit exams. When it comes to his unit exams Charlie remains unsure about aligning them to the 3DL framework.

**Reflection**

After implementing his 3DL unit Charlie reflected on how different this type of activity was from what he usually asks his students to do, and how he expected the recitation to go. Taking these thoughts into account he reflects on his feelings about 3DL as a whole.

Overall, Charlie's feelings about how the 3DL unit went are neutral. The problem seemed to be "a fairly big departure from the types of problems they're used to seeing in recitation [M]." Typical problems would "be a much more of a, you know, conceptually challenging, you know, just written problems, you know, require them to synthesize couple different concepts of lecture [M]." "But overall the unit didn't seem much different from other units in the class. Charlie expresses this as a "lateral step [M]", and describes student understanding as "the total amount they learned was no more no less [I]" and their grades "being within the noise [I]."

Charlie did take some lessons away after implementing the 3D unit. First, Charlie noticed that the problem did not achieve what he wanted it to. Charlie talks about what he wanted his students to notice from the problem in his interview, "the goal here as to try and provide some, you know, tangibility to this a morphus concept of energy. [...] The hope was that if we if they grind out the numbers, and so and then say, Oh, wait, these numbers that we just round out, give exactly, you know, the numbers that would be expected from this model, [. . . ] Yeah, and I don't think that I, the feedback I got was that that was not accomplished [M]." The problem also seemed to be "much more of a, of a, grind it out just sort of numerically challenging time consuming [M]."

Overall Charlie does not think he is going to continue to use 3DL. Although the clicker questions "ended up fitting into the lecture a very nice way that I liked a lot [M]." Charlie is not sure what to do with the recitation problem, he states, "I'm not sure. Whether this

is this should be tweaked, or whether it'd be more useful for them to do some more evolved conservation energy type calculations to get an idea of the utility of, of, of the method [M]." When asked about continuing use Charlie states, "I don't know. I mean, at this point, I think the easy answer is no [I]."

After collecting feedback and thinking about how the 3DL problem went Charlie has ultimately decided that he may not wish to continue 3DL.

### 7.2.2 Themes

#### Motivation/Ability to change assessment practices

Charlie's assessments are designed to test his students' conceptual understanding about the content being covered in the class. In order to test his students on their conceptual understanding, Charlie has a bank of test questions that he uses. This has resulted in test questions that Charlie likes and takes pride in. The way that he has aligned his instructional materials with his current exams results in Charlie not being inclined to change his assessment practices. He also notes that he did not have time to create an assessment item for his 3DL unit because he spent a lot of time creating the instructional material. The inability to align his assessment and instructional materials for his 3DL unit served as a reason for not continuing with 3DL.

#### Material placement and participation in instruction

Charlie teaches a class with three different components and therefore has to pick were to put his 3DL material. He chooses to implement 3DL clicker questions inside of his lecture component and an assignment in his recitation section. He chose to put a large portion of the 3DL activity into his recitation section due to the nature of the class and the time that is available in recitation classes to explore content. Charlie is the instructor for the lecture component of his class, but has recitation instructors for his recitation section. The recitation instructor was in charge of the instruction of the material and provided feedback to Charlie about how the material went. The feedback that Charlie received was about

students' approach to the problem and that the amount students learned was about the same. When reflecting on the unit, Charlie wants to keep the clicker questions that he was present for but not the recitation problem. All in all, Charlie's lack of participation in the instruction of the recitation problem contribute to his choice not to continue with 3DL.

#### Social interactions

Charlie's social interactions are confined to interactions that he has with colleagues inside of the Fellowship and with his recitation instructor. In particular he chooses to collaborate on his 3DL unit with another Fellow. While working with his colleague the choose to challenge themselves by incorporating scientific practices that aren't not typically present in their class. Charlie also interacted with his recitation instructor about the implementation of his 3DL unit. This interaction was focused on the 3DL activity and help form his opinion about continuing with 3DL.

## 7.3 Molly

Molly is a pre-tenure faculty member who teaches a studio-based (integrated lab and lecture) physics class taken by biology majors. Her class is focused on giving students the space to explore physics phenomena through the use of experiments, and because of this Molly wanted to learn how to assess her students on these lab skills. This served as her motivation to join the Fellowship. Her time in the Fellowship did not coincide with Charlie and Ron's, but she talks about the benefit of interacting with other faculty members in the Fellowship.

Molly's ideas to implement in her class were to create assessment items that really assessed lab skills as well as creating an honors option for students to explore scientific phenomena across multiple disciplines.

As Molly talks about her 3DL unit she spends a majority of her time talking about creating connections to biology and integrating scientific practices into her classrooms. These ideas are connected to the themes that are present across all of our Fellows. The themes are present in the stages of Molly's PR&A listed in Table 7.1.

### 7.3.1 Pedagogical Reasoning and Action

#### Comprehension

The ideas of 3DL connect to Molly's educational goals that involve both skills and content. These goals are shaped by the department, but tailored to her needs. Overall, Molly believes it is beneficial to have both content and practice goals for her classroom.

For her class, Molly would like students to develop the use of multiple tools. Molly teaches a physics class for biology students. For her class, she thinks it is important to leave with "a toolbox of skills[I]." This 'toolbox' is composed of "physics words and representations and like common usages of physics [I]" that they can use when they "encounter a new situation[I]." These tools should also "help them look at problems in a way that is not the same as what they get from biology and chemistry[I]."

Molly's educational goals extend beyond developing skills to include content goals as well. When it comes to content, Molly agrees with the set of content that she is given from the department, but she takes a longer time to focus on topics that might be more applicable for her biology students. Molly notes, "I definitely agree with, like, so, in terms of content I really prioritize energy thinking and I prioritize thermodynamics thinking, because those are content areas that I know are going to become useful to those students later in their biology trajectories[I]." She sees her goals and the department goals as intersecting, "there's definitely like content goals I would have that are coming from my department but are intersecting with me knowing who my students are[I]."

She also thinks it is beneficial to have content goals that are separate from practice goals. Molly states, "the language of like separating content from practices is that it's okay sometimes to be like, oh, right now, I want to make sure you guys have the vocabulary to understand that voltage and potential difference and potential like, they are all the same thing[I]."

On the whole, Molly believes the use of content and practice goals are both beneficial and align closely with the 3DL framework.

### Transformation

When Molly approaches design of classroom material, she likes to adapt borrowed material to fit the needs of her students. Integrating 3DL into the classroom fit nicely due to the studio structure of her classroom and because of the ideas she received from other Fellows.

Molly has a set approach for material design. When it comes to designing new material for the classroom Molly usually starts by "look[ing] for somebody else who has already written already fantastic problem on that topic. If it's like exactly what I want, then I take it, and most often though, it's not exactly what I want, right it most often it's something close to what I'm looking for, but not quite there. And so then I started the process of modification[I]." This process of modification entails "spend[ing] some time with some like biology textbooks or biology journal papers and I'm looking for connections to physics [I]."

For 3DL material, she uses the same process but looks for different information. Molly states, "I think that really changes for me is that I find myself looking for data, in like real data, like either collected by my students or in a paper or something like that, because I find it easier to ask real practice questions, like interpretation or analysis or something when there is some sort of data in front of a student[I]." Molly also uses a tool from the Fellowship, the Three-Dimensional Learning Assessment Protocol (3D-LAP)[7]. She describes her experience with the 3D-LAP as "some sort of protocol where you could sort of like checkbox, your, your like, you could look at your own assessments and say, like, how three dimensional were they? Yeah, and I had seen that and thought it was a useful tool[I]." For the design of 3DL material, Molly starts to prioritize the use of real data in her classroom material. The 3D-LAP also aids Molly ensuring that her material aligns with the 3DL framework. She also works hard to integrate scientific practices into her classroom because "if someone were to look at my classroom and say that I was only doing content without doing practices, I would be working really hard to change that [I]."

Integrating 3DL into her classroom, specifically scientific practices, also is beneficial for Molly because it allows her to "say what this problem is about, [...] the practice, and that's a, that's a powerful thing for a bunch of life science students in a physics class [...] they then

get to see a lot more biology because I'm not so concerned with getting all the biology stuff exactly right [I]." She goes on to describe this thought in more detail as "worry[ing] so much about getting the content right, that you forget that like, why that scenario is so interesting [...]is because it has something about that analysis or the interpretation or something about that is a practice focus [I]."

The structure of the class helps Molly integrate 3DL into her classroom. Molly recalls what teaching a purely lecture based class was like, "so I think it was a lot harder. And that in that setting to think about some of those practices as fitting like if I felt like I should belong in the lab [I]." With the studio structure of her current class students are able to engage in practices during lab.

Working with Fellows from other disciplines helped Molly with her material design. During the Fellowship Molly and other Fellows designed a cross disciplinary problem for students. Molly recalls this experience as "a cool thing that wouldn't have come about if I had not been in a group of people with Biology and Chemistry and like all of us together[I]."

Molly's general approach for material design remained unchanged when she started to create 3DL material except now she started to pay closer attention to the type of information that she presents to her students. The structure of her class and her colleagues in the Fellowship were also a benefit for Molly.

### Instruction

The 3DL assessment items that Molly's students completed focused on the biological phenomena of the "strain curve of two different component of bone [F]." This question required students to write down their response for two separate parts. Aside from her assessment items Molly feels her classroom materials are "great examples of Three-Dimensional problems [I]."

When it comes to instruction, Molly has developed a technique to her instruction. Molly has been teaching a class that is an "integrated lab lecture [I]" with multiple instructors. Due to the set-up of her class, Molly can choose to "do lab whenever we want to do it

[I]." The way Molly chooses to present and explore material is through a process she calls "applying and extending [I]." In her interview Molly describes this process, "I present them a problem, a phenomenon of some sort. And, and I asked them to think about, like, what kinds of things would they like to know about it? And, and then they, they designed some experiment, or to figure out some of the stuff that they would like to know about it [...] And then we spend the next day seeing how far those rules will take us [I]." When it gets to the end of the cycle Molly has the class "apply those rules and phenomena to something that has to do with biology, so something at the cellular level, usually or something that connects to a biology [I]."

### Evaluation

Molly's formal evaluation of her students takes place in the form of individual and group exams. The logistics of these exams came from discussions with other Fellows. Once she integrated 3DL into her exams, Molly found that she was able to assess the practice of science. After learning how to create 3DL formal exams, Molly was able to change her informal approach of evaluation to align with instruction.

In Molly's class she uses individual and group exams. The individual exams are composed of "a bunch of analytic problems" and "some coding work [I]" and Molly describes her group exams as a place where she is "testing their experimental understanding [I]."

When it came to generating exam ideas, Molly found the Fellowship to be very beneficial. In her interview she states, "I've like really enjoyed hearing from people and the different ways that they write exam questions and think about grading them. Um, because that's like one of the hard parts of faculty member, like grading is the worst [I]." In fact, Molly joined the Fellowship because she "heard from some folks that designing assessment questions that people had creative ways of doing that, that I would get some, like exposure to I guess [I]." She also found herself "[her]self trying to pull [scientific practices] in more [I]." Molly also mentions designing 3D exam questions is useful because it allowed her to accurately assess what she wanted to assess. Her prior work with Ruben (pseudonym), a Fellowship

coordinator, "really helped me with my exam questions make them better using 3D, 3D dimensional learning [I]." This process took place by "[Ruben] would look at my exam questions, and he would help me see that, while implicitly there was a practice there, I wasn't explicitly asking students to show me their understanding of the practice[I]." The end results were very positive. Molly recalls, "my questions just got much cleaner and like students would produce what I really wanted them to do [I]." 3DL assessments have allowed Molly to pay closer attention to what she was assessing.

Molly's practice with 3DL exams helped her create assessments to informally test her student's understanding in class in the form of clicker questions. Molly states, "so I think since I've gotten better at writing those test questions that do practices and then I can translate that to like writing clickers style questions that you could use a lecture class [I]."

All in all, Molly's structure of exams has not changed due to 3DL or the Fellowship although she did benefit from hearing from other Fellow's exam practices. Molly's exams benefited from the use of the 3DL framework because she was able to assess scientific practices. Ultimately, her work designing exams also helped her design clicker questions to test her students informal understanding.

**Reflection**

Molly recalls different 3DL materials going differently in her classroom. Due to Molly participating in an earlier cohort Molly's interview occurred one year after her participation in the Fellowship, Molly has more difficulty reflecting on how her 3DL unit went. She is able to reflect on an exam question and classroom problem. Molly recalls that one of the 3DL exam problems that she implemented was very successful. Molly states, "Everyone got that question right. I was so like, I remember because it was like so easy to grade [I]." Another problem that Molly implemented did not go well. Molly recalls that it "fell on its face [I]." Molly goes on to elaborate why, "I remember it as like a really like a thing that I simplified to the reduced level because that's what I do in physics, right? These are two point charges connected by a distance. And for a bunch of students who had strong chemistry backgrounds,

they saw partial charges and much more like possible of like bending [I]." Overall, the 3DL material that Molly created went well, but some of the simplifications that Molly made were difficult for students with strong STEM backgrounds not in Physics.

### 7.3.2 Themes

#### Motivation/Ability to change assessment practices

Molly had joined the Fellowship wanting to learn how to assess scientific practices. Molly spent a lot of her time in the Fellowship learning about new assessment practices and working with Ruben on creating new assessment items. Molly's new assessment items aligned more closely with her instructional items because of this alignment she feels inclined to continue the use of her materials.

#### Material placement and participation in instruction

Molly teaches a class that has a studio format (combined lecture and lab). Due to the structure of her classroom she is able to integrate the use of scientific practices into her classroom activities. She also has a specific process of instruction that she utilizes inside of her class that helps her students investigate biological phenomena through the use of scientific practices. Molly notes that she likes her process of instruction because it allows her students to come up with new and interesting questions that she had not though of before. The integration of scientific practices into her classroom and her participation in the instruction leaves Molly wanting to continue using 3DL principles.

#### Social interactions

Molly interacts with other Fellows inside of the Fellowship. These interactions have given her new ideas about assessment practices. Molly's motivation to learn about new assessment practices was one of her main reasons for participating in the Fellowship, and the interactions she had inside of the Fellowship served this purpose. She also talks about the benefit of interacting with Fellows outside of the field of Physics. Working with non-Physics Fellows

allowed her to think about her material development from different perspectives. All of these beneficial interactions contribute to her positive feelings about the Fellowship and 3DL.

# Chapter 8

# Cross-case Analysis

In order to look for common factors that influence Fellow's design and implementation of 3DL material we cross-analyzed each case by comparing and contrasting themes from each one of the 5 stages of a Fellow's PR&A. The themes were articulated at the beginning of Sec 7 and Table 7.1 point out where they appear in the data.

## 8.1 Pedagogical Reasoning and Action

### 8.1.1 Comprehension

Ron, Charlie, and Molly all view 3DL as aligning with their educational goals for their classes. In particular, they all want their students to be able to develop problem solving skills, and be able to apply their knowledge in various scenarios that they encounter. Ultimately, Ron and Molly seem to remain positive about 3DL, while Charlie does have some skepticism about the purpose of 3DL integrating with his student population.

### 8.1.2 Transformation

The ways that our Fellows transform their ideas to classroom material can be divided into their approach to material design, structure of their classroom, and their social interactions

in and out of the Fellowship.

When it comes to material design Ron, Charlie, and Molly all approach material design in different ways. Ron has experience using material provided to him, for the most part Charlie creates his own material from scratch, and Molly adapts pre-existing material to suit her needs.

Ron and Molly teach classes that only have one component, lecture for Ron and studio for Molly (she notes that the structure of her class is well suited for the 3DL framework), thus they do not have to make a decision about where they should put their instructional material. On the other hand, Charlie teaches a class with a lecture, recitation, and lab component; therefore, Charlie had to decide what component would be the best fit for the 3DL unit.

The social interactions that the Fellows experience also affect the way that they approach material design. All three Fellows worked with colleagues to build their material. Unlike Ron and Molly, Charlie only kept his interactions surrounding 3DL between other faculty inside of the Fellowship. His interaction with Bill provided his with a collaborator and help on the design of his 3DL unit. The social interactions that Molly encountered helped gave her new exam ideas and helped her to integrate biological phenomena into the classroom. Although Ron has learned a lot from his colleagues in the Fellowship, his colleagues outside of the Fellowship have less than meaningful conversations with Ron about new teaching practices. In particular, Ron sees his colleagues outside of the Fellowship as having an "old school" perspective.

### 8.1.3 Instruction

Our instructors have different experiences when it came to the instruction of their 3DL unit. Ron and Molly were able to be present for the entire activity and were able to choose how to manage the classroom and explain the material. On the other hand, Charlie implemented some material in his lecture but a large portion of the material was put into his recitation sections due to those sections being a place where students are given the opportunity to

practice problem solving. The placement of the 3DL unit also put constraints on the instruction of the material. Charlie had to rely on another instructor, George, to implement his unit, and it was George's choice to encourage a "divide and conquer" approach.

### 8.1.4 Evaluation

When it comes to evaluation, Ron, Charlie, and Molly use similar techniques and formats for informal and formal evaluation.

For informal evaluation, all three Fellows prefer to use clicker questions. Formal exams for Molly benefited from the interactions with other Fellows, and integrating 3DL into her exam was positive as she was able to start to assess how her students engage in science. On the other hand, Ron and Charlie did not create a 3DL assessment. For Ron this is due to the course management system that his department uses, and for Charlie it is because his exams already assess what he wants to evaluate. Additionally, Charlie put his 3DL in a part of his class that he does not typically assess. Ultimately, both Charlie and Ron see being unable to align their instructional materials with their assessment as a problem.

### 8.1.5 Reflection

Upon reflection Ron, Charlie, and Molly all had different experiences with their 3DL unit and their plans for the continued use of 3DL.

Ron continually mentions how there was a palpable difference in the room, and Molly talks about the benefit and surprise of listening to her students come up with new ideas. However, Charlie was only able to reflect on student grades due to the nature of his participation in the 3DL unit. He notes that the 3DL unit was a "lateral step" from other classroom material.

As for plans for the continued use of 3DL, Ron and Molly seem positive about using 3DL in future endeavors while Charlie does not see the benefit of the continued use of 3DL.

## 8.2 Themes

Through our cross-case analysis we found three themes: motivation/ability to change assessment, classroom structures/instructional practices, and social interactions.

### 8.2.1 Motivation/Ability to change assessment

All three of our Fellows have specific assessment practices. Ron uses a course management system, Charlie's current assessments test his student's conceptual understanding, and Molly wants to integrate scientific practices into her exams. Charlie has already built his exams from his instructional materials and likes the concepts that they test, and Molly is currently in the process of aligning her instruction of scientific practices with their assessment. Their assessment practices and instructional materials influence each other, and Molly's ability to asses and instruct scientific practices has a positive influence on her continued use of 3DL.

On the other hand, Ron's use of a course management system and Charlie's inability to create an assessment item for his 3DL unit causes discomfort with their plans for the continued use of 3DL. The course management system that Ron uses restricts him from using multiple choice questions. Ron does not find multiple choice formatting conducive to the 3DL framework. Charlie was strapped for time when creating the assessment for his 3DL activity. Both Ron and Charlie's discomfort with the lack of alignment between their assessment and instructional materials contribute to their reservations about 3DL. Unlike Charlie it does not stop the use of 3DL, but he does note it as a barrier that he will have to overcome.

### 8.2.2 Classroom structures/Instructional practices

The structure of our Fellow's classroom effects their instructional practices and their overall buy in of 3DL. Ron, Charlie, and Molly all teach classes with different classroom structures. Ron teaches a lecture class, Charlie teaches a class with a lecture, lab, and recitation components, and Molly teaches a studio class. The studio format of Molly's class allows

her to focus on scientific practices by exploring biological phenomena, and the educational resources that Ron uses allows him to create a student led activity in his lecture activity. Unlike Molly and Ron, Charlie had to choose where to place his 3DL activity. Due to the teaching progression Charlie has for his class, he decided to create a 3DL activity for the recitation component of his class.

The placement of their material influences their instructional practices. Ron and Molly were able to be present for the instruction of their unit. Their participation in instruction resulted in them developing a personal insight on the ways in which students responded to the material and how they felt while teaching the material. The impressions that they were able to form from instruction served as a main motivating factor to continue with the use of 3DL. Charlie's recitation activity was taught by his recitation instructor. Charlie had to rely on student grades and the feedback his colleague provided. The feedback he got from his colleagues and the grades were neutral, but he formed a negative impression about continuing with 3DL.

### 8.2.3 Social Interactions

We see that all three Fellows are influenced by social interactions. The interactions that all three Fellows have inside the Fellowship influence the ways in which they learn about new teaching ideas and supports them in their material development. All three decide to work collaboratively on their material design. Charlie's choice for collaboration comes from wanting to save time in his design. Ron and Molly also discuss how the Fellowship helps them come up with new ideas for activities and assessment practices. For Molly a lot of the interactions inside of the Fellowship were focused on assessing scientific practices and taking a biological perspective to material design. The social interaction that Fellows have inside of the Fellowship help them take up 3DL and integrate it into their classrooms.

Ron is also influenced by interactions outside of the Fellowship. Ron classifies his interactions as 'old school' and does not view these interactions has helpful or supportive of his new ideas. In fact, Ron refrains from sharing his new ideas with a co-instructor because

of the interactions that he has had outside of the Fellowship. The social interactions with people outside of the Fellowship hinder the spread of 3DL throughout Ron's department.

Interactions with students also influences Ron and Molly's view of their instruction. Interacting with his students sparked Ron's motivation to join the Fellowship. During the Fellowship, Ron and Molly were able to participate in the instruction of their entire 3DL unit. This left a positive impression on Ron and Molly as they were able to reflect upon the conversations they were having with students. Their positive experience interacting with their students also served as a reason for continued use of 3DL.

# Chapter 9

# Discussion

## 9.1 Alignment of Assessment and Instruction

The ability to align assessment and instruction directly influences whether faculty buy into 3DL. Fellows who did not have the chance to align their instruction with their assessment items had mixed reactions to continuing the use of 3DL in their classrooms.

The Fellowship focuses on the principles of LGDD to help them align all of their materials to their learning goals. All three Fellows created learning goals and instructional items, but both Ron and Charlie never created an assessment item. For Ron this is due to the course management system that his department uses, and for Charlie it is due to a lack of time and because his exams already assess what he wants to evaluate. Molly is able to align her exams with the framework after working closely with Ruben. She feels very positive about her class and has confidence that she is assessing how students engage in doing science. Their views on their assessments ultimately affects their instructional materials. Both Charlie and Ron see being unable to align their instructional materials with their assessment as a problem. For Charlie this makes him want to stop the use of 3DL materials; although, it does not fully stop Ron from the use of 3DL, but he does note it as a barrier that he will need to overcome.

All three Fellows mention the importance of aligning instruction and assessment, but

unlike Molly both Ron and Charlie struggle to align their assessment with instruction. The Fellowship is designed around the premise that changing assessment leads to change in instruction[74], and our research suggests that there is a correlation between the ability to align instruction to assessment and continued use of said materials. More specifically we found that assessment design is influenced by the current state of assessments tools/technology, and how well it can be integrated into instruction.

There is a lot of work out there that outlines ways for faculty to align their instruction with assessment[72;73;90], but there is little work that investigates the challenges faculty encounter when aligning their materials or developing assessment items. Although the Fellowship spent time talking about assessment design and the process of aligning assessment with instruction, it did not spend time to understand the logistics of assessment design and the current state of their assessments beyond talking about what it is that they want to assess. FLCs should address the topics surrounding current assessment development as a way to help faculty adopt new instructional practices.

## 9.2 Spread of 3DL

We see that the culture of the department working through classroom structures and course management systems inhibits the use of 3DL. Furthermore, social interactions within the department stops the spread of ideas surrounding 3DL.

### 9.2.1 Classroom Structure

We see the classroom structures imposed by departments affect material design and play a part in the plan for the continued use of 3DL. Ron, Charlie, and Molly all teach courses with different classroom structures. The structure of Ron and Molly's classes allow for one class component, lecture for Ron and studio for Molly. Whereas Charlie has three components in his class: lecture, lab, and recitation. Due to the structures of their classrooms Charlie has to decide what section he would like to implement his 3DL material unlike Ron and Molly.

Throughout all of Charlie's stages of PR&A his decision to implement his material in the recitation affects the way he participates in instruction, how he gauges the effectiveness of the unit, and eventually his thoughts on continuing with 3DL material.

The placement of the 3DL unit puts constraints on the instruction of the material. Ron and Molly were able to be present for the entire activity and were able to choose how management of the classroom and explanation of the material would look like. Charlie had to rely on another instructor, George, to implement his unit, and George made decisions concerning instruction and management of the 3DL unit. By looking across the stages of Instruction and Reflection in PR&A we see that their ability to participate in the instruction of the 3DL unit directly affects their feelings about their 3DL unit. In their reflections, Ron and Molly are able to speak to how the instruction went and how they felt about the material. However, Charlie was not able to do this and could only reflect on how students performed on the material, and because the grades did not differ between the 3DL unit and his old material Charlie does not see the benefit for continuing with 3DL.

The structure of the classroom, and faculty participation in instruction influence Fellow's plan for continued use of 3DL. Structures of classrooms are often out of the control of instructors, and this can impact how faculty interact with their classrooms. More specifically, classrooms that rely on more than one instructor have an added barrier as other instructors might not be aware of the main instructor's goals[91]. Other research has found that faculty often use their intuition and general feelings to see if a technique worked[68], and that the types of interactions instructors have with students during instruction also affect their use of pedagogical practices[18]. This all goes to support Turpen, Dancy, and Henderson's claim that faculty are more convinced by their own experiences rather than with data[69]. Support provided from professional development leaders rarely includes observation and feedback during implementation[65]. One solution for this could be the use of peer-to-peer observations[18]. FLCs should encourage faculty to use their intuition and experience as well as student outcomes to support faculty buy-in. This can be done by providing faculty with opportunities to participate in and reflect on their own experience with new material as well as the ability to learn from student outcomes.

### 9.2.2 Course Management Systems

Ron struggles to use 3DL because of the departmental history with a course management system. The use of the course management system affects the design of his material. Ron mentions the use of this course management system when describing his exams, but becomes a larger problem when Ron tries to align his exams to his instruction. Ron notes this as one of his main concerns when reflecting upon his experience.

Ron's trouble with the course management system echoes the work of Zohrabi that finds faculty's motivations for adopting RBIs can be negatively impacted due to the use of certain textbooks or online platforms[68]. But, unlike Zohrabi we see that Ron's use of the course management system affects his use of assessment rather than motivation to change it.

### 9.2.3 Social Interactions

One way that the Fellowship supports faculty is through interactions with other Fellows. Yet the social interactions Ron has outside of the Fellowship affects his plan for continued use of 3DL.

Ron, Charlie, and Molly all had positive experiences interacting with Fellows inside of the Fellowship. All three of them were able to collaborate with Fellows on their materials, this proved to be a positive experience for our Fellows. The conversations that occurred as part of Fellowship meetings gave our Fellows new ideas to bring into their classrooms. These interactions are products of the design of the FLC

Ron is also negatively impacted by the social interactions he has outside of the Fellowship. Outside of the Fellowship, Ron has less than meaningful conversations about new teaching practices. We see that this does not stop Ron from pursuing and trying new instructional/teaching strategies, but it does stop him from collaborating with his co-instructor. The experience Ron has had with other colleagues in his department has stopped him from sharing his ideas about 3DL and does not support the purpose of the bottom-up approach of FLCs.

### 9.2.4 Departmental Culture

Defining departmental culture as the use of a shared set of beliefs, customs, practices, and artifacts[49], we see that departmental practices such as classroom structures influence Charlie's participation in instruction. Ron's use of departmental used artifacts affect his ability to create assessment items. Customs and beliefs in the department also affect his social interactions, and discourages Ron from sharing new ideas. This ultimately hinders the goals of bottom-up approaches to professional development by stopping the spread of certain teaching ideas. The Fellowship was created based on the hope that faculty involved in the Fellowship would spread ideas across colleagues and hopefully though departments and institutions. We see the spread of new practices and ideas depends on the tools and environments used/created by the department and the people within them. In order to utilize the bottom-up feature of FLCs professional development needs to focus on the departmental culture that they are a part of, and be attentive to the way these cultures could affect the spread of new ideas.

## 9.3 Limitations

The limitations present in our study come from our focus on Physics, our case selections, and our use of the PR&A framework.

This study focused on Fellows that are a part of the Physics discipline. We chose to focus on Physics Fellows because our Physics expertise would lend itself to understanding the design of Physics classroom materials as well as the physical and cultural contexts that our Fellows participate in. Since this study was conducted with Physics faculty, the claims that are made are confined to Physics departments and professional development programs. Although it would be reasonable to assume that course structures and alignment of assessment and instructional materials are all factors that would influence material design for other STEM Fellows outside of the Physics discipline.

The Fellows that we selected for our cases are all faculty members at large and predom-

inantly white institutions. They also all freely chose to participate in a long-term teaching fellowship. The demographic make-up of the institutions that our Fellows participate in effects the culture of their department as well as the considerations that Fellows take into account when designing classroom material. These considerations could look vastly different for Fellows that do not work at similar universities; therefore, our claims about the culture of departments are limited to Faculty participating in large and predominately white universities. Our Fellows also chose to participate in a two year teaching fellowship because of the practices that our Fellows use may not extend to the experiences that every faculty member faces when designing instructional and classroom materials.

The use of the framework of Pedagogical Reasoning and Action also limits the scope of our research investigation. By focusing on Fellows' PR&A we were able to investigate the influences on the design of a Fellows' classroom material, but not influences that affect other experiences that our Fellows face inside of the Fellowship. These experiences may include their motivation to join the fellowship, new ideas learned that go beyond instruction and material design, and interactions that influence other areas of their professional life.

# Chapter 10

# Conclusion

In our study we investigated influences on faculty uptake by utilizing the PR&A framework. We explored the PR&A of three cases in order to determine the influences on material design, and plan for continued use of 3DL.

Our first research question was concerned about influences outside of the Fellowship that affect material design. We find that the culture of the department that our Fellows exist in effect their material design. More specifically, the departmental culture influences course management systems, classroom structure, and social interactions that all influence their material design.

The second idea that we wanted to investigate was the influences on the plans for continued use of 3DL. Our study reveals participation in instruction and the ability to align assessment to instruction all positively impact our Fellow's thoughts about the continued use of 3DL. More specifically we find faculty participation and classroom structure influence how faculty feel about the change that they are making. Therefore, it is important for faculty to collect evidence of student learning as well as participating in teaching experiences in order to use their intuition.

Finally, we explored the ways in which the FLC supports Fellow's adoption and plan for continued use. We discover that the FLC provided Fellows with a space to share new ideas, learn from other's ideas, and work with other Fellows on material design. The FLC also

spent time talking about the importance of aligning instruction and assessment; although this does not help Ron and Charlie to align their instruction and assessment, it does influence how they view the utility of their 3DL unit. This suggests that the FLC should spend more time talking about how to align instructional and assessment items.

## 10.1 Recommendations

Our work suggests that FLC designers should spend time talking about assessment, encouraging participation in instruction, and supplying the necessary tools to help promote change. We also recommend that the research community investigates the ways in which faculty use and design assessment items.

Unlike Molly who had additional help and applicable resources, Ron struggled to make the assessment items that he wanted to do to the nature of the course management system that requires multiple choice formatting. In order to prevent discontinued use of their design ideas due to assessment practices, FLC facilitators should include discussions on how to design assessment items and address common issues such as formatting.

Participation in instruction is a valuable experience, and in our cases we see this directly affect Molly, Ron, and Charlie's buy in to 3DL. More specifically we note that Charlie would have benefited from observing his students working on the 3DL activity. In order to encourage instructors to participate in instruction and use their intuition as valuable data, FLC designers need to understand that data does not always drive change and encourage participation in instruction through peer observations or reflections.

Lastly, we see that all three of our Fellows participate in different types of social interactions. These interactions have an effect on the spread of ideas throughout a department. This is apparent in Ron's case as he tries to bring 3DL into a class that he coteaches. In order to promote change beyond the FLC, FLCs need to work towards supplying participants with the tools and resources that will help them promote change within their department especially in regard to moving towards different assessment and instructional formats.

Along with our results from our research we found that the process of assessment design

from the perspective of the practitioner is also underrepresented in the literature. As a research community we need to further investigate how faculty use and design assessments.

## 10.2 Future Work

In the future this work can be applied to Fellows from other disciplines in our Fellowship. Exploring the influences on material design for faculty in different disciplines gives us the opportunity to explore the cultural influences that are common in the different STEM fields. The identification of these influences allow us to think about design features that support multidisciplinary FLCs as well as design features that would support each field separately.

As mentioned in the recommendations further attention into the process of assessment design and usage can be investigated within the context of the Fellowship. Investigating properties of assessment design and use would help us build tools and resources to help faculty create assessment items that align with their instruction.

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# Appendix A

# Interview Protocol

**General info and consent script**

*Explain interview/project*

"I have emailed you the consent form, we will go over that and then we will conduct a recorded interview about the ways you approach material design. The interview will take about an hour."

*Talk about the consent form*

Make sure to mention that participation is voluntary, identity and interview will remain confidential, and they have to right to withdraw from the study at any time.

*Start recording*

"Thank you for agreeing to be a part of this research. My name is Lydia Bender and I am a graduate student in Physics at Kansas State University. This interview is designed to gain an understanding of the ways that faculty approach design for classroom materials. If you do not wish to answer a question for any reason just let me know."

**General questions about creating materials**

1. What class are we going to talk about in the context of this interview

2. Classroom Management

3. Goals for students

    (a) Where did these come from?

        i. Are any of these imposed from the department?

        ii. How about other faculty?

4. Evaluation of student understanding

    (a) How does this influence the type of material that you chose to design?

    (b) What about other types of interactions with students?

        i. Does this change the way that you classroom is run?

5. What are you exams typically like?

6. How do you create material?

    (a) Does the way you teach/manage a classroom dictate how the material is designed? (prefer certain type of problems verse others)

    (b) Situational constraints?

        i. If these constraints changed from X to Y, would you develop a different kind of problem?

    (c) Are other faculty involved in this process?

**General questions about the fellowship**

1. How was your experience in the fellowship?

2. What was your motivation to join the fellowship?

3. What did you find helpful? What did you find unhelpful? (other faculty, forum, readings, assignments)

(a) Forum (cohort 3 only)

(b) Readings

(c) Assignments

(d) Backwards Design

(e) Presentations

(f) Feedback

(g) Where did this feedback happen

(h) Interaction with other faculty and site leaders

(i) other institutions

**General questions about 3DL**

1. Can you tell me more about what Three-Dimensional Learning is?

   (a) Core Ideas

   (b) Scientific Practices

   (c) Crosscutting Concepts

   (d) How do you see these three things work together?

   (e) Did you have any previous knowledge of 3DL before the fellowship?

2. How do you feel about trying to incorporate 3DL ideas into your classroom?

   (a) 3DL and the educational goals of the class

**3DL and their material**

[Pull up their material]

1. 3DL and the design of the material

(a) Did the process of material development that you previously mentioned change when creating 3DL material?

2. Unit for the material

   (a) How did 3DL factor into this?

   (b) CIs, SPs, and CCs?

3. The kind of problem developed

   (a) Did 3DL influence this decision? (i.e. multiple choice, problem solving, CQ, lab, recitation)

   (b) Different CIs, SPs, and CCs effecting this decision? (i.e. developing models could be a multiple choice but evaluating information could be long answer)

   (c) Situational Constraints?

4. Material, 3DL, and students in general

5. Material, 3DL, and their students

   (a) Aspects of 3DL and student population (Do certain CIs, SPs, and CCs apply where others do not)

   (b) How would this change if your students were X instead of Y?

6. How comfortable do you feel giving your students a 3DL problem on an exam?

7. How were you planning on teaching this material?

   (a) How did this have an effect on the design of the material?

8. Were you able to use this material in your classroom?

   (a) How did that go?

   (b) What did you learn from teaching this material?

9. Do you still think about 3DL when creating material for your class now?
    (a) Is this something you see yourself doing in the future?
10. How do you see 3DL fitting with your classroom material?
    (a) How (if at all), do you use 3DL when you're planning your course?
        i. Do they look at their class content and then find how 3DL connects or do they use 3DL to guide their decisions about what should be taught?
    (b) Do certain aspects of 3DL fit better than others? What are these? (i.e. certain scientific practices are easier than others)

# Appendix B

# Codebook

**Description:** PR&A is a theoretical framework that describes a teacher's reasoning when making decisions about pedagogy and content delivery. As a teacher goes through the process of creating classroom material they think about five different stages: Comprehension, Transformation, Evaluation, Instruction, and Reflection. (Instruction happens during material implementation, and Reflection occurs after students have seen that material)

**Categories & Definitions**

***Comprehension***: involves faculty thinking about the set of ideas that they want to teach, and how those ideas connect to the educational purposes of their class. *Coding Definition*: Faculty talking about their educational purposes of the class or the educational purposes that they were given, their understanding of 3DL, and how these ideas are connected.

***Transformation***: broadly focuses on turning their 3D design ideas into instructional material. *Coding Definition*: Faculty talking how they are choosing to represent ideas, how they are going to teach material (what kind of instructional selections they are going to use), how the material fits with their students and the student population, or how content will fit into the classroom

***Evaluation***: centered around ways faculty choose to evaluate student understanding inside of the classroom as well as formally testing their understanding on exams. *Coding Definition*: Faculty talking about how they test student understanding formally (i.e. exams) or informally (i.e. in class, homework, etc.). This could be talking about how assessments are typically set up and/or used.

***Instruction***: the decisions about the act of teaching their material (i.e. classroom management, how material should be presented, interaction with students). *Coding Definition*: Faculty talking about how they managed the classroom when teaching their material, and how material was explained/discussed. These are observable acts, something that you could observe if you were watching the instruction.

***Reflection***: Faculty's thoughts about how their 3DL unit (most 3DL units contained an activity/problem and an assessment) went, and what they learned from implementation would fit under this category. *Coding Definition*: Faculty talking about how the experience of teaching the 3DL unit went, or what they learned from teaching the unit. This is focused on the 3DL unit went. Occurs after implementation.

***N/A***: This coding is given to a quote that does not fall into any of these categories

**Coding Strategy** Some quotes can be very long and dense. I have found the following strategy useful:

1. What is the purpose of the statement?
    (a) Are they talking about instructional materials/techniques?
    (b) Are they talking about the set up of their class?
    (c) Are they talking about how their 3DL unit went
2. What part of the class are they concerned with?