5-2017

Student Development as Cross-Disciplinary Team Members: Real-Time Observations of Student Experiences During a Team Project

Rachel Kristen Anderson
Clemson University, rsundbe@g.clemson.edu

Follow this and additional works at: https://tigerprints.clemson.edu/all_dissertations

Recommended Citation
Anderson, Rachel Kristen, "Student Development as Cross-Disciplinary Team Members: Real-Time Observations of Student Experiences During a Team Project" (2017). All Dissertations. 1875.
https://tigerprints.clemson.edu/all_dissertations/1875

This Dissertation is brought to you for free and open access by the Dissertations at TigerPrints. It has been accepted for inclusion in All Dissertations by an authorized administrator of TigerPrints. For more information, please contact kokefe@clemson.edu.
STUDENT DEVELOPMENT AS CROSS-DISCIPLINARY TEAM MEMBERS: REAL-TIME OBSERVATIONS OF STUDENT EXPERIENCES DURING A TEAM PROJECT

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Engineering and Science Education

by
Rachel Kristen Anderson
May 2017

Accepted by:
Dr. Julie Martin, Committee Chair
Dr. Karen High
Dr. Leidy Klotz
Dr. Todd Schweisinger
Dr. Barbara Speziale
Abstract

Recent graduates entering the professional field must draw on their content knowledge as well as their collaboration skills to address professional projects. These projects increasingly call for diverse skill sets from multiple disciplines and personal backgrounds and interests thereby requiring professionals to engage with cross-disciplinary differences. In order for undergraduate students to be prepared for teamwork as professionals, they need to experience and practice collaboration as students. However, undergraduate education typically incorporates mono-disciplinary student experiences that do not scaffold an understanding of or appreciation for differences in viewpoints and training of individuals in technical and non-technical fields. Incorporating effective collaboration experiences into the curriculum requires a deeper understanding of how students approach teamwork and develop as effective team members during a project.

My research uncovers the experiences of students during a cross-disciplinary project through a real-time data collection approach. I became a participant observer on a single cross-disciplinary student team and observed team meetings, interviewed team members, and collected written documents from students to elicit thick, rich descriptions of their development as team members during the project. I operationalize an existing framework for cross-disciplinary professional practice as potential stages of development students might experience during a project. Through the lens of this existing model, I identify the student trajectories through these development stages as well as the events and social structures that sometimes impede student development.
This dissertation uses a multi-manuscript format to discuss my contribution to the literature in four unique ways.

- I expose the “messiness” of qualitative research by sharing an audit trail of my research experience.
- I expand the current understanding of student cross-disciplinary teamwork by presenting four student cases showing a range of salient student roles and how those roles developed during the project.
- I provide a detailed account of how a sub-team of three engineering students navigated their roles and engaged with cross-disciplinary difference during a five-day intensive project.
- I also examine social norms and power structures in higher education to uncover how they influence student and faculty actions during a project and their subsequent impact on student development.

Together, these four manuscripts expand the current understanding of student cross-disciplinary collaboration and hold implications for researchers, practitioners, policy makers, and even students.
Dedication

This work is dedicated to my husband, Zach. Thank you for working so hard to support our family while I finished my degree. You have been a true example of dedication and commitment to putting family first. Thank you for empowering me to do the same.
Acknowledgements

I want to acknowledge my family who supported me throughout this process. I owe a heart-felt thank you to my parents, Cindy and Russell, and my step-parents, Skip and Andree, who were by my side every step of the way from moving ten hours from home to switching degree programs to accepting a position at Clemson. Your love and support have made such a difference in my life.

Thank you, Julie, for your guidance and mentorship over the past three years. Thank you for always believing in me and pushing me to grow as a scholar and as an individual. Your strength and compassion have served as an example that I hope to emulate for the students I will mentor.

Thank you also to my committee, Leidy, Todd, Karen, and Barbara, for your feedback and mentorship. Your individual perspectives as administrators, researchers, and practitioners have helped my work pose implications for a broad audience beyond education research.

To Dr. Robin Adams, thank you for making time to discuss my research. Your feedback and perspective shaped my work and encouraged me to address implications beyond what I initially thought possible.

I also want to thank my friends and colleagues who kept me grounded, provided perspective, and reminded me that I was not alone in this process. Thank you Shannon, Stacey, Gus, and Jared.

Special thanks to my past advisors and mentors, Dr. Little, Dr. Hoekje, and Ms. Varley. I see now how the opportunities you created for me throughout my high school and undergraduate education provided experiences and confidence for reaching this milestone. Thank you.

Finally, I want to thank my ten participants who let me be part of their cross-disciplinary team experience. Though this work, I hope that your stories and experiences will reach and touch others as they have me.
# Table of Contents

Title Page .......................................................................................................................... i

Abstract ............................................................................................................................. ii

Dedication .......................................................................................................................... iv

Acknowledgements .......................................................................................................... v

List of Tables ..................................................................................................................... viii

List of Figures .................................................................................................................. ix

Chapter 1 ........................................................................................................................... 1
  1.1 Broad Models of Team Performance and Effectiveness ............................................. 2
  1.2 Teamwork Models Specific to a Cross-Disciplinary Context ................................. 3
  1.3 Operationalizing the Existing Model in a New Context: Undergraduate Students 9

Chapter 2 ........................................................................................................................... 16
  2.1 Abstract .................................................................................................................... 16
  2.2 Introduction .............................................................................................................. 16
  2.3 The Qualitative Research Tradition: Background, Terminology, and Objectives 18
  2.4 Turning my Interest in Cross-Disciplinary Experiences into a Research Study ... 23
  2.5 Getting Started: Forming an Undergraduate Cross-Disciplinary Team ............... 25
  2.6 Decisions Made in “Making the Data” ................................................................. 27
  2.7 Decisions Made in “Handling the Data” .............................................................. 42
  2.8 Conclusion ............................................................................................................. 49

Chapter 3 ........................................................................................................................... 51
  3.1 Abstract .................................................................................................................... 51
  3.2 Introduction .............................................................................................................. 51
  3.3 The Existing Cross-Disciplinary Teamwork Model .............................................. 52
  3.4 Creating a Space for Undergraduate Cross-Disciplinary Teamwork .................. 54
  3.5 My Real-Time Method for Investigating Student Roles ..................................... 56
  3.6 The Salient Roles of Student Team Members ...................................................... 61
  3.7 Examining Student Roles Through the Lens of the Existing Cross-Disciplinary Framework ................................................................. 72
  3.8 Conclusions and Implications ............................................................................. 81

Chapter 4 ........................................................................................................................... 83
  4.1 Abstract .................................................................................................................... 83
  4.2 Introduction .............................................................................................................. 84
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1: Descriptions and attributes of each category of the cross-disciplinary professional practice model taken directly from Adams and Forin (2014)</td>
<td>7</td>
</tr>
<tr>
<td>Table 1.2: Detailed description of the four manuscripts comprising this dissertation</td>
<td>12</td>
</tr>
<tr>
<td>Table 2.1: Definitions of common terminology in qualitative research</td>
<td>21</td>
</tr>
<tr>
<td>Table 2.2: Demographics of my ten study participants including academic major and year in college</td>
<td>29</td>
</tr>
<tr>
<td>Table 3.1: Demographic information for the four cases presented in this manuscript</td>
<td>61</td>
</tr>
<tr>
<td>Table 3.2: Summary of unique roles and stages of development illustrated in these four student cases</td>
<td>80</td>
</tr>
<tr>
<td>Table 6.1: Overview of the research questions, key findings, and implications for each manuscript</td>
<td>130</td>
</tr>
</tbody>
</table>
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>Reproduction of Adams and Forin’s (2014) model for professional cross-disciplinary practice</td>
<td>6</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Illustration of my initial data collection plan including interviews, progress reports, observations, and a focus group</td>
<td>28</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>A representation of the final data collection plan that I carried out during my study</td>
<td>28</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>A diagram representing my overall data collection and analysis process with the final goal of expanding the current understanding of cross-disciplinary collaboration</td>
<td>46</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>A representation of the existing cross-disciplinary model for professional practice taken directly from Adams and Forin (2014)</td>
<td>53</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>An illustration of my data collection and analysis approach</td>
<td>57</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>An illustration of Scott and Ryan’s constant position at the strategic leadership stage of the cross-disciplinary practice model</td>
<td>75</td>
</tr>
<tr>
<td>Figure 3.4</td>
<td>A representation of Mark’s contradictory responses to different situations he encountered during cross-disciplinary collaboration</td>
<td>77</td>
</tr>
<tr>
<td>Figure 3.5</td>
<td>Illustration of Annie’s progression through the working together and intentional learning staged of the existing cross-disciplinary model</td>
<td>78</td>
</tr>
<tr>
<td>Figure 3.6</td>
<td>Comparison of all four students’ approaches to cross-disciplinary teamwork illustrated through categories of the existing cross-disciplinary professional practice model (R. S. Adams &amp; Forin, 2014)</td>
<td>79</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Reproduction of the Adams and Forin’s (2014) cross-disciplinary professional practice model</td>
<td>85</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>Diagram of my overall study process including the collection of multiple data sources (A through F) as well as my analysis technique</td>
<td>88</td>
</tr>
<tr>
<td>Figure 5.1</td>
<td>A representation of Adams and Forin’s (2014) existing cross-disciplinary practice model</td>
<td>105</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Figure 5.2</td>
<td>Diagram of the five data types I collected during my study and the connection among these different sources</td>
<td>112</td>
</tr>
<tr>
<td>Figure 6.1</td>
<td>Diagram of the anticipated trajectory of student cross-disciplinary development past a single semester</td>
<td>134</td>
</tr>
</tbody>
</table>
Chapter 1

Preface

As society is challenged with addressing increasingly complex and global issues, the nature of professional practice is becoming more cross-disciplinary. Multiple viewpoints, skillsets, and disciplinary perspectives are necessary to brainstorm solutions and connect ideas to achieve more comprehensive resolutions. With this recent push toward cross-disciplinary collaboration in the professional context, it has become even more important to prepare students for working among different disciplines and engaging with differences among team members. Yet the current undergraduate curriculum, especially within the field of engineering, is not typically designed to expose students to cross-disciplinary work. Engineering senior capstone experiences, for example, generally enroll only engineering students, making them mono-disciplinary. In addition, these experiences are not designed to engage students with the different interests, viewpoints, and personal backgrounds that can bring valuable insights to a project. While engineering students graduate with the content knowledge and design experience they will need as professionals, they often have no exposure to working with others from non-technical disciplines outside or to capitalizing on differences as a means of achieving broader solutions. This lack of cross-disciplinary collaboration experience perpetuates a void in the professional training of engineers.
Addressing this void requires developing and implementing cross-disciplinary experiences for students that mimic those of professional practice. This requires a better understanding of student cross-disciplinary perceptions and approaches, which govern their development as effective cross-disciplinary team members. Over four decades of research comprise the current understanding of team performance and effectiveness, but less research has focused on the topic of cross-disciplinary teamwork. Of those that do address cross-disciplinary collaboration, few define the individual as the unit of analysis. While understanding an entire team’s approach is useful, this method does not acknowledge the individual nature of learning and development. By investigating student cross-disciplinary experiences at the individual student level, researchers and practitioners can better understand the most influential approaches to training students to be effective cross-disciplinary team members.

1.1 Broad Models of Team Performance and Effectiveness

The broad body of literature on team performance and effectiveness offers insight into general team interactions within a number of disciplines. Teamwork models are often developed with a particular context or discipline in mind (Brannick, Salas, & Prince, 1997, Chapter 1); however, many of these models address similar team behaviors and traits (e.g. Borrego, Karlin, Mcnair, & Beddoes, 2013; Dickinson & Mcintyre, 1997; Mathieu, Maynard, Rapp, & Gilson, 2008; Salas, 2005). The most commonly cited, seminal model is McGrath’s (1964) Input-Process-Outcome (IPO) teamwork model. This model details inputs such as team member characteristics and traits as well as
organizational attributes of the team (in Mathieu et al., 2008). The team then applies specific processes based on these inputs to obtain outcomes (in Mathieu et al., 2008).

New insights into teamwork have motivated adaptations to the IPO teamwork model. These adaptations have mainly addressed secondary aspects of the existing model or expanded its context (e.g. Cohen & Bailey, 1997; Joseph E McGrath, Arrow, & Berdahl, 2000); however, a more drastic change to McGrath’s (1964) IPO model was suggested by Ilgen et al. (2005), over forty years after the IPO model was first introduced. Their research suggested an Input-Mediator-Outcome-Input (IMOI) model for describing team performance (Ilgen et al., 2005). Ilgen and colleagues (2005) reviewed the current team performance literature and noted trends toward identifying both processes and emergent states that can influence team outcomes (e.g. Marks, Mathieu, & Zaccaro, 2001). They suggested the term “mediators” to describe both the processes (i.e. member interactions and performed tasks) and the emergent states (i.e. individual member and team traits such as trust, climate, and confidence) that can influence movement toward team outcomes (Ilgen et al., 2005; Mathieu et al., 2008). The IMOI model also better illustrates the “feedback loop” that often happens during teamwork and, in particular, how outputs from one aspect of teamwork can be used as inputs to another team task (Ilgen et al., 2005).

1.2 Teamwork Models Specific to a Cross-Disciplinary Context

Mono-disciplinary team experiences often differ from cross-disciplinary collaborations. These differences can manifest as barriers to teamwork or to learning. Adams, Mann,
Jordan, and Daly (2009) found that language used by the team, roles of individuals on the team, and organizational and design structures are often different for cross-disciplinary teams and can result in boundaries that must be negotiated by the team. Richter and Paretti (2009) investigated student interdisciplinary teams and found that students can struggle with interdisciplinary perspectives, and this can make it difficult for students to learn and succeed in interdisciplinary contexts. Recognition of distinctions between how cross-disciplinary teams interact compared to mono-disciplinary teams has led to additional research on cross-disciplinary teams.

Much of the recent research on cross-disciplinary teams has taken place in the context of engineering design. A number of studies have specifically investigated undergraduate cross-disciplinary design experiences (e.g. Hotaling, Fasse, Bost, Hermann, & Forest, 2012; McFarland & Bailey, 2015; Miller & Olds, 1994; Rhoads, Whitfield, Allenstein, & Rogers, 2014). Many of the undergraduate design team studies self-identify as multidisciplinary or interdisciplinary; however, study participants are often all from the same field, engineering. This general trend is seen through much of the literature with few studies of undergraduate student teams incorporating both technical and non-technical disciplines working together (e.g. Allenstein, Rhoads, Rogers, & Whitfield, 2013; Anderson, Schweisinger, & Speziale, 2015; Baier & Tao, 2007).

Teamwork models specific to cross-disciplinary teams provide additional lenses with which to examine teamwork. Schaffer et al. (2008) proposed a cross-disciplinary team
learning framework for understanding the processes used by teams and the learning that takes place during team projects. Schaffer’s et al. (2008) framework combines Ilgen and colleagues’ (2005) IMOI teamwork model and Fruchter and Emery’s (1999) assessment model for cross-disciplinary learning teams. Schaffer’s et al. (2008) model analyzes cross-disciplinary work at the team level by identifying processes and emergent states the team utilizes as they work together toward an outcome. Another cross-disciplinary framework was recently published by Hsu (2015) as part of her dissertation work. She drew upon retrospective interviews elicit the various experiences of students with involvement in interdisciplinary collaborations. Her model details the range of students’ engagement with difference and perception of purpose in interdisciplinary learning (Hsu, 2015).

Another cross-disciplinary team model, developed by Adams and colleagues (2010; 2009; 2014), focuses on the individual level of teamwork. Their model outlines how professionals working in engineering contexts experience cross-disciplinary teamwork. Adams and Forin (2014) define cross-disciplinary as “a collection of practices associated with thinking and working across disciplinary perspectives” (p. 103). To study professional cross-disciplinary experiences, Adams’ research team conducted retrospective interviews with professionals experienced in working with people from different disciplines. Details and themes from these recounted experiences shaped the existing model, which highlights four distinct categories of professional cross-disciplinary work: working together, intentional learning, strategic leadership, and
challenging and transforming practice. A representation of Adams and Forin’s cross-disciplinary professional practice model is shown in Figure 1.1. The model is hierarchical so each category builds on the previous one to incorporate a new level of cross-disciplinary understanding.

![Figure 1.1: Reproduction of Adams and Forin’s (2014) model for professional cross-disciplinary practice](image)

Together these categories detail the various ways complexity, goal motivations, and differences among team members are experiences and how these aspects influence individual’s actions and perceived identities. Specific attributes or facets that represent individual’s experiences define each category. These attributes further delineate the nuanced differences among the four categories of the model. Table 1.1 provides an explanation of the key idea behind each category and lists the attributes of each. The content of Table 1.1 was taken directly from Adams and Forin (2014).
Table 1.1: Descriptions and attributes of each category of the cross-disciplinary professional practice model taken directly from Adams and Forin (2014)

**Working Together** – *working together with people who have different training to effectively find a better solution*

1. Knowing what you and others contribute and points of synergy
2. Recognizing disciplinary differences in what people do and how they communicate; an iterative process of asking questions, challenging assumptions, and listening for understanding
3. Being comfortable with asking for information that might seem obvious to an expert in that domain
4. Taking personal responsibility to be an effective collaborator

**Intentional Learning** – *intentional learning so everyone gains (me, my team, my stakeholders)*

1. Creating opportunities to learn new perspectives or ways of knowing
2. Purposefully educating each other to collectively enable a systems perspective
3. Learning through experience and failure
4. Learning how to negotiate meanings across perspectives and formulate or investigate problems through multiple lenses
5. Having a passion and appreciation for continual learning

**Strategic Leadership** – *strategic leadership to enable work and facilitate a better outcome*

1. Making or enabling conceptual connections
2. Building allegiances, shared ownership, and trust
3. Managing differences to create new paradigms or frameworks that leverage diverse perspectives

**Challenging and Transforming Practice** – *challenge and transform practice to integrate systems and produce an outcome greater than the sum of its parts*

1. Critically challenging disciplinary practice and investing in the ways conflict can be transformative
2. Integrating stakeholders as collaborators
3. Attuning to the human aspect of complex systems
4. Advocating less visible perspectives by taking into account the broader context
5. Embracing cross-disciplinarity as an everyday practice
This existing model for cross-disciplinary collaboration proposes a new interpretation of cross-disciplinary work as a *practice* rather than strictly a team *structure* (i.e. how many different disciplines are present on the team) (R. Adams, personal conversation, February 23, 2017). As a practice, cross-disciplinary work requires an individual to interpret and engage with individual differences, project complexity, and goal motivations. Adams and Forin (2014) incorporate Gloria Dall’Alba’s (2009) professional framework of thinking, acting and being to understand the nuanced ways of interpreting individual’s engagement with difference, motivation, and complexity. The complex and interconnected nature of the four categories of the model can make it difficult to operationalize in its entirety.

Other researchers have used this cross-disciplinary model to classify teams (e.g. Coso, 2014) and to determine an approach for describing cross-disciplinary practice (e.g. Hsu, 2011). For example, as a separate study in addition to her dissertation work, Hsu (2011) applied Adams and Forin’s (2014) model to observe a team of graduate and undergraduate students. From her observations, she proposed an additional category to the existing cross-disciplinary model which represents “no awareness of cross-disciplinary collaboration” (Hsu, 2011, p. 6). However, no other current research has sought to test or expand Adams and Forin’s (2014) framework.
1.3 Operationalizing the Existing Model in a New Context: Undergraduate Students

My dissertation work applies Adams and Forin’s (2014) framework for cross-disciplinary professional practice as an initial lens for investigating cross-disciplinary work in a new context: undergraduate students. I operationalize the existing model as a preliminary list of potential developmental stages students may experience during cross-disciplinary teamwork to address the overall question: \textit{In what ways do undergraduate students progress through the stages of cross-disciplinary development while working on a cross-disciplinary project?} My research draws on specific elements of the existing model to focus on team members’ roles and how these roles influence students’ perceptions, actions, and development during a team project. While the existing cross-disciplinary practice model provides a good starting point for understanding what it is like to work on a cross-disciplinary team, it does not capture the developmental process individuals experience while working on such a team. To uncover this development process, I utilize a unique, real-time data collection approach to capture the experiences of undergraduate students \textit{while} they work on a cross-disciplinary team project. In this way, my work \textit{moves beyond an understanding of practice and sheds light on the developmental process} associated with student cross-disciplinary teamwork.

In order to investigate in real-time the experiences of undergraduate students as they work on a cross-disciplinary team, I recruited study participants from a single cross-disciplinary student project course. The project was formed through an undergraduate research program and challenged the student team with developing a business plan for a
potential makerspace on the university campus. Once established, the makerspace would provide individuals with access to prototyping equipment, such as 3D printers and laser cutters, at little to no cost. Ten of the undergraduate students enrolled in the makerspace project were participants in my research.

My work borrows from ethnographic (Angrosino, 2007; Reeves, Kuper, & Hodges, 2008; Singer, 2009) and case study (Baxter & Jack, 2008; Stake, 1994; Yin, 2009) research traditions. Specifically, I followed an ethnographic data collection approach featuring real-time observations of the makerspace team’s interactions. I also collected data in the form of individual interviews, written documents, and my own personal memos. Together these multiple sources of data provide a thick, rich description of student experiences as they navigate cross-disciplinary collaboration.

My overall dissertation is formatted as a multi-manuscript document, allowing me to talk about my contribution to the field in four specific ways. Each of the four main chapters of my dissertation is written as a stand-alone manuscript. As such, there is overlap in the content of each chapter, as each must individually set the stage for my research context and approach. The entire document is written in first-person, active voice, using ‘I’ and “my” to communicate my work. This approach is intentional as it acknowledges my role as an instrument in the study, co-constructing the data with my participants (Lincoln & Guba, 1985, p. 39; Patton, 2015, p. 604; Watt, 2007, p. 82). Singer (2009) explains, “The ethnographer is `the research instrument par excellence,’ an active participant in the
research process” (p. 192). As an ethnographic researcher, I was a participant observer on the makerspace team, making my first-hand observations and personal memos a source of data for understanding the experiences of my participants.

As a way of further acknowledging my role in this work, I present my findings in each chapter as an ethnographic narrative (Angrosino, 2007; J W Creswell, 2013; Van Maanen, 1988). The main goal of this ethnographic narrative technique is to “draw the reader into a vicarious experience of the community in which the ethnographer has lived and interacted” (Angrosino, 2007, p. 16). I use each narrative to re-tell the story of, or restory, the experiences of my participants (Ollerenshaw & Creswell, 2002). Angrosino (2007) points out that these restorying techniques “can reach and move people and teach them about the experiences of others in ways that would never be possible with the standard scientific monograph...” (p. 81). In constructing each narrative, I drew upon the example of other ethnographers, such as Rebekah Nathan (2005) and Louis Bucciarelli (1994), who published their ethnographic narratives as books.

While my approach to writing each manuscript was similar, the purpose of each paper is unique. Each chapter was also written with a different audience in mind allowing my work to transcend traditional boundaries to reach both researchers and practitioners. Table 1.2 outlines the four manuscripts that comprise my dissertation including the manuscript title, research question, audience, main sources of data, and the unit of analysis for each paper. The purpose of each manuscript is also outlined in the table.
Table 1.2: Detailed description of the four manuscripts comprising this dissertation

<table>
<thead>
<tr>
<th>Manuscript Title</th>
<th>Research Question</th>
<th>Audience</th>
<th>Main Data Sources</th>
<th>Unit of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 2. <em>A Real Report from the Trenches of a PhD Dissertation: Exploring the Inherent &quot;Messiness&quot; of Engineering Education Research Through an Audit Trail</em></td>
<td>N/A</td>
<td>Novice Qualitative Researchers</td>
<td>Memos</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Goal:</strong> To expose the messiness of qualitative research and provide a specific case as an exemplar for new researchers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter 3. <em>Narratives of Students’ Salient Roles and Trajectories Through Cross-Disciplinary Development</em></td>
<td>What team roles do undergraduate students find most salient during a cross-disciplinary team project?</td>
<td>Education Researchers and Practitioners</td>
<td>Observations, Interviews, Written Documents, Memos</td>
<td>The individual student</td>
</tr>
<tr>
<td><strong>Goal:</strong> Expand the current understanding of student teamwork through a rich description of the salient roles students took on during a cross-disciplinary project.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter 4. <em>The Game Day Project: How a Sub-team of Engineers Experienced Cross-Disciplinary Difference</em></td>
<td>How do students perceive and engage with cross-disciplinary difference?</td>
<td>Engineering Education Researchers</td>
<td>Focus Group Interviews, Observations</td>
<td>A sub-team on the makerspace project</td>
</tr>
<tr>
<td><strong>Goal:</strong> Provide a detailed account of how three students managed sub-team roles and engaged with cross-disciplinary difference.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter 5. <em>Power Structures and Social Norms in Higher Education: How “Ruling Relations” Govern Faculty Influence on Student Cross-Disciplinary Development</em></td>
<td>How do the structures and norms of higher education mold the actions and perceptions of faculty and students during a cross-disciplinary project?</td>
<td>Practitioners</td>
<td>Observations, Personal Interactions, Memos, Interviews</td>
<td>The project team as a whole</td>
</tr>
<tr>
<td><strong>Goal:</strong> Examine the current structure of undergraduate education and the opportunities a faculty mentor has to foster student cross-disciplinary development.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The methods chapter of my dissertation is written as an audit trail detailing the challenges I encountered and decisions I made during my study. In this way, I am transparent about my research process and expose the “messiness” of qualitative research. The primary audience for this paper is novice qualitative researchers. I present my work as a specific example of a qualitative research study and encourage others to share their experiences. My hope is that together, we can further the conversation around quality in qualitative research.

The next three chapters (3, 4, & 5) of my dissertation use different data sources to present key findings from my work. Chapter 3 expands the current understanding of student cross-disciplinary collaboration by examining the roles students found most salient during the makerspace project. This paper uses interviews observations, written documents, and memos to identify these roles and what they communicate about student’s approaches to cross-disciplinary collaboration. The unit of analysis in this chapter is the individual student. I present four student cases that exemplify varied approaches to teamwork. The goal of this paper is to reach both education researchers and practitioners. Both audiences can directly benefit from a deeper understanding of student approaches to cross-disciplinary collaboration as each continues to research cross-disciplinary experiences and develops and manages student projects.

The fourth dissertation chapter examines the team dynamic of a sub-team of three engineering students as they navigated challenges in completing a specific project. In
working together on this five day, intensive project, the three students must engage with the cross-disciplinary differences they notice within their sub-team. The primary data source for this paper is a focus group I conducted with the three sub-team members as a follow-up to the makerspace project. While elements of this manuscript are relevant to practitioners and even students, I see the primary audience as engineering education researchers.

Chapter 5 takes a step back from the details of my work to examine the power structures and social norms at play in higher education and the role these have in dictating student cross-disciplinary development. This chapter highlights the opportunities a faculty member has to foster student cross-disciplinary development through the example of the makerspace faculty mentor, Dr. P. The narrative of Dr. P’s management of the makerspace team highlights shining moments and missed opportunities in fostering student development while acknowledging the norms and structures dictating both the students’ and the faculty member’s actions and perceptions. My goal for this paper is to promote a heightened awareness of these norms and structures and empower practitioners to create shining moments as opportunities for student development in their projects and classrooms.

The final chapter of my dissertation outlines the key findings and implications for research and practice resulting from each manuscript. I acknowledge limitations of my
work and suggest opportunities for future work that can further extend the understanding of student cross-disciplinary collaboration.
Chapter 2

A Real Report from the Trenches of a PhD Dissertation: Exploring the “Messiness” of Engineering Education Research Through an Audit Trail

2.1 Abstract

Research publications show the clean, tidy version of the research process; however, the actual research process is rarely “neat” or “clean”. This paper will expose the “messiness” I encountered during my qualitative, dissertation research. I present my research process as an audit trail outlining the decisions I made while developing and implementing my study of a group of undergraduate students working on a cross-disciplinary team. My goal in presenting an audit trail of my research is to present my work as a specific example to assist those just beginning their qualitative research journey. I want to make qualitative work more accessible to a broad audience while communicating the trustworthiness of my work through a detailed account of my research process. Individual readers may find that certain aspects of my research experience resonate more than others. I encourage you, the reader, to take what is useful, and consider if and how it might help advance your own research.

2.2 Introduction

Researchers write and edit their publications to ensure the research process is neatly and clearly communicated so that others can easily understand their work. However, the
research process is rarely “neat” or “clean”. The researcher has to continually make
decisions to adapt his or her approach as challenges arise, additional data is needed, or
when the initial process does not go as planned. Research is in fact a rather “messy”
process. In my own dissertation research, I also encountered this inherent “messiness.”
This publication is intended to communicate the challenges I encountered during my
dissertation research study as I observed and interviewed ten undergraduate students
working on a cross-disciplinary project team.

This manuscript is written as an audit trail (Carcary, 2009; Lincoln & Guba, 1985; D. L.
Miller, 1997; Wolf, 2003) in first person, active voice, following the American
Psychological Association (APA) guidelines (Publication Manual of the American
Psychological Association, 2010). By writing this paper as an audit trail, I can be
transparent about decisions I made during my dissertation work as well as the motivation
behind those decisions. An audit trail also provides an avenue for me to reflect on and
communicate my role throughout my qualitative dissertation research. Qualitative
research is inherently interpretive (Patton, 2015; Walther, Sochacka, & Kellam, 2013),
and my use of first person, active voice is intentional as it communicates the direct role
the researcher plays as an “instrument” in qualitative research (Lincoln & Guba, 1985, p.
39; Patton, 2015, p. 604; Watt, 2007, p. 82). My goal in writing a research audit trail as a
conference paper is to communicate the “messiness” of qualitative research by using my
own work as an example by which others can learn. My intention is to be straightforward
about the steps I took and decisions I made during my study as a way of restoring order to
the messy research process. This level of transparency with study details and decisions serves multiple purposes:

1. Inform audience members from a broad range of backgrounds, who may be unfamiliar with qualitative research, so that they find my research more salient and accessible,

2. Provide study information in a straightforward manner so that the audience can assess the validity and reliability of my study,

3. Present my work as a specific example to assist those just beginning their qualitative research journey.

2.3 The Qualitative Research Tradition: Background, Terminology, and Objectives

My dissertation study borrows from multiple methodological traditions within qualitative research. Before I present the details of my study, I will give some background on the qualitative research tradition (Borrego, Douglas, & Amelink, 2009; Van Note Chism, Douglas, & Hilson, 2008), its goals and objectives, and common terminology. This introduction to qualitative research is important for understanding the terminology and overall structure of my work. For example, my choice of first person, active voice, use of the terms like “thick” and “rich,” and inclusion of participant quotes may be awkward for those familiar with research in traditional science or engineering fields. A glossary of key, qualitative research terms can be found in Table 2.1.
Educational research generally follows one of three main methodological traditions: quantitative, qualitative, and mixed methods research (Borrego et al., 2009). Quantitative researchers often utilize surveys or other numerical measures to make inferences or identify correlations that are generalizable to a larger population (Borrego et al., 2009). Qualitative researchers collect textual data through interviews, observations, documents, or other methods in an effort to understand the lived experiences of individuals or groups (Borrego et al., 2009). A mixed methods approach combines qualitative and quantitative approaches in a specific way which best answers the desired research question(s) (Borrego et al., 2009; John W Creswell & Plano Clark, 2007). My research follows the qualitative research tradition to explore the development of students as cross-disciplinary team members.

Qualitative educational research often seeks to gain insight into the lived experiences of an individual or group of people through direct interaction between the participant and the researcher. This connection between the qualitative researcher and his or her participants is acknowledged through the identification of the researcher as an “instrument” in the study (Lincoln & Guba, 1985, p. 39; Patton, 2015, p. 604; Watt, 2007, p. 82). Qualitative research is therefore inherently interpretive (Patton, 2015; Walther et al., 2013). The researcher must carefully make decisions to build the validity and reliability of the work and establish its trustworthiness (Krefting, 1991; Patton, 2015, Chapter 9; Shenton, 2004; Walther et al., 2013; Watt, 2007) as he or she collects and draws conclusions from data. Qualitative researchers often follow a number of
approaches to incorporate validity and trustworthiness within their research. One approach may include applying an established framework for validity, such as Walther and colleagues’ (2013) qualifying research quality framework. Another approach involves reflexively reflecting on preconceptions and potential biases brought to the study (John W Creswell & Miller, 2000; Patton, 2015, Chapter 8; Watt, 2007).

Qualitative research takes into account the context surrounding a phenomenon or experience (Borrego et al., 2009; Van Note Chism et al., 2008). Unlike quantitative research, which seeks to produce findings that are generalizable to a broader context, the objective of a qualitative study is to achieve transferability of findings beyond the narrow context under which the study was performed (Borrego et al., 2009; Van Note Chism et al., 2008). Rather than seeking to prove or disprove a hypothesis, qualitative research aims to capture the experiences of a limited number of participants and present those experiences in a way that the reader can relate to in their own situation or context (John W Creswell & Miller, 2000; Patton, 2015, Chapter 8). Qualitative findings include “thick, rich” descriptions of aspects that are salient for the participant(s) (John W Creswell & Miller, 2000; Patton, 2015, Chapter 8). Sometimes aspects that are not salient for participant(s) can also be telling. Researchers often apply an existing framework or model as a lens to analyze their data, and they may present their findings in a variety of ways, such as in a table of themes and quotes or as a narrative describing an individual’s experiences from an outside viewpoint (Patton, 2015, Chapter 8).
Table 2.1: Definitions of common terminology in qualitative research

<table>
<thead>
<tr>
<th>Qualitative Research Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflexivity</td>
<td>Identifying personal biases, perceptions, and motivations and considering how these aspects influence one’s work.</td>
</tr>
<tr>
<td>Transferable Findings</td>
<td>Findings presented in enough detail that elements of the work can be relevant in new contexts.</td>
</tr>
<tr>
<td>Thick, Rich Description</td>
<td>A description that includes a large amount of detail so that the reader can clearly understand and resonate with the participant’s experience.</td>
</tr>
<tr>
<td>Framework</td>
<td>An existing theory or model used to situate one’s research and often to guide analysis.</td>
</tr>
</tbody>
</table>

Each research tradition or field of study has adopted its own terminology and methods for communicating the validity and reliability of work. The unique nature and number of diverse fields employing qualitative traditions have posed a challenge for qualitative researchers to develop common terminology and practices for illustrating validity and reliability. Walther, Sochacka, and Kellam (2015; 2013; 2014) recently published a quality framework for interpretive research that provides a model for researchers to communicate the validity and reliability of their work. The Qualifying Qualitative Research Quality (Q³) framework specifies six categories of quality. The following categories and definitions were taken directly from Walther, Sochacka, and Kellam (2013):

- **Theoretical Validity** – is concerned with capturing the agreement between the data or theory generated and the social reality of the context under investigation
- **Procedural Validity** – focuses on incorporating processes or features into the study that will mitigate threats to validity and improve the fit between the data and reality
• **Communicative Validity** – ensures that the experiences of the participants are accurately portrayed to and understood by the researcher and that the data is handled in a way that best communicates the reality of participant experiences to a relevant audience

• **Pragmatic Validity** – considers whether the theories, frameworks, and ideas the researcher brings to the study fit with the social reality and considers the applicability of the results to the social context

• **Ethical Validity*** - focuses on aspects of integrity and responsibility during the research process (*not included in the 2013 publication, but presented at Q³ workshops, conferences, and in subsequent publications (Walther et al., 2015; Walther & Sochacka, 2014).)

• **Process Reliability** – ensures that data is collected and recorded in a dependable way and aims to mitigate random influences on the researcher’s ability to see the social reality

The Q³ framework recommends the use of each of these six category in two main stages of the study; “making the data” and “handling the data” (Walther et al., 2013). The following sections of this paper detail how data was “made” (collected) and “handled” (transcribed, organized, archived, analyzed, reported) throughout my study in order to investigate the multiple ways undergraduate students understand cross-disciplinary teamwork and grow as cross-disciplinary team members. Throughout the remainder of this audit trail, I will detail my motivations for conducting this study, my reflexivity
throughout the work, as well as the details and decisions that influenced how I conducted various aspects of the research. I will connect these decisions with the six categories of validity and reliability in the Q$^3$ framework by including the appropriate category of quality in parenthesis at the end of the sentence.

2.4 Turning my Interest in Cross-Disciplinary Experiences into a Research Study

My motivation to study cross-disciplinary teams stems both from my past academic training as well as my current work as a graduate student in Engineering Education. I have a cross-disciplinary background: a bachelor’s degree in Physics and a master’s degree in Mechanical Engineering. When transitioning from Physics to Mechanical Engineering, I experienced first-hand the challenges of learning to communicate and work within a different discipline. This struggle is what first initiated my interest in cross-disciplinary experiences and cross-disciplinary growth.

My work with the undergraduate research program, Creative Inquiry (CI) (https://www.clemson.edu/centers-institutes/watt/creative-inquiry), also bolstered my interest in cross-disciplinary experiences. As the graduate research assistant for Creative Inquiry, I speak with faculty and students from different disciplines about their research projects and find their different research approaches and terminologies appealing. Many CI research projects include students from a wide range of disciplines coming together to work on a single project. Through my assistantship, I was able to interview a group of recent graduates who had previously worked on a cross-disciplinary CI team (Anderson
et al., 2015). My retrospective interviews with these recent graduates illuminated some of their unique experiences, specifically challenges they faced when working on a team with other students from various disciplines. My conversations with them highlighted the end-state of their cross-disciplinary work, but I found that I wanted to know more about what happened *during* the cross-disciplinary project. I started thinking about how I could design a study to fill in the gaps left by these retrospective interviews and examine student development in real-time. I wanted to determine: What specific experiences during a cross-disciplinary project are most influential for each student? How do these experiences influence a student’s perception of cross-disciplinary teamwork? I wanted to examine in *real-time* how undergraduate students experience cross-disciplinary teamwork and how these experiences shape their perceptions and their development as an effective cross-disciplinary team member.

I began conducting a literature review on the general topic of cross-disciplinary teamwork. During my literature search, I came across a framework for cross-disciplinary professional practice published by Robin Adams and her colleagues (R. Adams et al., 2010; R. S. Adams & Forin, 2014; R. S. Adams, Mann, Forin, & Jordan, 2009). They developed their cross-disciplinary practice framework from retrospective interviews with professionals who had prior experience working on cross-disciplinary teams. Adams’ team investigated various ways cross-disciplinary work can be experienced and suggested a model identifying four different “facets” of cross-disciplinary practice: working
together, intentional learning, strategic leadership, and challenging and transforming practice (R. S. Adams & Forin, 2014).

Adams and Forin (2014) developed their model of cross-disciplinary practice from accounts of professionals working in cross-disciplinary environments. I initially had no idea whether or not aspects of this existing model were applicable in an undergraduate student context. To test its relevance to this new context, I applied the existing model to the data I had collected during my conversations with the group of recent graduates who had previously worked on a cross-disciplinary CI team (Anderson et al., 2015). I found that many facets of the professional cross-disciplinary experience identified in the existing model were also salient for undergraduate students. Evidence that the existing model was applicable beyond the professional context solidified my decision to use it as an initial framework for my dissertation work. I designed a study to operationalize categories of the existing model as potential stages of undergraduate student development during a cross-disciplinary team project. This approach would allow me to answer the overarching research question: In what ways do undergraduate students progress through the stages of cross-disciplinary development while working on a cross-disciplinary project?

2.5 Getting Started: Forming an Undergraduate Cross-Disciplinary Team

In the midst of conducting a literature review and developing my research question, my assistantship supervisor asked me to form an undergraduate research project through the
Creative Inquiry program. She wanted the students to develop a business plan for starting a makerspace on the university campus. This makerspace would provide students with access to prototyping equipment, such as 3D printers, at little to no cost.

As I started planning the makerspace student project, I soon realized that a cross-disciplinary team with training in business, marketing, and engineering would be necessary to effectively address the overall goal of the project. This cross-disciplinary team of undergraduate students would be a good participant group for me to investigate, in real-time, the experiences of each student as they learned how to be an effective member of a cross-disciplinary team. I realized that I would need help in executing this makerspace project and collecting data for my dissertation, so I asked a faculty member in Mechanical Engineering with prior experience with 3D printers for his assistance. The faculty member and I decided it would be best for him to take the lead role as the primary project mentor while I collected data on the students for my dissertation study. My ethnographic data collection approach relied on my ability to build rapport with the students and be seen as a member of their team. My primary role was an ethnographic researcher, but I also retained a minor facilitator role in the project. I helped develop the project syllabus and handled communication and assignment posting on the online course management system for the project.
2.6 Decisions Made in “Making the Data”

My qualitative research study followed an emergent design (Patton, 2015, Chapter 2) combining methodological traditions in ethnographic (Angrosino, 2007; Reeves et al., 2008; Singer, 2009) and case study (Baxter & Jack, 2008; Stake, 1994; Yin, 2009) research. My data collection process closely followed an ethnographic approach, where I was a participant observer (Angrosino, 2007; Van Note Chism et al., 2008) on a student team. In my study, I interacted with a group of students enrolled in a cross-disciplinary team project over the course of a semester. This specific context makes my work an ethnographic case study of a single cross-disciplinary student team (Singer, 2009).

Following ethnographic and case study methodologies, I collected data from multiple sources (observations, interviews, and documents) and triangulated (John W Creswell & Miller, 2000; Patton, 2015, Chapter 9) those sources to obtain a deep, rich understanding of each student’s experience on the cross-disciplinary team.

I utilized multiple forms of data collection and data types to elicit a complete understanding of student cross-disciplinary development during the team project. My initial plan for making the data (shown in Figure 2.1 below) comprised four main data collection processes including observations, semi-structured interviews, written documents, and a focus group. However, my plan evolved as challenges arose. Figure 2.2 shows how I actually implemented the data collection plan in order to answer my research question. In the rest of this section, I will discuss the decisions that transformed my study from my initial plan in Figure 2.1 to my final implementation in Figure 2.2.
2.6.1 Participant Recruitment and Informed Consent

While recruitment issues are not unique to studying undergraduate students, having my research associated with an undergraduate course made recruitment a two step process: 1)
student enrollment in the course and 2) gaining informed consent of students in the course. After identifying the students enrolled in the makerspace project as potential study participants, I had to rely on the course description to be of interest to students in a range of disciplines in order to get a cross-disciplinary sample for my research. The group of students who enrolled in the makerspace project was not as cross-disciplinary as I had initially hoped. Table 2.2 shows the pseudonyms, majors, and years of the ten participants in my study. The bulk of the student team was engineering majors, despite writing and rewriting the project description to encourage non-engineering students to join the team. Ultimately, I had to make a conscious decision to not be preoccupied with the make-up of my participant pool for fear of missing out on understanding the experiences these students would have during the project.

Table 2.2: Demographics of my ten study participants including academic major and year in college

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Declared Academic Major</th>
<th>Year in College</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew</td>
<td>Chemical Engineering</td>
<td>Sophomore</td>
</tr>
<tr>
<td>Annie</td>
<td>Psychology (Minor in Art)</td>
<td>Senior</td>
</tr>
<tr>
<td>Emma</td>
<td>Architecture</td>
<td>Sophomore</td>
</tr>
<tr>
<td>Gabe</td>
<td>General Engineering</td>
<td>Freshman</td>
</tr>
<tr>
<td>Hunter</td>
<td>Mechanical Engineering</td>
<td>Sophomore</td>
</tr>
<tr>
<td>James</td>
<td>General Engineering</td>
<td>Freshman</td>
</tr>
<tr>
<td>Mark</td>
<td>Industrial Engineering</td>
<td>Sophomore</td>
</tr>
<tr>
<td>Ryan</td>
<td>Mechanical Engineering</td>
<td>Junior</td>
</tr>
<tr>
<td>Scott</td>
<td>Material Science and Engineering</td>
<td>Junior</td>
</tr>
<tr>
<td>Tim</td>
<td>General Engineering</td>
<td>Freshman</td>
</tr>
</tbody>
</table>

My first opportunity to build rapport (Marshall & Rossman, 2011; Patton, 2015, Chapter 7) with the students I would be observing was through the consent form. I initially had
some concerns that the undergraduate students would not understand the goals and methods of my research and would therefore be reluctant to share their experiences and perceptions with me. I ultimately adapted my consent form to include clear, accessible language that undergraduate students, not familiar with qualitative research, would understand (Ethical Validation). For example, rather than using the term “interview” which some students might associate with the job application process, I used phrases like “talk one-on-one” or “informal meeting.” I was also aware that students might associate the term transcript with official university documents containing their grades. I explained my desire to have our conversations transcribed using the phrase, “turned from audio files into text files which are easier to analyze.” My careful word choice and clear communication of my research goals helped me initially connect with my participants and make them feel more comfortable sharing their experience with me (Communicative Validity, Ethical Validity). The entire informed consent document I used for my study can be found in Appendix A.

2.6.2 Interviews

I conducted semi-structured interviews (Lincoln & Guba, 1985; Patton, 2015, Chapter 7; Van Note Chism et al., 2008, Chapter 4) (Figure 2.2, data type A) with each team member at the beginning of the makerspace team project. These initial interviews served as a mechanism to get to know each individual student and to gain trust and continue building rapport (Marshall & Rossman, 2011; Patton, 2015, Chapter 7) with each participant (Ethical Validation, Communicative Validation). These initial interviews also
served as a baseline for individual student’s current experiences with and viewpoints toward cross-disciplinary teamwork. I also interviewed each participant at the end of the semester to uncover his or her perceptions of working on the team. Interviewing participants both at the beginning and end of the project uncovered if and how the team project changed each student’s perception of and approach to cross-disciplinary teamwork (*Procedural Validation, Communicative Validation*).

Because the makerspace project took place over 14 weeks of a semester, I also wanted to implement some type of data collection procedure halfway through the semester. I anticipated using this mid-semester data to elicit a more complete story of each student’s experience throughout the project (*Procedural Validation, Process Reliability, Communicative Validity*). I initially planned to conduct a mid-semester focus group with the entire team. I expected that by the middle of the semester, the makerspace project would have progressed to a point where student perceptions and approaches to cross-disciplinary teamwork may have changed. However, as the time for my mid-semester focus group drew near, I became concerned with using the team’s weekly meeting time as a focus group session to discuss my research. The student’s makerspace project was progressing, but there was still a lot to be done before the end of the semester. Planning a focus group with all ten of my study participants at another time outside the project’s weekly meetings would have been difficult with the students’ busy schedules. My desire to capture the rich, individual experiences of each of my participants also influenced my decision to rule out a focus group with the entire team as a data collection method. I was
concerned that a focus group would not allow each student the opportunity to freely share his or her opinions and experiences (Communicative Validity, Process Reliability). My ability to ask personalized questions or detailed follow-up questions during a focus group would also be limited (Communicative Validation, Process Reliability). I ultimately decided instead to conduct another round of individual interviews with each team member at the mid-point of the semester (Procedural Validation).

This mid-semester interview gave me the chance to ask each participant about his or her perception of the faculty mentor and the mentor’s role on the team as well as my role on the team. After conducting my first interview with students, I regretted not asking them about their initial perceptions of the faculty mentor and myself during the initial interviews. I knew that my presence in the team meetings could influence student views and potentially their behavior throughout the project. To benchmark their initial perceptions, I asked students during the mid-semester interview to think back to the beginning of the project and report their initial opinions (Procedural Validation, Process Reliability). I then asked students to give their current opinions of myself and the faculty mentor and our individual roles on the team. During the mid-semester interview, I also asked additional questions related to the existing cross-disciplinary model (Pragmatic Validation). I developed a unique set of interview protocol questions for each of the ten students based on my observations in weekly team meetings (Figure 2.2, data type B and D) and each student’s progress reports (Figure 2.2, data type E) (Procedural Validation).
This resulted in the development of ten unique interview protocols for just the second round of interviews.

My initial data collection plan also included interviewing the two faculty mentors for the project to gain their insights into makerspace team interactions. However, I did not follow through with my plan to conduct interviews with the faculty mentors. My study goal is to capture the true social reality (Walther et al., 2013) of undergraduate student cross-disciplinary development during a team project. The thick, rich data I collected during one-on-one interviews with my student participants helped me realize that the best way for me to capture this social reality was to see the experience from the individual student’s point of view (Communicative Validation). While interviewing the faculty mentors would provide another source of data, I was concerned that data from faculty would cloud my ability to see the true reality of the students (Process Reliability, Theoretical Validation). However, because I was helping the primary faculty mentor facilitate the makerspace project, I informally met with him following most of the weekly makerspace team meetings. We used this time to check-in with each other on how the project was progressing and plan upcoming assignments and deadlines.

2.6.3 Observations

In addition to multiple interviews with each student, I observed (Angrosino, 2007; Lincoln & Guba, 1985; Patton, 2015; Van Note Chism et al., 2008, Chapter 4) weekly team project meetings throughout the semester (Figure 2.2, data types B and D). My
observations allowed me to remain informed of the team’s progress on the makerspace project, the roles of each team member, and team interactions as project decisions were made (Communicative Validation). I based my initial observation protocol on the main categories of Adams and Forin’s (2014) cross-disciplinary practice framework (Pragmatic Validation). I created a table with each category of the existing model as well as the descriptions provided by Adams and Forin in the first column of my table. In the second column, I specified my three main data collection methods (interviews, progress reports, and observations). In the final column, I noted potential ways to operationalize the existing model based on each data collection method. These operationalization tables helped me organize my initial data collection strategy and plan data collection from multiple sources to permit triangulation during my later analysis (Procedural Validation, Process Reliability). These tables also served as a template for developing questions for my interview protocols and progress reports as well as for planning my observation protocol. However, I continually adapted my observation protocol based on past team observations, analysis of progress reports written by students, and continual memoing; remaining open to new themes emerging from the data (Pragmatic Validation).

During the first makerspace team meeting of the semester, I introduced my research to the students and provided them with an IRB approved consent form. I explained that I would be observing and audio and video recording their weekly makerspace team meetings. After introducing my study and answering the students’ questions about their
role in the study, I sat at the back of the room at a separate table from the rest of the team to conduct my observation. I positioned my audio recorder and three conference microphones on the table where the team sat, and I situated the tripod with my video camera at an angle so that the entire group was visible. I took notes from the back of the room on how the team was interacting during their discussion, but I found it difficult to hear their conversation from so far away.

The first team meeting had taken place in a warehouse-like space that was not conducive for clear audio recording. After communicating this concern with the faculty mentor for the project, he arranged for the team to have the remainder of their weekly meetings in a conference room. The new meeting space provided better audio and video quality and made it easier for me to hear the student’s conversations during meetings (Process Reliability). I gave careful thought about how to position the audio recorder and microphones, deciding that I could get the best sound quality by putting them along the center of the conference table in the middle of the room and positioned my video camera on top of a cabinet at one end of the room. This new, single table, room layout coupled with my inability to hear the team’s conversation during the first meeting prompted me to conduct my subsequent observations while sitting at the conference table with the students.

Before each weekly team meeting, I arrived early to set up my audio and video equipment. I wanted to have my equipment set-up before the students arrived in order to
draw less attention to the microphones and video camera (*Process Reliability*). I then prepared my field notebook (Figure 2.2, data type B) for the day and kept a copy of Adams and colleagues’ cross-disciplinary model handy to reference before and during my observations. As students arrived for the meeting, I noted any interactions I had with them prior to the start of the meeting in a separate section of my notebook. Noting my interactions with each student helped me track my dual role as an ethnographic researcher and member of the team (*Process Reliability*).

During the weekly makerspace team meetings, I sat with the student team and faculty mentor while documenting field notes in my notebook. I used sticky note tabs to annotate interesting interactions and discussions during the meeting. I refrained from commenting during the meeting in order to retain my primary role as a researcher and mitigate my influence on the team as they made decisions for the project (*Process Reliability*). I often had to make a conscious effort to remain quiet during the team’s conversation and felt torn between my desire to see the project succeed and my desire to collect accurate data for my study. On a few occasions, however, the team requested resources for the project that I had access to through my position as a research assistant for CI, such as email list-serves, which students could not directly access. At those times, I shared my feedback on the availability of those resources for the project.

My observations over 14 weeks of the semester gave me ample opportunity for checking-in with team members in the event I needed to clarify an observation. Following one of
the early team meetings of the semester, I approached one student to ask what he was
typing on his computer during the meeting. Despite telling him that I was just curious to
see what he was using his computer for, I quickly sensed his rising level of discomfort
with my questioning. This experience made it clear that while member check-ins could
provide an additional source of data, they may also threaten my level of rapport with the
students (Ethical Validation, Process Reliability, Communicative Validation). I realized
that while I would like to understand every aspect of a student’s cross-disciplinary
experience, I knew that it would be impossible for me to know everything. I also
decided that some aspects of the students’ experiences, such as what they were doing on
their computers during meetings, were not necessary to answer my research question
(Theoretical Validation). Additionally, I realized that using approaches the students
perceived as intrusive would not benefit my research (Process Reliability,
Communicative Validation). I did not use member check-ins during the remainder of my
data collection, so I removed them from my final data collection diagram in Figure 2.2.

2.6.4 Memos

Memoing is a common research technique in qualitative research (Birks, Chapman, &
Francis, 2008; Van Note Chism et al., 2008; Watt, 2007). Memos are a written record of
researchers’ thoughts, ideas, and impressions and can take many different forms: formal
or informal, structured or stream-of-consciousness. They can serve multiple purposes in
a qualitative study depending on the specific methodology being applied. For example,
grounded theory researchers utilize memos throughout their research as a tool to help
them reflect on and process their data. Charmaz, a prominent grounded theory researcher, explains, “Memos catch your thoughts, capture the comparisons and connections you make, and crystallize questions and directions for you to pursue” (Charmaz, 2014, p. 162)

Memoing is one key way an ethnographic researcher can record his or her perceptions and experiences during a study. Ethnographic studies, in general, aim to provide rich, thick descriptions of participant experience(s) through direct, prolonged interaction with the participant in his or her natural environment (Singer, 2009). Memos can serve as a source of data, as well as an analytic tool, in an ethnographic study. Singer states, “The ethnographer is `the research instrument par excellence,’ an active participant in the research process” (Singer, 2009, p. 192). An ethnographer’s role as a research instrument makes his or her perception and interpretation of the experience an important source of data.

My process of continual memoing throughout my research helped me document my experience as a researcher, process my thoughts, and develop and adapt my emergent data collection protocol. My initial plan (Figure 2.1) incorporated memos as a supplemental data source with my observation field notes. However, I memoed following interviews with participants, after weekly meeting observations, after reading student progress reports, as well as throughout each phase of my data analysis. I also kept an electronic journal of my experiences as an ethnographic researcher on a project
management system (Basecamp). Memos turned out to be a unique data source for my study and are shown as a separate data type (data type C) in Figure 2.2.

My utilization of memos and journals in various ways throughout the study helped me remain aware of and transparent about my role in and perceptions toward my work and remain true to the social reality of my participants (Procedural Validation, Pragmatic Validation). The following bulleted items describe the different ways I applied memoing during the “making the data” phase of my study:

- I made an effort to memo after each student’s individual interview. However, I was not always able to follow this plan due a back-to-back interview schedule or additional time commitments. My memos following interviews were often stream-of-consciousness reports of aspects that stood out to me, or thoughts and opinions I had about the interview. These memos also included notes for myself on what we talked about as well as potential topics I could address in later interviews with that student or aspects to be more aware of during observations (Procedural Validation, Process Reliability).

- I periodically memoed shortly after team meeting observations. I wrote these memos in a section of my study field notebook or recorded them in the notes section of my phone as I walked to my car at the end of the day. Many times, I found walking the 10 minutes to my car allowed my mind to rest and think through the events of the day.
I also regularly journaled about my research in an online project management software system (Basecamp). These stream-of-consciousness accounts became a regular, almost daily, time for me to record and process my thoughts and experiences, evaluate my research method, and document my ideas. These journal entries also served as a mechanism for me to share my thoughts with and gain feedback from my research advisor, who also had access to my dissertation Basecamp page. My Basecamp journal entries were often unstructured. Sometimes my entries included specific questions for my research advisor, other times they were stream-of-consciousness reports of what happened that day.

2.6.5 Progress Reports

Students were required to write periodic reports (Figure 2.2, data type E) as part of their course grade associated with the makerspace project. These written documents (Patton, 2015, Chapter 6; Van Note Chism et al., 2008, Chapter 4) served a dual purpose: 1.) they were an additional source of data for my study that allowed me to capture the individual student’s cross-disciplinary experience without having to conduct additional interviews (Procedural Validation), and 2.) they provided a gradable assignment (a completion grade) for the one-credit makerspace project course. The faculty mentor for the makerspace project and I discussed an appropriate name for these graded reports. We saw the name for these assignments as playing a key role in students’ interest in completing the assignments and their willingness to take the assignments seriously. We decided on the term “progress report.” These progress reports would serve as a
mechanism for enrolled students to communicate with the faculty mentor and myself their individual roles in the project, perceptions of the team, and what they were learning during the project (Communicative Validation).

Each progress report included two to three overarching questions along with a list of bulleted potential talking points to help guide students as they constructed their responses (see Appendix B for an example progress report). I designed each report to take no more than 15 minutes to complete. Report questions were designed to help students think deeper about topics such as career goals, trust, disciplinary differences, and teamwork. Most of the progress report questions addressed topics in Adams and Forin’s (2014) cross-disciplinary practice model that proved to be difficult or impossible to investigate through observations alone, such as trust (Procedural Validation, Pragmatic Validation). A handful of progress report questions also addressed topics of interest to the faculty mentor, such as a mid-semester report of individual contributions to the project and questions asking students to report the task on which they were currently working.

I often assigned a particular progress report topic based on situations I noticed during my observations (Procedural Validation). I documented these interesting situations in my field notes and memos so that I would remember to ask about them in a later progress report. As I became more immersed in my research, I also became aware of additional topics or questions that I chose to address using a progress report assignment. The feedback loop for progress report data also went the opposite direction. I found that
student’s responses to progress reports informed adaptations to my observation and interview protocols (Procedural Validation).

2.7 Decisions Made in “Handling the Data”

After “making the data,” Walther, Sochacka, and Kellam (2013) address validity and reliability in “handling the data.” The processes of organizing, storing, analyzing, and presenting findings are as important to the overall rigor of a qualitative study as the data collection process itself. Below I share how I handled the corpus of data collected during my work with the semester-long makerspace project.

2.7.1 Data Organization and Storage

One of the biggest challenges I encountered in dealing with the large amount of data I collected was maintaining organization and secure storage. I used a dedicated notebook to record my field notes (Figure 2.2, data type B), some memos, notes during interviews, and notes on any other interactions I had with the students. Four divider tabs separated each type of data/notes. Early on, I would scan each sheet and save the images on an external hard drive and on Basecamp as additional data back-up mechanisms. However, this pattern faded off toward the end of the semester due to my inability to keep up with scanning and saving around 10 pages of hand-written field notes and memos each week. (My field notebook was a 5 by 7 inch binder style notebook.) In addition to documenting memos in my notebook, I often wrote my thoughts and perceptions directly into Basecamp. I used an online transcription company to transcribe all 29 interview
recordings (one student only completed two separate interviews with me) which resulted in nearly 500 pages of typed transcripts. I also had a handful of team meeting recordings transcribed.

I used an external hard drive to save all audio and video files from weekly team meetings in folders labeled with the meeting date. A separate folder housed the audio recordings and transcripts for each of the three rounds of interviews. This allowed me to locate all first interviews at once, for example, in case I wanted to analyze them as a group. I also labeled each interview file with the student’s pseudonym so that I could easily locate all three interviews from a single participant. I stored progress reports in another folder separated by assignment and labeled with each student’s pseudonym.

The unit of analysis for my research study was the individual student, so it was important for me to consider each student’s individual experience as a “case”. I created structured tables to help me organize each participant’s interview and progress report data. A third table addressed the categories and facets of the existing cross-disciplinary practice model. I used this table to record evidence from student interviews that appeared to fit each model category as well as notes for myself on aspects to investigate further during my analysis (Theoretical Validation).
2.7.2 Data Analysis

A key aspect of qualitative data analysis requires the researcher to remain close to the data. This familiarity with the data results from long periods of immersion and multiple passes through the data. Each pass adds an additional layer to the analysis process and often identifies a different aspect of the data to consider. Because qualitative research is inherently interpretive, the qualitative analysis process does not follow a prescribed approach. The researcher must use his or her judgment to determine the appropriate approach or combination of approaches to use depending on the goals of the study and the overall methodology being applied (Patton, 2015, Chapter 8).

My first pass through the data involved listening to each of the three interview recordings for a single participant while filling in tables I created for that student’s interview data. In the interview table, I noted what the student said in each of his or her three interviews with me using a separate column for each interview. A second table organized notes and direct quotes from each of the student’s ten progress reports. The final table organized evidence for each category of the existing cross-disciplinary practice framework. This table helped focus my initial analysis to address the main theoretical framework of my study (Theoretical Validation). However, I remained open to additional evidence that did not fit within the categories of the existing model and recorded these emerging topics at the end of the framework table (Pragmatic Validation). I ultimately combined these three data tables to create a packet of data for each student “case” in my dissertation. Organizing data in this way allowed me to consider the student cases independently as
well as compare and contrast among cases (*Procedural Validation*). This organization process was my first step toward familiarizing myself with the extensive amount of data I had collected. My initial process of sorting information into tables also helped me see similarities and differences among individual student’s experiences and formulate initial ideas for presenting my findings.

My subsequent passes through the data involved a cyclic process of reviewing the data, memoing about what I saw, moving forward with my analysis, and writing up portions of the findings before circling back around to reviewing and memoing as shown in Figure 2.3. Each step of this process often emerged out of necessity as I began writing my dissertation. As I first started writing, I regularly returned to my data tables, field notes, and audio recordings to familiarize myself with the context I was writing about (*Procedural Validation, Process Reliability*). During this process, I often recognized new aspects of the data that I had not noticed before. I memoed in Basecamp about the interesting nuances I saw in the data. Data review and memoing directed, and sometimes altered the initial direction of, what I was writing.
Figure 2.3: A diagram representing my overall data collection and analysis process with the final goal of expanding the current understanding of cross-disciplinary collaboration

I decided to construct ethnographic narratives (Angrosino, 2007; J W Creswell, 2013; Van Maanen, 1988) to present my findings in a meaningful way (Communicative Validation, Pragmatic Validation). It is common for ethnographic researchers to use narratives to communicate their findings, such as in the book Rebekah Nathan wrote about her experience of taking on the role of a student at a university (Nathan, 2005). I drew upon Nathan’s work and the work of other ethnographers such as Bucciarelli (1994) to develop a plan to accurately and meaningfully present my findings. I focused on the restorying (Ollerenshaw & Creswell, 2002) process in creating narratives for my participants. This required me to remain as close as possible to my participant’s words
and experiences. Yet during the process, the “messiness” appeared again in the tension I felt between my role as the ethnographic researcher to overlay my observations and perceptions into the narrative and remaining true to my data (Ethical Validation). My cyclic, multi-step analysis process helped me balance these obligations by allowing me time to reexamine the raw data and personally reflect, through memos, on what the data was saying and how I interpreted it (Procedural Validation, Pragmatic Validation, Communicative Validation). And as I wrote my findings, I also made it a point to have regular conversations with others about my research. I used these peer debriefing (John W Creswell & Miller, 2000; Lincoln & Guba, 1985; Van Note Chism et al., 2008) sessions as an additional means of reflection to ensure I was interpreting my findings in a meaningful way while remaining true to the data (Procedural Validation, Process Reliability, Communicative Validation).

I spent over a year entrenched in my data as I simultaneously conducted my analysis and wrote up my findings. During that time, I utilized multiple, creative techniques to help me think through and interpret the corpus of data I collected. I found mind mapping particularly useful in helping me understand connections among data and overarching topics to focus my analysis. I used different size and color sticky notes to construct a mind map of the overarching topics I saw coming out of my data. I grouped and rearranged the sticky notes to outline connections among topics. This process was particularly useful as I considered organizing my dissertation using a three-manuscript model. While the details of my analysis changed slightly for each manuscript, each relied
on the cyclic process of reviewing, memoing, analyzing, and writing to restory student experiences so that they could resonate with a broad audience (Communicative Validation).

2.7.3 Follow-up Data Collection

During my data collection, members of a makerspace project sub-team mentioned challenging tasks they approached as a smaller group outside the weekly team meetings. As I analyzed the breadth and depth of data from these students, I realized that these additional experiences potentially had a large influence on their development as team members. Therefore, I decided to further investigate these experiences through additional data collection (Procedural Validation). While collecting additional data from these participants after my initial data collection phase could have been a challenging task, I had remained in contact with all three students and luckily all three were still on campus and available to meet with me. My goal in collecting additional data was to better understand the relationship and interplay among the three members of the sub-team, and with this goal in mind, I decided to conduct a focus group rather than individual interviews (Procedural Validation, Process Reliability). This follow-up focus group (Van Note Chism et al., 2008, Chapter 4) serves as a key data source for one chapter of my dissertation. I would not have the thick, rich descriptions of these three students’ cross-disciplinary development without this additional data source (Procedural Validation, Communicative Validation).
2.8 Conclusion

Throughout this audit trail, I have shared my real, raw process of conducting a qualitative dissertation study in engineering education. I have included challenges I faced, set backs I had to overcome, and decision points that emerged while I was entrenched in this detailed, messy process. While my account is specific to my own experience; by publishing this as a conference paper, I hope to have it serve as an example for others starting their qualitative research journey. Individual readers may find that certain aspects of my research experience resonate more than others. I encourage you, the reader, to take what is useful, and consider if and how it might help advance your own research.

In addition to sharing my dissertation experience as an example, I would like to offer some suggestions for those starting their qualitative research journey:

1. **Embrace the “messiness” of the process.** Qualitative research is inherently messy, and being aware of and accepting this reality is a good starting point.

2. **Use memoing to your advantage.** Regardless of the specific methodological approach you decide to follow during your study, memo early and often. A dissertation study is a long process, and memoing or journaling about your thoughts and ideas will help ensure you do not forget anything along the way.

3. **Find creative, thought provoking techniques that work for you.** Qualitative research often generates a huge amount of textual data that you as the researcher must decipher. Be open to new, creative approaches, such as mind mapping, that can help you unpack your large amount of data.
4. **Talk to others about your research.** One aspect that was difficult to communicate in my audit trail was just how often I talked to and sought advice from others regarding my research. A qualitative researcher should never be alone in his or her research process. Use informal conversations and peer debriefing sessions as mechanisms to gain understanding and perspective of those around you. Seeking out multiple view-points will help you represent the true experiences of your participants in a meaningful way.

My experience has been that conducting qualitative research can be both extremely challenging and extremely rewarding. I encourage other qualitative researchers, whether just embarking on their process or who are already thoroughly engrossed in their work to consider the benefits of maintaining an audit trail. Not only can an audit trail help communicate the trustworthiness of your work to others, it can serve as a tool for tracking your thoughts, decisions, and ideas during a multi-year research study. In this way, an audit trail can help bring order to the messy process of qualitative research. Additionally, I encourage others to publish an honest, detailed account of their research process. Our willingness to be transparent about individual experiences as qualitative researchers will deepen the broader education research community’s understanding of the qualitative tradition. Through our reports of the detailed messiness of qualitative work, we will further the discussion around quality in qualitative work and its role in engineering education research.
Chapter 3

Narratives of Students’ Salient Roles and Trajectories through Cross-Disciplinary Development

3.1 Abstract

Student approaches to collaboration manifest as salient roles students take on during a team project. Understanding the potential motivating factors and trajectories of these roles expands the theoretical understanding of student cross-disciplinary work and holds implications for faculty and administration as they develop and manage student team experiences. This paper presents four student cases as narratives illustrating the most salient role each student exhibited during a semester-long project. Some students remained in the same role throughout the project while others experienced events that altered their roles. Awareness of the range of approaches students take to cross-disciplinary work poses implications for student teamwork research as well as practice.

3.2 Introduction

The field of engineering increasingly incorporates and relies on an interconnection among multiple disciplines and a range of diverse skill sets in order to solve global problems (Committee on Facilitating Interdisciplinary Research, 2005; National Academy Of Engineering, 2004). Projects that bring together students from multiple disciplines create contexts that mimic the increasingly common cross-disciplinary environment of professional practice. In this paper, the term cross-disciplinary refers to
“a collection of practices associated with thinking and working across disciplinary perspectives” (R. S. Adams & Forin, 2014, p. 103). Exposing undergraduate students to cross-disciplinary experiences can better prepare them for professional practice. In these experiences, students must negotiate competing objectives, communicate viewpoints, and navigate individual roles. How they experience cross-disciplinary teamwork as students will likely inform how they work on similar teams as professionals.

Much of what is known about an individual’s approach to cross-disciplinary teamwork is derived from studies of professionals. Furthermore, this prior research derives its understanding from retrospective accounts of these professionals’ experiences. Little is known about how undergraduate students approach a similar situation or how their approaches might change as they navigate a cross-disciplinary project. The current study employs a real-time approach to investigating undergraduate student development as team members during a cross-disciplinary team project. This paper will address the following research questions: What team roles do undergraduate students find most salient during a cross-disciplinary project? How do these roles reflect students’ understandings of and approaches to cross-disciplinary teamwork?

3.3 The Existing Cross-Disciplinary Teamwork Model

This study applies Adams’ and colleagues’ (2010; 2014; 2009) existing cross-disciplinary framework for professional practice as an initial lens to examine cross-disciplinary collaboration during an undergraduate student project. This model resulted from
retrospective interviews with professionals about their experiences working on cross-disciplinary teams and focuses on the individual as the unit of analysis. It communicates the range of approaches professionals take when working on a cross-disciplinary team and addresses an individual’s appreciation for difference and complexity as well as his or her identity as a member of the team. Adams and Forin’s (2014) framework identifies four main categories describing cross-disciplinary work in professional practice: working together, intentional learning, strategic leadership, and challenging and transforming practice. Figure 3.1 shows a representation of the hierarchical nature of these categories.

![Diagram of the cross-disciplinary model](image)

Figure 3.1: A representation of the existing cross-disciplinary model for professional practice taken directly from Adams and Forin (2014)

My study operationalizes the categories of Adams and Forin’s (2014) model as potential ways undergraduate students perceive and approach cross-disciplinary collaboration. Each student’s experience and approach to collaboration is unique, and this model enables me to investigate student cross-disciplinary experiences on an individual basis.
The student context is unique compared to the professional context under which the model was originally developed, so I also remain open to additional interpretations of and approaches to cross-disciplinary work that are not represented by the existing model.

This paper provides a thick, rich descriptions of student approaches to cross-disciplinary teamwork as illustrated by the roles each student found most salient during a semester-long cross-disciplinary team project. These chosen roles illustrate a student’s understanding of and subsequent approach to cross-disciplinary teamwork. These thick, rich accounts of student roles during a cross-disciplinary project will expand the existing cross-disciplinary practice model to an undergraduate student context and magnify the current understanding of student experiences during cross-disciplinary teamwork.

3.4 Creating a Space for Undergraduate Cross-Disciplinary Teamwork

While some institutions of higher education have made a push toward incorporating cross-disciplinary team experiences into the undergraduate curricula, the majority of team-based experiences in undergraduate education are mono-disciplinary. Engineering senior capstone experiences are a common example, with teams generally comprised of engineering students in the same major (i.e. all mechanical engineers). Hence, engineering students may not have many opportunities to collaborate with students in disciplines outside engineering, or even students from other engineering majors, during their undergraduate education. Undergraduate research projects provide one approach to facilitating cross-disciplinary experiences for undergraduate students.
The university in this study provides a space for cross-disciplinary undergraduate experiences through a campus-wide undergraduate research program called Creative Inquiry. The Creative Inquiry (CI) (https://www.clemson.edu/centers-institutes/watt/creative-inquiry) program allows students at all academic levels (freshman to seniors) and all majors to enroll in project courses for credit. These CI projects are team-based research experiences that incorporate hands-on approaches to real-world problems. The broad span and flexible nature of the CI program fosters opportunities for cross-disciplinary team projects.

My research investigates student development during a semester-long, cross-disciplinary Creative Inquiry project. The specific CI project challenged students to create a business plan for a makerspace on campus. The resulting makerspace would provide students enrolled at the university with access to prototyping equipment, such as 3D printers and laser cutters, at little to no cost. During the semester-long project, students developed a plan for how to establish and operate a makerspace, tested potential equipment for the space, and pitched their plan to university administration. Twelve students enrolled in the makerspace project. They represented five different engineering majors, psychology, architecture, economics, and tourism management. A sub-set of ten of these students participated in my research study (see Table 2.2 for a breakdown of the ten study participants).
3.5 My Real-Time Method for Investigating Student Roles

I took a qualitative approach (Borrego et al., 2009; Van Note Chism et al., 2008) to studying the members of the cross-disciplinary makerspace student team. My methods borrowed from ethnographic (Angrosino, 2007; Reeves et al., 2008; Singer, 2009) and case study (Baxter & Jack, 2008; Stake, 1994; Yin, 2009) research traditions. Following the data collection techniques of ethnographic research, I conducted real-time observations of the cross-disciplinary makerspace project team. Unlike the traditional goal of ethnographic research to examine the culture or beliefs of a group, my goal was to understand the experiences of individual students as a means of expanding the understanding of student approaches to cross-disciplinary collaboration. Both ethnographic and case study research involve collecting data from multiple sources to elicit a thick, rich description of the participant’s lived experience. During my study, I collected multiple types of data from different sources including observations (Angrosino, 2007; Van Note Chism et al., 2008, Chapter 4), interviews (Patton, 2015, Chapter 7; Van Note Chism et al., 2008, Chapter 4), and written documents (Lincoln & Guba, 1985; Van Note Chism et al., 2008, Chapter 4) as well as personal memos (Birks et al., 2008). I triangulated (John W Creswell & Miller, 2000; Patton, 2015, Chapter 9) these sources to gain a more complete understanding of student experiences. Figure 3.2 illustrates the connection among the five main types of data I collected and how each source worked together to influence the overall study process.
I took on the role of a participant observer (Angrosino, 2007; Van Note Chism et al., 2008) on the makerspace team. I sat with the team during their weekly makerspace team meetings and observed and recorded field notes about their actions and conversations. I also audio and video recorded the team during these weekly meetings. I utilized an online transcription service to transcribe the audio from some of the meetings (not all team meetings were transcribed) and used the video recordings to assist in the identification of individual speakers. I also wrote both structured and unstructured memos after team meeting observations and interviews to help me process my thoughts and note emerging aspects to look for in future data collection. My observations and
recordings generated 13 hours of team meeting recordings (data type D) as well as around 30 pages of hand-written field notes (data type B) and approximately 40 pages of typed and hand-written memos (data type C).

I developed my observation protocol based on the four main categories of Adams and Forin’s (2014) cross-disciplinary professional practice model: working together, intentional learning, strategic leadership, and challenging and transforming practice. Each category of the existing model served as a potential developmental stage a student might experience. However, applying this professional model to an undergraduate context meant that students’ experiences may not be represented by the existing model, so I also remained open to additional categories coming from the data. My 13 hours of team meeting observations provided real-time insight into how students approached cross-disciplinary teamwork. These observations also provided context and guiding questions for both my individual interviews with each student and written assignments that I called “progress reports”.

Students were asked to complete 10 written progress reports (data type E) throughout the semester as part of their grade for the makerspace project course. I designed these assignments and posted them on the course management software, Blackboard, for students to complete on a regular basis throughout the semester. Each progress report contained one to three questions and was designed to take 15 minutes to complete. Each question included additional guiding questions for students to consider as they wrote their
responses. Some progress report questions addressed aspects of the existing cross-disciplinary practice model that I could not easily observe during team meetings, such as trust. Specific features of team interactions noted during my team meeting observations motivated other progress report questions. I periodically reviewed progress report submissions and adapted my observation protocol based on student responses. I also used progress reports to inform the development of individualized interview questions.

I conducted three interviews with each of the 10 makerspace student team members participating in my research study (however, one student only participated in two interviews with me). An online transcription service transcribed each interview, and the transcripts, totaling nearly 500 typed pages, served as an additional source of data (data type A) for my research. I initially interviewed each student at the beginning of the project. During this first interview, I established rapport (Marshall & Rossman, 2011; Patton, 2015, Chapter 7) with each student and got to know him or her. I also discovered more about his or her motivation for joining the project, past team experiences, and expectations for his or her role on the team. My second round of interviews delved deeper into each student’s experience on the team and his or her perceptions of my and the faculty mentor’s roles on the team. In the final interview, I followed-up on topics brought up during previous interviews and asked each student to discuss the broader makerspace project as a whole as well as their view of my work and my role as a researcher. I also used these interactions to ask personalized interview questions based on what each student wrote in his or her progress reports or what I observed in team
meetings, which resulted in the creation of 29 unique interview protocols. I often memoed (data type C) after an interview to record my personal thoughts and note interesting topics to follow-up on or analyze later.

I triangulated (John W Creswell & Miller, 2000; Patton, 2015, Chapter 9) my observation, memo, interview, and progress report data to elicit thick, rich descriptions of each student’s experience on the team and how he or she chose to function on the team. I analyzed data for each student as an individual case. My analysis of each case followed a cyclic process of reviewing the data, memoing about what I saw in the data, analyzing the data, and writing a report of my findings.

In this paper, I present each case as an ethnographic narrative (Angrosino, 2007; J W Creswell, 2013; Van Maanen, 1988). These narratives are written in first person, active voice from my viewpoint as the ethnographic researcher. This approach acknowledges the ethnographer’s role as an “instrument” in the research process (Lincoln & Guba, 1985, p. 39; Patton, 2015, p. 604; Watt, 2007, p. 82) and follows the example of ethnographers such as Rebekah Nathan (2005) and Louis Bucciarelli (1994) who wrote entire books using an ethnographic narrative approach. The following narratives employ thick, rich descriptions to re-tell the story of, or restory, participant’s experiences in a way that allows it to resonate beyond the context of my study (Ollerepresent & Creswell, 2002).
3.6 The Salient Roles of Student Team Members

The following narratives provide a focused account of one particular aspect of each student’s cross-disciplinary team experience: their most salient role on the makerspace team. From my analysis, it was clear that some students had unique, salient roles they exhibited during the team project while others did not. I have selected four student cases (see Table 3.1) that exemplify clear individual roles based on my observations from the team meetings as well as my conversations with each student team member. Students often displayed multiple sub-roles depending on the current needs of the project, but I examined in detail the most salient role each student took on during the makerspace project and how that role developed and/or changed throughout the project. This analysis of how student roles play out on a cross-disciplinary team expands the existing theory of cross-disciplinary practice to an undergraduate student context and provides a theoretically rich analysis of student approaches to cross-disciplinary teamwork.

Table 3.1: Demographic information for the four cases presented in this manuscript

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Declared Academic Major</th>
<th>Year in College</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annie</td>
<td>Psychology (Minor in Art)</td>
<td>Senior</td>
</tr>
<tr>
<td>Mark</td>
<td>Industrial Engineering</td>
<td>Sophomore</td>
</tr>
<tr>
<td>Ryan</td>
<td>Mechanical Engineering</td>
<td>Junior</td>
</tr>
<tr>
<td>Scott</td>
<td>Material Science and Engineering</td>
<td>Junior</td>
</tr>
</tbody>
</table>

3.6.1 Scott – The Idea Connector

As a participant observer during the makerspace team meetings, I noticed that Scott asked a lot of questions during the team’s discussions. This stood out to me among other team members who often sat through an entire, hour-long meeting without contributing to the
conversation. And of the students who did talk during meetings, they were typically
reporting what they had done during the previous week or sharing their ideas on how to
move the project forward. However, Scott engaged with the conversation by asking
questions and often interjected his questions into an ongoing conversation. His routine
questions seemed to serve multiple purposes: 1) to clarify what was just said, 2) to find
out information necessary for moving forward, 3) to gain technical information, or 4) to
bring up a topic he believed the entire team should weigh in on.

At the fifth team meeting, the team was discussing administering a survey to potential
student users to determine the market need for a makerspace on campus. During the
conversation, Scott’s questions were purposeful and aimed at gathering information
necessary to move the project forward.

While the team brainstormed potential ways to distribute a survey, Annie asked,
“So, how are you going to make sure that people actually fill out surveys?
Because I am a psych major, we send out surveys all the time, and I never ever
take them. Like ever!”

The team laughed as James thought out loud, “Yeah, I mean...” before trailing
off.

“I am just saying,” Annie continued.

The faculty project mentor, Dr. P said, “I think that is a good point.”

Scott asked Annie, “What do you think the best way to get a response would be?”
Scott interjected his question into the conversation in an effort to refocus the conversation and find out how Annie thought the team should proceed. Annie answered Scott’s question and the team’s conversation moved on to discuss desired survey participant groups as well as potential approaches to distribute the survey. Toward the end of the discussion, the team had still not come to a consensus on their target survey participants. Scott asked the faculty mentor, Dr. P, a question to redirect the team and address this unanswered point, “So Dr. P, do you think we need to interview just Creative Inquiries or the general student population as well?” Scott’s question prompted the necessary information for the team to move forward with their survey plan and avoid confusion.

I mentioned to Scott during one or our interviews that I noticed him asking a lot of questions during team meetings. He explained,

> Whenever if I hear someone have a good idea, I'll ask a question about it almost to see if I can get them to think more about- if I hear someone have a good idea then I like to explore it a little more… I mean, yeah I think that people come up with a lot of good ideas and we should promote that.

He went on to say, “I guess if I ask a question it's because I might not understand where someone's coming from with it. So I'd like to see where they're coming from with it, see if we can roll with it.”

Scott also approached individual team members outside team meetings to ask additional questions about what they were working on. While I did not see this manifest during my
observations of team meetings, I discovered Scott’s continued efforts to connect information while talking with another member of the team. Early in the makerspace project, the team decided to divide into specialized sub-teams to address the business side and the technology side of the project. Scott chose to work on the business sub-team. But as I talked with members of the technology sub-team, which students called the tech team, I found out that Scott made an effort to learn about what they were doing as well. A member of the tech team told me that Scott asked him to be shown how the 3D printers worked. While this request seems simple, Scott was the only business sub-team member, with no prior 3D printing experience, to approach the tech team interested in learning about the equipment. Many team meetings were spent discussing the 3D printers, and it would have been difficult to follow these conversations without a basic understanding of the technology.

3.6.2 Ryan – The Interface

In talking with Ryan during his interviews, his passion for 3D printing was evident. Ryan was a sophomore mechanical engineering major and had recently purchased his own 3D printer. He was interested in starting a student organization for 3D printing on campus. Ryan had begun the process of forming the student organization before a faculty member he was working with found out about the makerspace team’s CI project and encouraged Ryan to join.
During the semester-long project, Ryan continued to interface between the makerspace team and other entities to move along his vision for 3D printing on campus. Early in the makerspace project, Ryan attended a meeting with university administration to discuss combining similar efforts for 3D printing across campus. As facilitators for the makerspace project, Dr. P and I were also invited to this meeting; however, the rest of the makerspace team was unaware of this conversation.

At the makerspace team meeting later that day, the team discussed a mission statement and determining the target customers for a makerspace. I distinctly remember hearing the team’s conversation and knowing that Ryan could answer those questions based on his earlier conversation with university administration. I wrote in my field notes, “I was waiting for Ryan to comment based on today’s earlier meeting [with administration].” I remember having to make a conscious effort to refrain from talking about the earlier administration meeting that I had also attended. I felt relieved when Dr. P asked Ryan to give a report from his meeting with university administration. Ryan filled the team in on the earlier conversation and the goals of his 3D printing student organization. During the semester, Ryan continued to meet with administration and student organization members and share his discussions with the rest of the makerspace team.

Ryan’s actions caused his teammates to see him as somewhat of a management person for the makerspace team. For instance, during an interview with me Scott reflected,
I guess I would assume that someone in business would want to be in the business stuff and take care of the related activities, but as the weeks have gone on, I've seen Ryan likes to do some management stuff, like started the club, and he likes to talk to the higher-ups.

Scott went on to say, “…it was good to see that just because it's [Ryan’s major is] engineering, it doesn't really make a difference, and he seems to be doing pretty good at it.”

As a member of the technical sub-team (students called this the “tech” team for short), Ryan continued to interact with people outside the project and share his experiences with his teammates. At one point during the semester, ESPN contacted Ryan about having something 3D printed for an upcoming ESPN Game Day event. Ryan then served as the primary interface between the other two tech team members (Hunter and Mark) and television show staff. During a focus group I later held with the tech team members, Hunter explained,

... me and Mark never even talked to the Game Day people at all, I don't think. We were getting all the information from Ryan, and I would remember that he would always promise some things, and we'd be like ‘Dude, now we have to do this!’

While Ryan’s role as an interface for the team did not fit with the traditional stereotype of a mechanical engineer, Ryan “enjoyed” this role. Over the course of the semester, Ryan
gained recognition from his teammates as the “management” or “business” person on the team as he interfaced with project stakeholders.

3.6.3 Mark – The Situational Collaborator

Mark was entering his junior year in industrial engineering and had prior experience with 3D printing. Mark had worked on a 3D printing Creative Inquiry project in the past, and he spent one semester as the primary student leader for that project. These prior team experiences helped him understand the importance of effective communication on team projects. He told me about a prior project where a piece of equipment had been disassembled without any explanation to the rest of the team as to why it was taken apart. Mark explained that this lack of communication ultimately set that project back an additional two weeks. This and other past team issues motivated Mark to do what he could to promote effective communication and documentation for the makerspace team, at least initially.

When the makerspace team decided to split into two sub-teams to address separate project objectives, Mark joined the technical sub-team, called the “tech team” for short. The tech team’s goal was to test different types of 3D printer equipment and make suggestions for equipment to include in a makerspace. Mark’s interest in and prior experience with 3D printing equipment made him a good fit for the tech team. All three members of the tech team, Ryan, Hunter, and Mark, described their sub-team as having a good working relationship. His tech teammates described Mark as an “expert” at 3D
printing and someone who helped them critically think through equipment ideas and decisions. Mark also engaged with the makerspace team as a whole by documenting the team’s discussions on his laptop during weekly makerspace meetings. He often led the tech team’s weekly reports to the rest of the team on what he and his teammates had worked on over the previous week. In the early, idea generation phase of the makerspace project, Mark was an active collaborator on the team and worked to establish effective approaches to communication. However, as the deadline for the final presentation to project stakeholders drew near, Mark began to question whether collaboration was the most effective approach to completing the project.

Behind the scenes, Mark was skeptical about the makerspace team’s ability to achieve their final objective of presenting their plan to project stakeholders. The team spent much of the semester creating slides explaining the mission, market need, and business plan for a potential makerspace. They brainstormed potential management structures for the space and the business sub-team developed a survey to gather market data. This survey was a topic of contention for Mark, and he brought up the survey many times during his interviews with me. He was openly unhappy with the amount of time it took the business sub-team to create and distribute their survey. At one point Mark commented,

Then again, I have to ask myself, “what did the business team really do that whole semester?” They made a survey I could have made in 5 minutes, and they sent it
out to some people. Like OK. I think the tech team could have handled that a little bit better.

This comment made it clear that Mark not only was irritated with the amount of time the business team took to develop the survey, but that he believed the tech team could have done it better. His irritation seemed to turn to distrust as the time for the final presentation drew near. During an interview, I asked Mark to talk about his current perception of the makerspace project. He said, “Honestly, I hate the slide show. I hate how it's organized, I hate a lot of things about it.” He went on to tell me that the three tech team members had met and agreed that the presentation “is probably not going to go well.” In fact, Mark had made plans to meet with the other members of the tech team to polish the presentation on their own.

I remember being surprised that Mark had not shared his concerns about the presentation with the entire makerspace team at one of the weekly team meetings. I observed every makerspace team meetings as part of my study, and I had no idea that Mark was so apprehensive about the final presentation until I talked with him during that interview. I asked Mark why he had not expressed his concerns to the rest of the team. He said he was “not sure” why he had not talked to the entire team, but talked with confidence about the tech team’s ability to polish the presentation and “coach” the other members of the team on how to present their slides. While Mark understood the value of teamwork and effective collaboration, he resorted to a non-collaborative approach to the project when confronted with the pressure of delivering a good final presentation. He knew the final
presentation to stakeholders would determine whether or not the makerspace project moved forward, and when faced with this reality, Mark’s desire to see the project succeed outweighed his desire to collaborate.

3.6.4 Annie – From Outsider to Contributing Team Member
Annie joined the makerspace team after the start of the semester causing her to miss the first team meeting where the team was introduced to the idea of a makerspace and the specific project objectives for the semester. During the second meeting, Annie sat at the conference table with the rest of the team. As I watched the team interact, I recorded in my field notes that Annie “seemed bored” and was “zoned out” during the meeting. I remember feeling anxious, waiting for Annie to contribute to the conversation or to ask a question. As the meeting drew to a close, I realized that Annie had not said anything during the meeting, and I made a note to ask her about this later.

During my interviews with Annie, I later found out that she was a senior psychology major who was looking for courses to fill her light schedule before graduation. However, Annie also talked about wanting to challenge herself during her last semester. Annie knew nothing about makerspaces or 3D printing, and she admitted that she “accidently” enrolled in the makerspace project. Annie told me that during her first meeting with the team she had no idea what the team was talking about. She explained, “I didn’t even have enough information about what we were talking about to have a question...” I was
surprised to hear her go on to explain that she would rather look up terminology later than interrupt the meeting to ask a question.

The faculty mentor for the makerspace project, Dr. P, also noticed Annie’s quiet, reserved demeanor during weekly team meetings. After a meeting early in the semester, Dr. P asked Annie how things were going. She told to him that she was feeling unsure about how she could contribute to the team. Annie continued to attend the weekly team meetings, but remained reserved and often did not contribute more than a sentence or two to the conversation. As I got to know Annie more through interviews and my observations of her interacting on the team, I realized how much she felt like an outsider on the team. Annie expressed concern during her interviews that her teammates might not be happy with her performance on the team, and she often referred to herself as a “slacker”.

Annie’s role on the makerspace team transformed when the team started discussing how to collect survey data as part of their market research. Annie’s training in psychology had exposed her to best practices in survey development and distribution, and Annie realized that this was her chance to help the team. She asked the team, “So, how are you going to make sure people actually fill out the surveys?” This was the first time I witnessed Annie truly engaging with the team’s discussion. During the next few meetings, she continued to help the team critically think through their plan for administering the survey. She asked questions and provided evidence from her personal
experiences as a psychology major and a survey participant. Annie openly contributed to the team’s conversation and provided valuable insight that directed the team’s actions. Her personal perception of the role she played in the makerspace project changed. She wrote in one of her progress reports,

My perspective on this project has definitely changed in that I do feel I have important capabilities to help in the development of our final project, even though I do not have a lot of experience with 3D printers/makerspaces.

She went on to describe herself as “a nice outside mind in a group of engineer, architect, and business majors”.

Over the course of the semester-long project, Annie’s role transformed from outsider to contributing team member. Helping the team create a plan for their market need survey was a turning point in Annie’s development as a member of the team. She recognized an opportunity to contribute and shared her knowledge and experience with her teammates. Her contribution ultimately gave her confidence in her ability to serve as a productive member of the team.

**3.7 Examining Student Roles Through the Lens of the Existing Cross-Disciplinary Framework**

Each student’s narrative illustrates the salient role he or she exhibited during the makerspace project. Some roles took time to develop while others appeared to be inherent in that student’s initial approach to cross-disciplinary teamwork. Still other roles
were situational based on the current pressures the student was experiencing. I examine these students’ pathways of role development through the lens of Adams and Forin’s (2014) cross-disciplinary professional practice model. This model highlights four categories of cross-disciplinary teamwork experienced by professionals, with each category representing a higher-level understanding of cross-disciplinary complexity, appreciation for difference, and feeling of identity (R. S. Adams & Forin, 2014). By overlaying these student narratives with the existing cross-disciplinary framework, the trajectory of each student’s approach to cross-disciplinary work becomes clear and deepens the current understanding of student cross-disciplinary development.

Scott and Ryan each took on a clear team role from the early stages of the project. Scott asked numerous questions during weekly team meetings to help his teammates explore new ideas and consider aspects of the project in a new way. His probing questions helped the team connect multiple viewpoints and ideas together to make the team’s solution more broad. From early on in the makerspace project, Scott served as a connector for the team. Scott’s connector role manifested from his belief in the value of sharing ideas to promote effective teamwork. Scott described a desire to “promote” good ideas within the team. And rather than relying on another student to ask questions that would connect ideas, Scott took on the leadership role of an idea connector for his team.

Ryan helped the team think more broadly by interfacing with project stakeholders. He acted as a project liaison to university administration and television station personnel. He
negotiated expectations of stakeholders with the abilities of his team and kept lines of communication open. Ryan served as an interface for the makerspace team. Ryan was driven by his personal passion for 3D printing and his desire to expand its use on campus. Ryan’s passion led him to step outside the traditional roles of his engineering major to handle communications with outside stakeholders.

The roles of “interface” and “connector” are described in the strategic leadership category of Adams and Forin’s (2014) professional practice model: “Leadership is central in that it involves being the ‘interface’, ‘connector’, or ‘communication specialist’ to cross disciplines, organizational functions, and cultures to proactively create an environment for innovation” (p. 116). As undergraduate students, Scott and Ryan, approached the makerspace project by taking on these “professional” roles as described in the existing model (see Figure 3.3). They approached cross-disciplinary teamwork as leaders, likely because they understood the need for a connector and an interface in order for the makerspace team to be effective. And they were willing to take on those roles even when it involved Scott drawing attention to himself while asking numerous questions or Ryan stepping outside traditional disciplinary norms to redefine a new role for himself as a “business” person on the team.
Mark initially engaged with the makerspace team by taking notes during meetings and heading his sub-team’s weekly reports to the rest of the team. His past team experienced informed his desire to encourage effective communication and collaboration among his teammates. However, as the project progressed Mark began to feel the pressure of an approaching deadline for the final presentation. After the business sub-team struggled to create a market need survey, Mark began to doubt that everyone could pull together to give a good final presentation to project stakeholders. Instead of bringing his concern to the team, Mark told me about his plan to finalize the project presentation with the few teammates he trusted. Mark valued and engaged in collaboration during the early, idea generation phase of the project. But when faced with the pressure of producing a final presentation that would move the makerspace project to the next step, Mark resorted to the approach he thought would be most efficient, completing the project on his own.
Mark’s opposing approaches to cross-disciplinary collaboration speak to the situational nature of teamwork. An individual’s approach to collaboration can change based on the situation he or she is currently facing. The pressure of an impending deadline or perceived value of a project’s final outcome can cause him or her to resort to a perceived most efficient method. This efficient method often does not include cross-disciplinary collaboration because of the additional time and effort it requires.

In Mark’s case, he began to see cross-disciplinary collaboration as a burden as the team tried to complete the final presentation on a tight deadline. Rather than approach the team with his concerns and propose an effective approach, Mark started making plans to finalize the project on his own. Mark’s avoidance of collaboration in the later stages of the project suggests that he did not value cross-disciplinary teamwork. However, his initial reflections of past ineffective team experiences coupled with his earlier efforts to encourage effective communication on the makerspace team illustrate Mark’s perception of the value of collaboration. This understanding of and appreciation for collaboration position Mark in the beginning categories of the cross-disciplinary practice model (R. S. Adams & Forin, 2014). Yet, his desire to finalize the project himself when faced with the final deadline situates his cross-disciplinary approach outside the existing model. These contradictory approaches to teamwork illustration of the situational nature of collaboration. Figure 3.4 represents Mark’s two approaches to cross-disciplinary work depending on the situation.
Figure 3.4: A representation of Mark’s contradictory responses to different situations he encountered during cross-disciplinary collaboration

Annie developed her role on the team as the project progressed, and her perception of cross-disciplinary teamwork developed with it. She initially felt like an outsider as a psychology major surrounded by mainly engineering students. Annie described being unsure where she would fit in on the team, and her self-doubt often caused her to remain quiet during team meetings. However, her role clearly changes when the makerspace team decided to distribute a market need survey. Annie was the only team member with experience developing and distributing surveys, and her teammates looked to her for advice. Instead of maintaining her quiet, outsider role on the team, Annie stepped into her new role as survey expert and shared what she knew with her teammates.

Annie’s transition from outsider to contributing team member was motivated by the team’s need for information related to a topic she was exposed to in her major. Her
initial outsider role placed her in the working together category of the existing model, which involves understanding team members’ roles and communication styles. Annie seemed to have an awareness of and appreciation for cross-disciplinary collaboration; however, she did not initially see an opportunity to personally contribute. But when that opportunity arose, Annie was quick to share what she knew with her teammates, making a seamless transition into the intentional learning category of the existing model (see Figure 3.5). Annie illustrated one aspect of intentional learning by “purposefully educating” her teammates to broaden the team’s perspective on the current task (R. S. Adams & Forin, 2014, p. 112). Annie’s role in the intentional learning stage involved sharing what she knew with her teammates to educate them about survey development and data collection.

Figure 3.5: Illustration of Annie’s progression through the working together and intentional learning staged of the existing cross-disciplinary model.
Ryan, Scott, Mark, and Annie’s narratives present the most salient roles these students exemplified during the cross-disciplinary makerspace project. These roles illustrate each student’s unique understanding of and approach to collaboration. Figure 3.6 shows all four student’s approaches in relation to the existing cross-disciplinary framework. These differences in student approaches stem from different sources of motivation for each student.

![Diagram showing student approaches](image)

**Figure 3.6:** Comparison of all four students’ approaches to cross-disciplinary teamwork illustrated through categories of the existing cross-disciplinary professional practice model (R. S. Adams & Forin, 2014)

Ryan’s interests in 3D printing and starting a makerspace on campus motivated him to interface with project stakeholders to move the project forward. Scott’s motivation to serve as a connector came from his personal appreciation for diverse viewpoints and lack of fear in asking questions to encourage discussion. Mark and Annie’s team roles, however, were motivated by specific events that occurred during the project. Mark understood and appreciated cross-disciplinary collaboration when he could see the benefits of various viewpoints and approaches during the idea generation stage of the project. However, as Mark experienced the pressure of the approaching deadline for the
team’s final presentation, he began to see collaboration as an obstacle to success. Rather than confront the team with his concerns, Mark began to see completing the project on his own as the most efficient way to address the situation. Annie grew in her approach to cross-disciplinary work over the course of the project. Her motivation for growth came from a clear opportunity to contribute to the team’s development of a market need survey. Rather than continuing to act as an outside member of the team, Annie took advantage of the opportunity to contribute and shared her disciplinary experience with the rest of the team. A summary of these results is shown in Table 3.2 below.

Table 3.2: Summary of unique roles and stages of development illustrated in these four student cases

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Salient Role</th>
<th>Stage of Cross-Disciplinary Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annie</td>
<td>From Outsider to Contributing Team Member</td>
<td>From Working Together to Intentional Learning</td>
</tr>
<tr>
<td>Mark</td>
<td>Situational Collaborator</td>
<td>Intentional Learning in some situations and disengagement from collaboration in other situations</td>
</tr>
<tr>
<td>Ryan</td>
<td>Interface</td>
<td>Strategic Leadership</td>
</tr>
<tr>
<td>Scott</td>
<td>Connector</td>
<td>Strategic Leadership</td>
</tr>
</tbody>
</table>

Together these four student cases expand the current understanding of cross-disciplinary practice to a student context. These student’s unique roles and different motivating factors determined individual trajectories through the stages of cross-disciplinary development. Each student joined the team at a different developmental starting point, yet this starting point did not necessarily determine his or her overall trajectory. Specific events over the course of the project altered some students’ approaches to cross-
disciplinary collaboration in unique ways that could not have been predicted by the students’ initial stage of development.

### 3.8 Conclusions and Implications

Considering these four student experiences together highlights students’ various approaches to cross-disciplinary collaboration. Scott, Ryan, Mark, and Annie all experienced different factors that motivated their chosen roles on the makerspace team. Scott and Ryan’s roles remained consistent throughout the project and demonstrated strategic leadership for the team. Annie and Mark’s roles changed over the course of the semester causing Annie to transition into an active role on the team while Mark’s role was situational. As the timeline for the final presentation drew near, Mark acted on what he believed was a more efficient approach to completing the project, which ultimately involved his disengagement from the team.

This work furthers the current theoretical understanding of cross-disciplinary teamwork by highlighting students’ different starting points and trajectories through cross-disciplinary development. By operationalizing the existing cross-disciplinary model for professionals in a student context, this work uncovers some of the factors that can influence student development as cross-disciplinary team members. This expansion of the existing model provides a stepping off point for other engineering education researchers to investigate cross-disciplinary student experiences. This work can also inform practitioners as they develop and lead cross-disciplinary student projects. With an
understanding of the range of beginning points and trajectories in cross-disciplinary development, practitioners can be aware of and better monitor student engagement and development during team experiences.

I would like to acknowledge Dr. Robin Adams for her insights into my work. Her feedback was instrumental in my interpretation of Mark’s case.
Chapter 4

The Game Day Project: How a Sub-team of Engineers Experienced Cross-Disciplinary Difference

4.1 Abstract

Preparing students for the cross-disciplinary collaborations they will experience as professionals goes beyond creating opportunities for students from different disciplines to work together. Effective team members value everyday collaborative differences that transcend disciplinary training. This paper shares the narrative of three engineering students as they navigated team roles during the Game Day project. Through this project, these students developed a broader understanding of and appreciation for the differences each of them brought to their team. They came to understand difference as coming from their individual interests, skills, and backgrounds rather than solely disciplinary training. These students’ Game Day experience poses implications for developing influential team experiences that expose students to cross-disciplinary work. These experiences must go beyond the structure of the team (the number of disciplines involved) to create opportunities for students to become aware of and engage with difference. Empowering students to effectively work within everyday team differences can make them more effective collaborators as professionals.
4.2 Introduction

Cross-disciplinary collaboration is a fundamental component of professional practice. And these diverse collaborations are becoming more essential as the workforce is faced with global challenges requiring skillsets from a range of disciplines. Part of becoming a professional requires understanding and appreciating the value of diversity on cross-disciplinary teams. This diversity is most commonly recognized as disciplinary differences; however, different backgrounds, viewpoints, skillsets, and interests also contribute to the breadth of a team. Knowing how students perceive and engage with cross-disciplinary difference can expand the theoretical understanding of student teamwork and inform the development of effective cross-disciplinary experiences for students.

Adams and Forin (2014) define cross-disciplinary as “a collection of practices associated with thinking and working across disciplinary perspectives” (p. 103). This definition acknowledges cross-disciplinary work as a practice rather than a team structure (i.e. individuals from X number of disciplines) (R. Adams, personal conversation, February 23, 2017). It takes into account individual skillsets, interests, and viewpoints as differences that can bring diversity to any team. In their study of cross-disciplinary collaboration in professional practice, Adams and Forin (2014) identify key categories and facets of professional cross-disciplinary work: working together, intentional learning, strategic leadership, and challenging and transforming practice. They include awareness of and engagement with difference as a component of their cross-disciplinary model of
professional practice. Figure 4.1 shows a diagram of the four categories of the model and their hierarchical relation to one another.

Figure 4.1: Reproduction of the Adams and Forin’s (2014) cross-disciplinary professional practice model

This existing model identifies the various ways differences are experienced by cross-disciplinary team members and how these differences influence individual actions, perceptions, as well as identities (R. S. Adams & Forin, 2014). Each higher level of understanding involves a clearer idea of what makes team members different and how to interact with and capitalize on these differences. In the first category of the model, working together, difference is understood as “disciplinary training” (R. Adams et al., 2010, p. 1163; R. S. Adams & Forin, 2014, p. 112). At the highest category, team members begin to challenge and transform practice as they come to see difference as transcending disciplinary boundaries (R. Adams et al., 2010; R. S. Adams & Forin,
Difference is now perceived as coming from one’s background and lived experiences rather than one’s discipline.

While the existing model describes how professionals experience difference, this paper investigates the concept of cross-disciplinary difference in a new context: undergraduate students. I utilize a real-time data collection approach to elicit thick, rich descriptions of student cross-disciplinary experiences during a team project. I observed and interviewed ten students enrolled in a semester-long, cross-disciplinary team project. This paper focuses on a sub-team of three engineering students to investigate the team dynamic as the students worked on a project I call the “Game Day” project. Their collaboration during this project ultimately shaped the team members’ awareness of difference and approach to interacting with difference on a cross-disciplinary student team. In my examination of this sub-team, I address the question: How do undergraduate students perceive and engage with cross-disciplinary difference?

4.3 Understanding Student Perceptions of Cross-Disciplinary Difference: My Approach

My work borrows from multiple qualitative (Borrego et al., 2009; Van Note Chism et al., 2008) research traditions including ethnographic (Angrosino, 2007; Reeves et al., 2008; Singer, 2009) and case study (Baxter & Jack, 2008; Stake, 1994; Yin, 2009) research. Specifically, I applied ethnographic research as a data collection method. I observed in real-time a cross-disciplinary student team as well as collected data from other sources.
Figure 4.2 shows my overall study process starting with forming the student team through the undergraduate research program, Creative Inquiry (https://www.clemson.edu/centers-institutes/watt/creative-inquiry). Additional details on my study methodology including my analysis approach can be found in Chapter 2.

The cross-disciplinary student project was open to any undergraduate student interested in joining the team and tasked the student team with developing a business plan for a makerspace on campus. Once established, the makerspace would provide university students with access to prototyping equipment, such as 3D printers, at no cost. Twelve students enrolled in the semester-long makerspace project. A sub-set of ten of these students were participants in my research study (see Table 2.2 for demographic information on all ten participants). The students ranged from freshman to senior and represented 5 unique engineering majors (chemical, industrial, mechanical, material science and engineering, and general engineering) as well as architecture and psychology.

The makerspace team met with a faculty project mentor on a weekly basis to discuss individual tasks, progress on the project, and objectives for the upcoming week. I took on the role of a participant observer (Angrosino, 2007; Van Note Chism et al., 2008) during those meetings and sat at the conference table with the rest of the student team taking notes on their discussions and interactions (data type B). I also audio and video recoded the weekly team meetings to obtain transcripts of the team’s discussions (data type D). I refrained from contributing to project discussions unless the team requested
information that I could provide, such as email addresses for other Creative Inquiry teams, which students could not directly access. I also collected data in the form of semi-structured interviews (Patton, 2015, Chapter 7; Van Note Chism et al., 2008, Chapter 4) with individual team members (data type A) and “progress report” documents (data type E) written by students (Patton, 2015, Chapter 6; Van Note Chism et al., 2008, Chapter 4). Personal memos (Birks et al., 2008) (data type C) served as an additional source of data for my research. Each data source interplayed with the others to direct my emergent data collection approach (Patton, 2015, Chapter 2).

Figure 4.2: Diagram of my overall study process including the collection of multiple data sources (A through F) as well as my analysis technique.
The student team determined early in the semester that project objectives fell into two main categories; technology and business/marketing. The team subsequently decided to create two focused sub-groups to work on each of these topics. Students were able to select which sub-team they wanted to work on. Most of the students chose to work on the business sub-team. Three engineering students, Hunter, Ryan, and Mark, volunteered for the technology team, which the students called the “tech” team. The tech team’s primary objectives were to evaluate different 3D printer technologies and make suggestions for equipment to include in the makerspace.

During my interviews with Hunter, Ryan and Mark, I found out that the tech team was involved in additional projects that the rest of the makerspace team did not know about. In order to find out more about these additional projects and the tech team dynamic, I scheduled a focus group (data type F) with the tech team during the summer following the makerspace project. At that time, it had been about 6 months since I observed the makerspace project during its first semester. The project had continued into a second semester, and I remained in contact with many of the makerspace team members during that time. My goal for the focus group was to get a deeper look into the tech team dynamic, what roles each of the tech team members played on the team, and how they made decisions about their interactions with the rest of the makerspace team.
My analysis began with organizing data from each student into tables, which facilitated examining each student’s experience as a single case. My analysis then followed a cyclic process of reviewing the data, memoing about what I was seeing in the data, sorting and analyzing data of interest, and writing up my findings. Each pass through the data added an additional layer of thick, rich description to the tech team’s experience. I combined findings from my focus group with each of the three tech team students’ cases and shifted my unit of analysis to the tech team as a whole rather than an individual student. Through this approach, I uncovered the dynamic of the tech team as they navigated individual roles and engaged with cross-disciplinary difference.

4.4 The Tech Team

The three members of the tech team, Hunter, Ryan, and Mark, were mechanical and industrial engineering majors. Each student had previous 3D printing experience and was excited to test out the team’s makerspace equipment. Hunter, Ryan, and Mark each served as a lead technician for one of the three 3D printers the tech team tested. Although each tech team member worked individually on his printer, the team also met regularly to assist each other and collaborate on additional aspects of the project. Hunter, Ryan, and Mark attended the weekly makerspace team meetings and reported their progress to the rest of the team. Despite continual interaction with the rest of the team, the tech team ultimately functioned like a separate project team. In fact, the three engineers went beyond their sub-team objectives and took on their own projects related to 3D printing.
During the focus group, Hunter, Ryan, and Mark told me about a separate project I am calling “the Game Day project”. They described an intense, five day venture where they scanned and 3D printed models of ESPN TV show hosts’s heads. The tech team was contacted by ESPN a few days before the premier of an ESPN Game Day broadcast looking for some student created artifacts for air during the broadcast. Hunter, Ryan, and Mark decided to take on the project. At the time, the rest of the makerspace team, including the faculty project mentor and myself, were unaware of the tech team’s involvement on this project. The Game Day project was the tech team’s first experience navigating separate team member roles and their experience ultimately shaped their awareness of and engagement with cross-disciplinary difference on a student team.

The following ethnographic narrative (Angrosino, 2007; J W Creswell, 2013; Van Maanen, 1988) illustrates the tech team’s experience during the game day project. The goal of an ethnographic narrative is to “reach and move people and teach them about the experiences of others in ways that would never be possible with the standard scientific monograph…” (Angrosino, 2007, p. 81). I apply the narrative analysis technique of restorying (Ollerenshaw & Creswell, 2002) to retell their story as they described it to me during the focus group. Ollerenshaw and Creswell (2002) describe restorying as, “… the process of gathering stories, analyzing them for key elements of the story (e.g., time, place, plot, and scene), and then rewriting the story to place it within a chronological sequence” (p. 332). The tech team’s conversation during the focus group bounced
around as each student remembered a different event during the game day project. I have 
reorganized their conversation to give a chronological depiction of their experience. I 
draw on the example of other ethnographic researchers, such as Rebekah Nathan (2005) 
and Louis Bucciarelli (1994), and let my participants own words tell their story through 
using direct quotes. By restorying Hunter, Ryan, and Mark’s game day experience, their 
narrative can speak to a broader context through the experiences of the reader.

4.4.1 The Game Day Project

Hunter, Mark and Ryan met with me over the summer in a small glass-walled classroom 
in a new building on campus. I set up my audio and video equipment while they talked. 
I then began asking Hunter, Ryan, and Mark about the times they met together outside 
the weekly makerspace team meetings. They identified their mutual interest in 3D 
printing as what initially brought them together to work on the makerspace equipment. 
Hunter explained, “Yeah, we were just really into 3D printing, and we liked all that stuff. 
Then very quickly, the Game Day thing came about...”

As I listened to Hunter, I remembered observing a makerspace meeting where the tech 
team members showed off a miniature, 3D printed bust of an ESPN TV show host. 
However, the tech team did not share the details of that project with the rest of the team. 
In fact, during that meeting the 3D printed bust was quickly pushed aside. No one 
realized the hard work and long hours the tech team had put into creating the 3D print. 
As I sat with Hunter, Ryan, and Mark at the focus group, they shared the details of the
Game Day project. I invite you, the reader, to imagine yourself sitting with me, listening to the tech team’s account of the project.

Ryan reminisced, “That’s how the lady got my name... She just emailed me, and was like, ‘I saw on some website that you’re doing 3D printing stuff.’”

Hunter laughed as Ryan continued, “Then she started asking, ‘Can you like print pictures of these guys?’ I was like, ‘Yeah, we could, but you might as well just use a regular printer for that. We can try to do 3D models.’ Actually, I said we could before knowing whether or not we could...”

Hunter interrupted, “Yeah! Ryan would always promise things that were nearly impossible. Because it was on a Monday, I think, when we started talking to them. We didn’t have a scanner. We didn’t have any software.

Ryan piped in, “We had a vague idea of what to do.”

“And we had like 2 hours experience on the [3D] printer,” Mark added.

Everyone laughed as Hunter continued, “And we didn’t have a computer that could run the printer, that could run the scanner, because it uses so much GPU, so we had literally nothing we needed... I knew you could use a Kinect scanner. So we’re like, ‘That’s your best bet. That’s the only one we can get.’ So we got that and then I spent a day trying to get it to work on my laptop. It wasn’t strong enough. I never used it before, so I didn’t really know what was wrong. Tried my buddy’s. That didn’t work, so I was like, ‘We need like a gaming laptop.’ I just happen to know Jake had one.”

“Yeah. Jake is a good friend of mine from [work],” Mark added.

Ryan explained, “Hunter brought in the Kinect one day and he is like, ‘Yeah, there’s a way to do it.’ And I was like, ‘If there’s a way to do it, we could figure it out.’ So then I told them [the game day people] we could do it. And it was like, ‘Alright, we gotta figure out how to do this by Thursday.’”

Hunter remembered, “Thursday afternoon was the first print, so they scanned me, and we printed myself out. We were like, ‘It does work. You can do it,’ but I was the only one who really knew how the scanner worked because once you scan, there’s a bunch of settings you had to do to get it to be a manifold print.”
“We scanned them Friday morning. We were up all night Friday.” Ryan explained.

Mark corrected, “I think I left at 4:30 that morning and went home and got like two hours of sleep and then came back. I think these guys were up all night.”

Hunter remembered, “We printed two [ESPN host's] heads because we thought his was going to fail...”

Hunter also continued, “I had the biggest Red Bull you could buy. Jake brought me one, and I drank it at like 1 in the morning. ... I enlisted my Printer Bot to do one of the heads. I ran out of filament halfway through, so up to here on [ESPN host’s] head was one shade of orange and then the top half was a different shade. It was like the best one, best quality. I was like, ‘I can't use this!’”

Ryan stated, “We needed one more day. One more day and then-“

“We needed like 6 more hours.” Hunter interrupted.

Ryan agreed, “Actually, yeah. Half a day.”

As I listened to the tech team’s account of the Game Day project and their continued discussion about team member roles, I realized that this experience was a turning point in the tech team’s awareness of cross-disciplinary difference. In the midst of the Game Day project, Hunter, Ryan, and Mark began to see how their different interests, skillsets, and backgrounds could contribute to the project in unique ways. This heightened their awareness that cross-disciplinary difference can be defined broader than traditional disciplinary training.

4.5 The Tech Team’s Engagement with Cross-Disciplinary Difference

Each tech team member took on a specialized role on the team as they approached projects throughout the semester. The tech team described Hunter as the designer, Mark
as the technical expert, and Ryan as the “business/communications” person. All three tech team members were sophomore and junior-level engineering majors, so they had a few years of disciplinary grounding in their major. Yet, as they navigated roles during the Game Day experience as well as in their other endeavors, the tech team members began to take on “unconventional” roles outside those traditionally associated with their discipline.

Of particular interest was the role Ryan took on as the “business” person for the team. Ryan handled all communications with ESPN Game Day staff and negotiated their expectations with tech team capabilities. His teammates described Ryan’s team role in terms of his involvement with the Game Day project,

…me and Mark never even talked to the ESPN people at all, I don't think. We were getting all the information from Ryan, and I would remember that he would always promise some things, and we'd be like ‘Dude, now we have to do this!’

Ryan “enjoyed” his role as the business/communications liaison and his teammates let him handle this aspect of the team’s work even though he did not have any formal training in business or communications. They recognized that despite Ryan’s lack of formal training, he had the interest and necessary skillset to manage the team’s communications with outside stakeholders. Also, neither Hunter nor Mark were interested in taking on the role of communicator.
Seeing these differences in personal interests and strengths play out during the Game Day project altered how the tech team chose to engage with their differences. For example, while Ryan was familiar with 3D printers and their capabilities, he recognized that the technical aspects of the equipment and designs were not his strength. Rather than try to take over the more traditional engineering aspects of the Game Day project, Ryan stepped aside to let his teammates do what they were good at. Ryan explained,

…best example I can give is when we were scanning the heads [for the game day project]. I definitely could have figured it out, it probably would've took me a week to do. It took Hunter a day and a half. When he was doing that stuff, we kind of stepped back and said ‘This is your thing. Do it.’ He killed it! I think previously I had never had that experience.

Through working together, the tech team members realized the benefits of defining team roles based on individual strengths and interests rather than disciplinary training. This realization not only changes how they chose to engage with each other as members of the tech team, but also how they thought about engaging with cross-disciplinary difference in general, especially during the idea generation phase of a project. Ryan explained,

If you have a car engine and you want to know the exact numbers for emissions, and how much fuel it burns, then go to an engineer. But if you're trying to think up the best way to do some project, just because the project is engineering… it doesn't mean you need … an engineer. Which I think a lot of people fall into thinking, and I think it's a bad way to think because it limits you so much. I think
that's one of the really great thing about our team. Just because the three of us were engineers, we were not at all afraid to think outside the box and consider other options that might be more suited to a different major.

Hunter, Ryan, and Mark’s collaboration during the Game Day project fostered an awareness of cross-disciplinary difference at the highest level of Adams and Forin’s (2014) professional practice model. The tech team’s understanding that difference transcends disciplinary training positions their approach to cross-disciplinary work within the challenging and transforming disciplinary practice stage of the model. This stage “expands an awareness of difference to include lived experiences and recognizing how boundaries between differences are socially constructed and negotiable” (R. S. Adams & Forin, 2014, p. 123). This genuine team experience facilitated Hunter, Ryan, and Mark’s realization that cross-disciplinary collaboration is a practice that can take place regardless of the structure of the team. Despite all coming from engineering disciplines, the students on the tech team noticed separation in what each person could contribute to the team and they began to see value in capitalizing on their different interests and skillsets to accomplish team goals. Hunter, Ryan, and Mark recognized that differences transcend disciplinary boundaries to include individual experiences and viewpoints making everyday teamwork cross-disciplinary.
4.6 Conclusion

For Hunter, Ryan, and Mark, cross-disciplinary difference became more than just differences in the training they received in their major courses. Instead, they saw differences in their past experiences and interests as motivators for shaping team roles. The tech team members came to appreciate the benefits of not being tied down to traditional disciplinary roles and in doing so, challenged the way they engaged with disciplinary norms. Through engaging with cross-disciplinary difference during the Game Day project, they came to appreciate the added value in considering differences in experience as well as training to generate more diverse ideas and address problems in a broader way. Hunter, Ryan, and Mark ultimately realized that cross-disciplinary collaboration goes beyond the structure of a team and is a form of everyday practice.

4.7 Implications

Hunter, Ryan, and Mark’s Game Day project experience illustrates a specific instance that redefined these students’ understanding of cross-disciplinary difference. While the tech team’s case speaks to the potential evolution of students’ engagement with cross-disciplinary work, it is important to realize that the context of this Game Day project is unique. This project was real for these students, not constructed by a faculty member as part of the curriculum. The tech team members were approached by ESPN staff with a genuine project related to a topic they were each passionate about. It was clear to these students that the project outcome was solely dependent on them, which motivated them to find the best approach to complete the project on their limited timeframe.
In light of the tech team’s unique experience that prompted a higher level understanding of cross-disciplinary work, preparing students for cross-disciplinary professional practice must go beyond facilitating opportunities for students in different disciplines to work together. While this achieves a cross-disciplinary team structure, it does not necessarily create an opportunity where students become aware of and engage with difference.

Regardless of the team structure, faculty can facilitate awareness of differences beyond disciplinary training through conversations and structured student reflections. Challenging students to identify differences in the personal experiences and interests of their teammates can lead to the realization that “the difference is already in the room” (R. Adams, personal conversation, February 23, 2017) even if the room is full of only engineers. Empowering students to effectively work within everyday differences should be the main goal of effective cross-disciplinary projects. This skill will transfer beyond their undergraduate coursework to make students more effective collaborators as professionals.
Chapter 5

Power Structures and Social Norms in Higher Education: How “Ruling Relations” Govern Faculty Influence on Student Cross-Disciplinary Development

5.1 Abstract

Faculty play a significant role in student cross-disciplinary development. However, student’s reliance on faculty for leadership and guidance can inhibit student development as cross-disciplinary professionals. This paper takes a step back from investigating student teamwork to examine the social norms and power structures in higher education that influence the actions and perceptions of both faculty and students during a project. Smith (1987) uses the term “ruling relations” to describe these structures and norms. As an example, these ruling relations can perpetuate student’s reliance on faculty members for information rather than taking an initiative to seek out the necessary information for themselves. Similarly, faculty are under pressure to show productivity on projects, a demand that is often at odds with the approach of structuring a truly student-led course.

I present a narrative of one faculty member’s experience leading a student project. His story draws attention to the norms and structures of higher education that effect both his actions and ultimately the development of his students as team members during the project. This narrative illustrates how the faculty member created shining moments for fostering student development by challenging the current structures and norms of higher
education and giving students the power to dictate the direction of the project, as they would in professional practice. Through this example, I aim to raise awareness of the role of ruling relations in the classroom and empower faculty to establish opportunities for students to practice and develop as cross-disciplinary professionals.

5.2 Introduction

One goal of including cross-disciplinary projects in the undergraduate curriculum is to expose undergraduate students to an environment that mimics professional practice, which regularly involves collaboration across multiple disciplines. By working in this environment, students learn how to navigate different viewpoints and develop as effective team members while working together to find a solution to a problem. In this paper, cross-disciplinary refers to: “a collection of practices associated with thinking and working across disciplinary perspectives” (R. S. Adams & Forin, 2014, p. 103). While cross-disciplinary student experiences are designed to mimic teamwork in professional practice, elements of higher education, such as social norms and power structures remain. These higher education structures and norms influence the actions of both students and faculty as they navigate demands and adhere to reward systems. This paper examines how these norms dictate interactions between students and faculty during cross-disciplinary projects and how these interactions can foster or inhibit student development as effective cross-disciplinary team members.

Smith (1987) coined the phrase “ruling relations” to describe how power structures and
social norms dictate individual’s actions in a specific setting. These power structures are inherent in social systems and perpetuated through written documents (i.e. laws, contracts, syllabi) and through the continuation of social norms (i.e. the tenure and promotion process, or the classroom dynamic where instructors stand at the front of the room) (Pawley & Phillips, 2014). These ruling relations dictate the structure of and interactions within many social institutions, including higher education. These structures and norms often go unnoticed but can have a significant influence on the thoughts and actions of both students and faculty and subsequently, on student development as cross-disciplinary team members. This interplay is especially important to consider when attempting to develop or implement a student experience that ultimately asks students to explore a paradigm that may be new to them and approach a problem as professionals, such as during a cross-disciplinary project.

In a typical higher education classroom, students sit at the back of the room facing a chalkboard, whiteboard, or more recently, a projector screen. The instructor for that course stands at the front of the room and presents information that students are expected to remember and understand. Instructors assign homework, administer exams to test students’ understanding of concepts and ultimately assign grades to each student in the class based on his or her individual performance. Students are accustomed to this hierarchical structure where they look to the instructor for both knowledge and approval, in the form of a grade. Cross-disciplinary projects can disrupt this structure by asking students to work as a team on an open-ended project with no clear right or wrong answer.
Students are asked to disregard their conventional motivation for a good individual grade and trust their teammates, from completely different disciplines, to contribute their unique skills and training to the project. For a student, being an effective cross-disciplinary team member can mean applying a different paradigm from most of their other class experiences and collaborating without looking to the instructor for the “right” answer or being concerned with an individual grade.

These power structures and social norms within higher education also influence faculty members’ thought processes and actions in the classroom. Faculty in both tenure track and non-tenure track positions juggle multiple, often competing, expectations. These can include demonstrating a high level of productivity in areas such as research, teaching, and service. With these responsibilities in place, faculty are often discouraged from taking on additional projects that do not increase productivity in these required areas. If a faculty member chooses to make time for an additional project he or she is particularly passionate about, there is a continual awareness of the fact that his or her involvement could be professionally detrimental if the project is unsuccessful in achieving project goals. These standards of productivity placed on faculty pose a risk to the management style required to lead cross-disciplinary projects that prepare students for professional teamwork. These projects can require faculty to emphasize the professional skills of the team and allow the student team to develop and rely on their own expertise, which challenges the traditional norms faculty experience in many other areas of their work.
The goal of this paper is to draw attention to the structures of higher education that effect both faculty and students and present strategies that have the potential to foster student development as effective cross-disciplinary team members. These strategies, and their subsequent influence on students, are presented through a real-time account of observations during a cross-disciplinary student project. This real-time account will present one faculty member’s approach to leading a cross-disciplinary student project and identify shining moments and missed opportunities in influencing student development. An existing model of cross-disciplinary professional practice is used as an initial lens for identifying the stages of cross-disciplinary collaboration and examining the role of the faculty mentor in facilitating the progression of an undergraduate team through these stages. I explore the questions: How do structures and norms in higher education mold the actions and perceptions of faculty and students during a cross-disciplinary project? What faculty actions foster and prohibit student cross-disciplinary collaboration and growth? In answering these questions, this work will uncover the influence of ruling relations (Smith, 1987) on the implementation of cross-disciplinary project courses and empower faculty to develop and manage effective undergraduate cross-disciplinary teams.

5.3 Applying the Existing Cross-Disciplinary Framework to a Student Context

The current study applies an existing model for cross-disciplinary professional practice (R. Adams et al., 2010; R. S. Adams & Forin, 2014; R. S. Adams et al., 2009) as an initial lens for investigating a new context: undergraduate student teams. Adams and
Forin (2014) developed their model from retrospective interviews with professionals working in engineering contexts. The existing model, shown in Figure 5.1, includes four main categories of professional cross-disciplinary work: working together, intentional learning, strategic leadership, and challenging and transforming practice. Each category outlines an increasing level of intricacy in how professionals experience project complexity and disciplinary difference and how these experiences mold their actions and perceived identities (R. S. Adams & Forin, 2014).

My study operationalized each category of the model as a potential stage of undergraduate cross-disciplinary development during a project. Applying this existing model to an undergraduate student context requires understanding the interplay between the categories of the model and the norms and structures of undergraduate education.
The following sub-sections define each category of the model, with definitions coming directly from Adams and Forin (2014), and situate each category in the undergraduate student context.

5.3.1 Category 1: Working Together

The first category of the model represents one of the most basic aspects of cross-disciplinary teamwork: working together. Effectively working together means understanding each person’s different skillsets and approaches to problem solving while acknowledging that everyone has a specific role he or she can play (R. S. Adams & Forin, 2014). Furthermore, working together requires an awareness of disciplinary differences and the benefits of collaborating across those disciplines (R. S. Adams & Forin, 2014). When disciplinary differences are not realized and collaboration is not valued, the first category of cross-disciplinary teamwork may not be reached. Hsu’s (2011) work suggests a lower level model category (category 0) where team members do not appreciate the benefits of collaboration and instead choose to divide tasks and continue to work independently throughout the project.

Undergraduate education utilizes grades to evaluate a student’s understanding and ability related to a topic. Students have traditionally been indoctrinated into a culture where everyone must work for their own grade. This mindset encourages students to work on their own rather than rely on their teammates to follow through when the stakes are high. This can discourage students from appreciating collaboration, especially with students
from different majors, levels of training, and approaches to problem solving.

5.3.2 Category 2: Intentional Learning

The second category of Adams and Forin’s (2014) cross-disciplinary practice model is intentional learning. Reaching this stage of cross-disciplinary teamwork requires an individual to build on his or her appreciation for difference and collaboration and realize that effective teamwork requires learning new things (R. S. Adams & Forin, 2014). Intentional learning is often facilitated by challenges and/or failures experienced “on the job” (R. S. Adams & Forin, 2014, p. 114). The value of intentional learning is that it can benefit everyone, from the individual team member to society as a whole, since the subsequent project outcome will address multiple viewpoints (R. S. Adams & Forin, 2014).

Learning is central to education, and students often take on a learning mindset without much prompting, especially after enrolling in a graded project course like the one in this study. However, intentional learning during cross-disciplinary teamwork goes beyond general learning to include an understanding that scholarship beyond one’s discipline is essential for effective teamwork (R. S. Adams & Forin, 2014). In an undergraduate student context, an individual student’s motivation can lead to intentional learning, but the faculty mentor can also facilitate this approach through structured conversations, assignments, and by example.
5.3.3 Category 3: Strategic Leadership

The third category of the cross-disciplinary model moves from learning beyond a discipline to ensuring that cross-disciplinary work can take place. Strategic leadership involves individuals taking on leadership roles as facilitators, “communication specialists”, and “connectors” for the team (R. S. Adams & Forin, 2014, p. 116). These individuals lead the team by enhancing the cross-disciplinary environment so that a greater outcome is possible (R. S. Adams & Forin, 2014). The strategic leadership stage of cross-disciplinary practice involves building trust among the team and making connections between learned concepts (R. S. Adams & Forin, 2014).

Students often look to the faculty mentor for leadership both in the classroom and during an open-ended project. The faculty member generally provides the necessary problem information to students and communicates with outside stakeholders before proposing a direction to the student team. This typical classroom structure can deter students from making an effort to gather and connect information themselves. This dynamic can also encourage students’ trust to lie with the expertise of the faculty member rather than the developing expertise of their teammates.

5.3.4 Category 4: Challenging and Transforming Practice

Challenging and transforming practice is the final stage of cross-disciplinary collaboration identified in the existing model (R. S. Adams & Forin, 2014). At this stage individuals on the team start to question the common practices associated with individual
disciplines and see opportunities to transcend these disciplinary norms (R. S. Adams & Forin, 2014). In order to challenge and transform practice, an individual must come to understand differences among team members as resulting from backgrounds and experiences rather than strictly from one’s discipline (R. S. Adams & Forin, 2014).

Higher education commonly defines individuals, classes, and activities based on discipline. And a student’s academic major often serves as a source of identity during his or her time in higher education. These structures and norms likely do not encourage students to challenge and transform disciplinary practice, but may have the outcome of encouraging students to conform to a specific set knowledge, skills, and behaviors associated with a given discipline. Reaching this highest stage of cross-disciplinary understanding requires students to see cross-disciplinary differences as transcending disciplinary training to encompass interests, skills, and experiences unique to an individual.

5.4 Study Participants: Forming the Undergraduate Cross-Disciplinary Team

Traditional undergraduate engineering education does not expose students to cross-disciplinary projects until late in their academic training, if at all. Undergraduate research is one potential mechanism for facilitating cross-disciplinary undergraduate projects. My research study utilized an undergraduate research program, called Creative Inquiry, to provide a platform for initiating cross-disciplinary student projects.
The Creative Inquiry (CI) (https://www.clemson.edu/centers-institutes/watt/creative-inquiry) program encourages student engagement in hands-on, team-based projects in a wide range of fields. Students enroll in CI projects typically for 1 hour of elective credit. CI projects are mentored by a faculty member and internally funded by the university. With the support of the CI program, I worked with a faculty member in mechanical engineering, Dr. P, to implement a makerspace project. Students enrolled in the makerspace project worked together over the semester to develop a business plan for a new makerspace on campus. This makerspace would provide students with access to prototyping equipment, such as 3D printers, at little to no cost. A second faculty member with expertise in business and marketing, Dr. H, also assisted with the project.

The makerspace project was open to students from any major and any grade level. Twelve undergraduate students from freshmen to seniors enrolled in the semester-long project. The students majored in a variety of engineering disciplines as well as architecture, psychology, and economics. The student team met with the primary faculty mentor, Dr. P, on a weekly basis to share their progress from the previous week, gain feedback, and assign tasks for the following week. A sub-set of ten makerspace team members were participants in my research study.

5.5 Gaining Real-Time Insight into the Student Team

My research incorporates methodological approaches from ethnographic (Angrosino, 2007; Reeves et al., 2008; Singer, 2009) and case study (Stake, 1994; Yin, 2009)
traditions. My data collection process borrowed from elements of ethnographic research such as the use of real-time observations and involvement in a group or community over an extended period (Angrosino, 2007). I utilized this ethnographic approach to investigate student experiences and development over the course of the semester-long, cross-disciplinary makerspace project. As an ethnographic researcher, I took on a participant observer role on the makerspace project team (Angrosino, 2007; Van Note Chism et al., 2008). I observed 13, hour-long, weekly team meetings while sitting at the conference table with the rest of the student team. I also audio and video recorded these meetings as well as wrote field notes in my notebook totaling over 30 pages. I used the video recordings to identify individual speakers during each meeting to ensure the transcripts of each meeting were accurate. This real-time approach to data collection gave me a unique perspective for investigating how the team approached cross-disciplinary teamwork throughout the semester-long makerspace project.

In addition to my 13 hours of observations, I conducted 3 semi-structured interviews (Patton, 2015, Chapter 7; Van Note Chism et al., 2008, Chapter 4) with each of my 10 study participants and collected over 100 typed pages of written assignments (Patton, 2015, Chapter 6; Van Note Chism et al., 2008, Chapter 4) I called “progress reports”. Memos (Birks et al., 2008; Van Note Chism et al., 2008, Chapter 6; Watt, 2007) also served as a source of data for my study and generated around 40 hand-written and typed pages of data. Figure 5.2 illustrates the five data sources I collected and how they worked together to provide a deep, rich description of the student’s cross-disciplinary team
experiences.

Figure 5.2: Diagram of the five data types I collected during my study and the connection among these different sources

I worked closely with the primary faculty mentor for the makerspace project, Dr. P, throughout the semester. I assisted Dr. P with the project by overseeing the course management system (Blackboard) for the class and assigning progress reports. I often met informally with Dr. P after the makerspace team meetings to discuss the project and his team management style. After these meetings, I recorded my thoughts as memos in my notebook.

I remained entrenched in the data throughout my analysis of this large amount of textual data, ensuring that I stayed true to the lived experiences of my participants. I first organized my data into multiple tables allowing for later analysis based on data type or by individual case. My analysis approach followed an iterative process of reviewing
data, memoing, analyzing, writing, and then reviewing data again. Each cycle resulted in a deeper understanding of the experiences of my participants and how these experiences did or did not relate to the existing model.

I use an ethnographic narrative (Angrosino, 2007; J W Creswell, 2013; Van Maanen, 1988) to present the thick, rich detail of the faculty mentor’s role on the makerspace project. The main goal of this ethnographic narrative technique is to “draw the reader into a vicarious experience of the community in which the ethnographer has lived and interacted” (Angrosino, 2007, p. 16). The narrative utilizes thick, rich descriptions to re-tell the story of, or restory, participant’s experiences in a way that allows the reader to draw upon instances he or she finds salient (Ollerenshaw & Creswell, 2002). This type of ethnographic restorying may be unfamiliar to readers, but it serves as a vessel for transferring my research to other audiences. Angrosino (2007) points out that these restorying techniques “can reach and move people and teach them about the experiences of others in ways that would never be possible with the standard scientific monograph...” (p. 81). Through this restorying technique, a single case can speak to a broader context through the experiences of the reader.

The following ethnographic narrative illustrates the faculty mentor, Dr. P’s, involvement in each stage of cross-disciplinary student development through direct evidence from my observations, memos, interviews, and personal interactions. The account is written in first person, active voice from my point of view as the ethnographic researcher. This
approach is purposeful as it accurately represents my role as a participant observer and instrument in my study, co-constructing data with my participants. Singer (2009) explains, “The ethnographer is `the research instrument par excellence,’ an active participant in the research process” (p. 192). I use thick, rich descriptions to draw the reader into Dr. P’s experience to consider his role and the overarching role of ruling relations in the classroom environment.

5.6 Shining Moments and Missed Opportunities in Fostering Student Cross-Disciplinary Development

Dr. P designed the makerspace project to be structured differently than a typical undergraduate course. His objective was to make the project student-led, thereby empowering students to take ownership of the project and control its overall outcome. Structuring the makerspace project in this way required additional effort and considerations beyond a typical course. For example, Dr. P had to consciously structure opportunities for the team to brainstorm and discuss ideas while leaving the project plan flexible enough to accommodate the team’s suggested path forward. As a student-led project, Dr. P’s envisioned his role on the team as a “pack leader” who would monitor the team’s approach, make suggestions to help focus the team on broader objectives, provide opportunities for each student to engage with the project, and keep the team on a schedule.

Dr. P’s initial effort to implement the makerspace project as a truly student-led endeavor
is the first example of a shining moment in fostering student development. Dr. P had many conversations with me throughout the semester about the fine line between maintaining a peripheral role on the team and providing the necessary support for a novice, student team to succeed. He was continually aware of the balance between these roles and relied on his observations of the team dynamic to clue him in to where adjustments needed to be made. His efforts resulted in a team experience that positioned the students themselves at the forefront of the project.

At the first makerspace team meeting, students gathered around two tables pushed next to each other in a loft space over the shipping and receiving area of an engineering building on campus. Dr. P went over the syllabus for the course while I set up my audio and video equipment. Dr. P then explained the goals of the project, the learning objectives that Dr. P and I developed together, and the overall structure of a Creative Inquiry course. His introduction also exposed the students to the concept of cross-disciplinary teamwork through terminology in the syllabus and in Dr. P’s introduction to the course.

After completing his introduction to the course, Dr. P allowed time for me to introduce my study to the students. I introduced myself as a PhD student interested in studying cross-disciplinary teams and provided an overview of my research, which reiterated the cross-disciplinary nature of the project. I went over my study consent form with the students and asked if they had any questions. The students were hesitant to ask questions, but Dr. P filled the silence with questions that he expected might be of interest
to the students. This helped foster an environment where students saw questions as acceptable. Dr. P exposed the student team first hand to the idea that asking questions is a valuable way to approach a new topic or idea. Unknowingly, Dr. P may have also reinforced the typical power structure of an undergraduate course were students look to the faculty member for answers.

After I introduced my study, Dr. P asked the makerspace team to go around the table introducing themselves by giving their name, major, and their interest in the joining the makerspace project. Before letting the team discuss their ideas for the project, Dr. P asked, “So maybe the first thing would be to kinda talk about what teams you would like to form to create this business model.” This suggestion led the student team to discuss potential options for the number of sub-teams and goals of those sub-teams for the makerspace project. However, the team ultimately decided to delay splitting into sub teams until everyone had a clear, cohesive vision for the project.

Dr. P’s initial suggestion to split into sub-teams was likely motivated by his desire to ensure every student was able to engaged with and have a unique contribution to the project. However, this suggestion started the makerspace team down a path to divide-and-conquer rather than work together. Students’ busy course schedules often make them more concerned with finding an easy, quick solution rather than collaborating to find a solution that addresses broad objectives. Students are also accustomed to earning individual grades, and their motivation to receive a good individual grade can stand at
odds with true collaboration. Dr. P’s suggestion reinforced some of these social norms in education by encouraging students to divide rather than work together making it a missed opportunity for communicating the value of disciplinary difference and encouraging cross-disciplinary collaboration. The student team ultimately acted on Dr. P’s suggestion and split into two focused sub-teams, a business team and a technology team. Dr. P was ultimately aware of the need for continued collaboration among the sub-teams and later implemented a strategy to facilitate open communication within the student team.

At the second makerspace team meeting, two additional students, Annie and Ryan, joined the team. Dr. P started the meeting by addressing boilerplate issues such as enrollment in the course and access to the course management website, Blackboard. He then moved on to continue the conversation about how to divide and organize the team moving forward. I remember feeling uncomfortable with continuing on before allowing the new students to introduce themselves to the rest of the team or to catch Annie and Ryan up on the project. I documented my concern in my field notes, “We never really took time to bring them [the new students] up to speed on the project.” During the remainder of the meeting, Annie and Ryan remained quiet, and I noticed that they appeared to “zone out”. The team decided at the end of the meeting to divide into a “business” sub-team and a “technical” sub-team.

Without having a proper introduction to the project topic, Annie and Ryan were left to feel out their roles on the team for themselves. Despite not formally introducing Annie
and Ryan to the rest of the team or to the project in general, they each volunteered to join a sub-team that interested them. Ryan volunteered for the technical sub-team, “tech team” for short. The tech team would evaluate the makerspace equipment and report on each machine’s usability and ease of maintenance. Ryan had prior experience with 3D printers and was working to start a 3D printing student organization prior to joining the makerspace team. Annie, on the other hand, knew nothing about 3D printing or makerspaces. She chose to join the business sub-team, which would determine the market need for a makerspace on campus and suggest a mission for the space. During a later interview with me, Annie reflected on her feelings during her first meeting with the team, “I didn’t even have enough information about what we were talking about to have a question…”

Not providing Ryan and Annie with a proper introduction to the makerspace project and the other team members was a missed opportunity for fostering student development. Annie and Ryan did not formally meet their teammates or have a chance to introduce themselves and their discipline of study to the rest of the team making it difficult for them to imagine their potential roles on the project. However, Dr. P was experiencing the pressure of providing time for the team to develop a plan during the short period the team was together. In a one-hour meeting, Dr. P often struggled to address all of the topics that needed to be discussed. Having each of the ten students introduce themselves to each other once more during this second meeting would have taken up a large portion of the meeting time and delayed the team’s progress for another week. Dr. P was also
facing the realities of fluctuating enrollment in undergraduate courses. Students were regularly adding and dropping the makerspace project course throughout the first few weeks of the semester and the short class meeting time did not allow for formal introductions during each of these meetings.

Despite this potential set-back, Ryan was able to quickly find his niche with the technology sub-team, and he continued to excel as a strong team member throughout the project. His ability to adapt and grow into his role on a team was influenced by his initial interest in makerspaces and background in 3D printing. However, this missed opportunity perpetuated Annie’s feelings of being an outsider and a “slacker”. Annie had no prior exposure to the idea of a makerspace, and she subsequently struggled to understand where she fit in on the project team until about half-way through the semester.

Dr. P was a mechanical engineer by training and had little prior experience with developing a business plan. Before establishing the makerspace project, Dr. P reached out to a faculty member in the business department, Dr. H, to serve as a co-instructor and secondary faculty mentor for the project. Dr. H was unable to attend every team meeting, but he was invited to the fourth meeting to talk with the team about developing a “pitch deck” to present their business plan for a makerspace. By inviting Dr. H to the makerspace team meeting, Dr. P created an opportunity for the team, comprised mainly of engineering majors, to learn about business. However, this invitation also sent the message that when additional information is needed for the project, Dr. P will somehow
provide that information to the team. My conversations with Dr. P made it clear that he knew he did not have the expertise to assist the team with a business plan and saw this need as an opportunity to encourage cross-disciplinary collaboration with the business department. Dr. P did not intend to perpetuate the structures that encourage students to look to him as the instructor for necessary information. Dr. P himself was so accustomed to the typical classroom dynamic that he was unaware of the unintentional message he was sending his students by bringing Dr. H into a meeting.

During Dr. H’s business plan discussion with the makerspace team, he talked about project “stakeholders”. After observing Dr. H’s discussion, I became concerned that the team may not understand who stakeholders are or what their role is on a project. Incorporating stakeholders is one aspect of Adams and Forin’s (2014) cross-disciplinary framework, and I wanted to ensure students were aware of the function stakeholders can have in a project. I asked Dr. P to put together a short PowerPoint presentation on stakeholders for the next team meeting. Dr. P’s stakeholders presentation introduced stakeholders for the makerspace project and explained the importance of addressing stakeholder objectives and concerns in the final product of a project. This presentation was also yet another perpetuation of the notion that the instructor has the answers. At the time, I thought this would be a good way to foster student development by making sure they were informed and thereby encouraging the team to incorporate stakeholders into their decisions. However, as I look at this event under the lens of ruling relations, I see this as my missed opportunity to foster student development as effective cross-
disciplinary team members.

In fact, ruling relations can explain some of the comments students made about getting information from stakeholders during their interviews with me. One student was frustrated because he wanted more information from stakeholders as the team moved forward with the project. He revealed,

   I think I also kind of figured if there were answers to those questions, you [Dr. P and I] would have told us them…but I never really thought about asking if we could directly ask the stakeholders.

Despite my efforts to ensure students understood the role of stakeholders during a project, the students continued to act based on the norm of relying on the faculty member for information rather than seeking it for themselves.

Dr. P encouraged cross-disciplinary communication among team members by implementing a team meeting agenda to organize sub-team reports during weekly meetings. After Dr. P’s weekly report, the business and technology sub-teams would take turns giving a report of their progress from the previous week. These reports encouraged broad conversations and teammate feedback on activities. The implementation of sub-team reports counteracted the initial message Dr. P sent the team when he suggested they split into sub-teams. Dr. P’s implementation of sub-team reports was a shining moment for fostering student development. These reports conveyed to students that effective teamwork involves keeping each other informed and creating
opportunities for discussion among the entire team throughout a project rather than just coming together at the end to present a final product.

The team used some time during a meeting late in the semester to test some new equipment for the makerspace. A tech team member briefly introduced two new hand-held, 3D printer pens to the rest of the team. The team hoped that the pen’s simple design and ease of use would ultimately attract a wider range of students to the makerspace. Rather than have the tech team member show the team how the pen worked, Dr. P encouraged the non-engineering students to try out the pen and offer their feedback. Annie took advantage of this opportunity and went to the front of the room to inspect the new pen more closely. It was encouraging to see Annie engage with the 3D printer technology, especially considering her initial hesitance about contributing to the project. Dr. P creating this opportunity for non-engineering students to engage with the technology was the start of another shining moment for fostering student development. He encouraged the team to participate in cross-disciplinary communication and teach each other what they learned from using the pen. This gave the non-engineering students a voice in the technology conversation that had previously been dominated by the engineering students on the tech team.

The final objective of the makerspace project was to create a “pitch deck” presentation for project stakeholders. With this goal in mind, the team concentrated for the last half of the semester on making slides for their presentation, which did not require a cross-
disciplinary approach. Dr. P’s role transitioned from fostering cross-disciplinary
development to focusing the team on this final goal while engaging each member of the
team. Dr. P asked each student to volunteer to take the lead on a particular slide.
Students would then work on their slides individually and then present what they had
done to the rest of the team during the weekly meeting. Dr. P encouraged the team to
stay on task by relating student questions or discussion points back to the pitch deck
rather than letting the team toss around an idea like they had done at the beginning of the
semester. The students noticed Dr. P’s efforts to keep them on track. They described Dr.
P’s role as providing “focus” for the team and “keeping everyone on track”.

The makerspace team delivered their pitch deck presentation to project stakeholders at
the end of the semester. Throughout the semester, Dr. P ensured the project remained
primarily student-led. At the presentation, he briefly introduced the project and the team
to the audience and stepped aside to let the makerspace students take over. Each student
presented a slide in the pitch deck, and afterward the entire team contributed to
addressing audience’s questions. Dr. P’s effort to continually provide opportunities for
the students to take ownership of the project was a shining moment throughout the
makerspace course. By providing guidance from the sidelines, Dr. P gave the students
purpose and made it clear that they had control over the outcome of the project, just as
they would in a professional setting.
5.7 Discussion

During my observations of the team project, I was not aware of the social norms in higher education playing a role in the makerspace project. It was only after stepping back to analyze my observations that I was able to see evidence of ruling relations at work. This realization reinforces the idea that even if we are unaware of them, these power structures and social norms dictate faculty and student perceptions and actions. The narrative of Dr. P and the makerspace team illustrates how a faculty member with good intentions can encounter missed opportunities as ruling relations get in the way of student development.

Dr. P enjoys working with undergraduate students and continually seeks out opportunities to get involved. He typically leads multiple Creative Inquiry projects in a given semester in addition to his primary work load as a non-tenure track faculty member and instructor. He also regularly seeks out professional development opportunities in an effort to improve his teaching and mentoring practices. Yet despite his awareness of impactful approaches and concern for the best interest of his students, even Dr. P was unaware of the role ruling relations was playing during the makerspace project.

After constructing this narrative, I approached Dr. P to discuss the idea of missed opportunities and shining moments in his management of the makerspace team. During our conversation Dr. P revealed his thought process behind some of the decisions he made in managing the project. He described his management style as “transferring the power to the team.” In order to facilitate a truly student-led project, Dr. P saw the need to
let the team manage certain aspects of the teamwork process. For example, he referred to Annie and Ryan’s late enrollment in the project as a chance to transfer power to the team in integrating the new members. However, Dr. P was keenly aware that while this approach mimics professional team experiences, it requires close monitoring and potential intervention from the faculty member. He described his efforts as the “pack leader” to maintain a continual pulse on the dynamic of the team. In fact, Dr. P checked-in with students throughout the semester to see how they felt about the project and gain their feedback on the team dynamic. I remember overhearing a conversation between Annie and Dr. P after one of the team meetings. He talked with Annie about how things were going and offered some suggestions for how he saw her skill sets fitting into the project.

This example of introducing new students to the team and monitoring the team dynamic illustrates the complex nature of managing a student-led team in a way that fosters student development. And ruling relations work to make these experiences even more complex. Faculty can feel torn between their professional objective of showing tangible progress on a project and their desire to create a genuine team experience that allows students to develop as effective team members for professional practice. Dr. P’s shining moments in fostering student development are signified by instances where he challenged the current structures and norms of higher education. By raising an awareness of some of these overarching structures and norms, I hope to empower others to follow Dr. P’s
example in stretching these norms despite the complexities of balancing job responsibilities and student development.

5.8 Conclusion

The narrative of Dr. P’s role on the makerspace team illustrates shining moments and missed opportunities for encouraging student development. These shining moments guided the makerspace team through the first two stages of cross-disciplinary development: working together and intentional learning. By designing the project to be student-led while continuing to scaffold the project with adequate guidance, the makerspace students successfully met their objective while developing as cross-disciplinary team members along the way. Yet the structures and norms inherent in higher education got in the way of further development during the single-semester makerspace project.

This work uncovers some of the power structures and social norms at play in the classroom to inform and empower practitioners. Being aware of the ruling relations that govern student and faculty perceptions and actions is the first step toward challenging their role in higher education. Dr. P’s narrative illustrates how faculty can create shining moments that foster student development by deviating from these norms. His example illustrates the power faculty have to influence student development despite these ruling relations.
5.9 Recommendations for Practice

The four stage of cross-disciplinary development identified in this work can serve as a tool for planning the implementation of a project and evaluating student cross-disciplinary growth. Teams often begin a project in the working together stage of collaboration and progress to higher stages as they negotiate viewpoints and navigate project objectives. When planning a project, practitioners can operationalize the cross-disciplinary model as a timeline to guide student development. For example, it may be useful to ask, “At what point do I expect a leader to emerge on the team?” or “when do I want the team to rely on their own developing knowledge base rather than myself for content?” Outlining these milestones alongside project objectives can aid in the development of a focused agenda for the project, which can guide management of the team. These milestones in development can also serve as evaluation points to help determine whether or not the team is on track to reach both project goals as well as individual goals for professional growth. These assessments can take many forms, but short, written reflections, similar to the progress reports implemented in this work, have the potential to provide feedback on student progression through the stages outlined at the start of the project. Another approach could involve providing team members with a diagram of the cross-disciplinary model categories and asking them to identify where they believe they as individuals, or the team as a whole, currently are within the model’s stages. Having team members provide clear examples or evidence for their claims can help calibrate team member perceptions with those of the project mentor.
Chapter 6

Epilogue

6.1 Discussion

My research expands the current understanding of student cross-disciplinary work in a way that is accessible and usable by a broad audience. Through a combination of rigorous methods and accessible language, my work bridges the traditional gap between research and practice. Together researchers and practitioners can utilize this work to transform how cross-disciplinary student work is understood as well as developed and implemented within higher education.

By using real-time data collection to study an undergraduate cross-disciplinary team, my research shifts the current understanding of teamwork from team performance models and retrospective accounts of teamwork to a comprehension of individuals’ actions, perceptions, and motivations during cross-disciplinary collaboration. Through my qualitative research approach, I elicited thick, rich descriptions of student experiences. This qualitative approach coupled with real-time data collection moves my work beyond an understanding of practice and sheds light on the developmental process associated with student cross-disciplinary teamwork.

I detail my unique research approach as an audit trail in Chapter 2 of this dissertation. Through this audit trail, I present my research process as an example for novice
qualitative researchers and am transparent about the decisions I made and challenges I faced during my study. In this way, I expose the “messiness” of qualitative research and discuss my implementation of the qualifying qualitative research quality (Q^3) framework (Walther et al., 2013) to enhance the rigor of my work. The goal of this manuscript is to encourage other researchers to present the details of their “messy” research process to further the conversation around quality in qualitative research.

I use a case study approach to present my findings as three additional, stand-alone manuscripts. The cases I introduce exemplify an experience or a theme among multiple experiences, which speaks to the broader message of the manuscript. Each case uses a narrative approach to communicate my work to a broad audience and transfer it to different contexts. Van Note Chism, Douglas, and Hilson (2008) explain, “Although narrative analysis is focused on the experience of single individuals, when framed properly it can provide insights into larger issues that cut across multiple experiences” (p. 14). Each of these main chapters portrays a specific message based on the experiences of my participants and poses implications for both research and practice. The following table (Table 6.1) outlines the purpose of each paper as well as research questions, key findings, and implications.
Table 6.1: Overview of the research questions, key findings, and implications for each manuscript

<table>
<thead>
<tr>
<th>Manuscript Title</th>
<th>Research Question</th>
<th>Key Findings</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal: Expand the current understanding of student teamwork through a rich description of the salient roles students took on during a cross-disciplinary project.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Chapter 3. Narratives of Students’ Salient Roles and Trajectories Through Cross-Disciplinary Development | What team roles do undergraduate students find most salient during a cross-disciplinary team project? How do these roles reflect students’ approaches to cross-disciplinary teamwork? | - Students join cross-disciplinary projects at various stages of development and levels of desired team engagement  
- Personal factors, projects events, and stresses all shape the trajectory of student approaches to teamwork | **For Research:** Expands the existing model to a student context  
**For Practice:** Cases can inform the implementation of team projects through an awareness of variations in student approaches and motivating factors |
| **Goal: Provide a detailed account of how three students managed sub-team roles and engaged with cross-disciplinary difference.** |                                                                                   |                                                                                                                                                                                                             |                                                                                                |
| Chapter 4. The Game Day Project: How a Sub-team of Engineers Experienced Cross-Disciplinary Difference | How do students perceive and engage with cross-disciplinary difference? | - Genuine team experiences expose students to cross-disciplinary differences regardless of the team structure (number of different disciplines)  
- Three engineering students realized that cross-disciplinary difference transcends disciplinary training and is part of everyday teamwork | **For Research:** Shows the influence of team experiences outside the traditional cross-disciplinary team structure  
**For Practice:** Inform how practitioners choose to structure and incorporate real problems into cross-disciplinary experiences |
| **Goal: Examine the current structure of undergraduate education and the opportunities a faculty mentor has to foster student cross-disciplinary development.** |                                                                                   |                                                                                                                                                                                                             | **For Research:** Takes a broader approach to examining cross-disciplinary team research to uncover other factors at play  
**For Practitioners:** An awareness of ruling relations informs how team experiences can be structured and managed to foster student development |

Chapter 5. Power Structures and Social Norms in Higher Education: How “Ruling Relations” Govern Faculty Influence on Student Cross-Disciplinary Development  
How do the structures and norms of higher education mold the actions and perceptions of faculty and students during a cross-disciplinary project?  
What faculty actions foster and prohibit student cross-disciplinary collaboration and growth?  
- Structures and norms within higher education dictate the actions of both students and faculty during a project and can interfere with student development as professional team members  
- Faculty can create opportunities for student growth by developing student-lead projects that encourage students to deviate from these norms
Taken together, these papers address the broad topic of team member roles and approaches to cross-disciplinary teamwork in a student context. Chapter 3 compares and contrasts four students’ salient roles illuminating the breadth in initial student approaches as well as the unique trajectories of each student’s development over the course of a semester. Chapter 4 recounts the experience of three sub-team members as they negotiated team member roles during the Game Day project. And Chapter 5 considers the influence of ruling relations (Smith, 1987) in dictating the roles and interactions of students and faculty during team projects. While I collected a large amount of data from all ten members of the makerspace team, some experiences did not speak to the broader topic of team roles. And some students did not exhibit a salient role on the makerspace team, which manifested as participation on the makerspace team rather than engagement with their teammates.

The students’ experiences that are included in this work often overlap multiple chapters. Portions of Ryan’s experience, for example, are presented in each of the three main manuscripts. In addition, Annie and Mark also appear in multiple chapters of this dissertation. *This overlap speaks to the complex and interconnected nature of team experiences.* One event, such as a missed opportunity or a shining moment in faculty management, can cause a ripple effect that influences the trajectory of an individual over the course of the project, as was the case with Annie. *This overlap also speaks to the situational nature of cross-disciplinary work.* This work depicts Mark’s seemingly contradictory approaches to cross-disciplinary work in Chapter 3 and Chapter 4. In one
context, the pressure of an impending deadline for the makerspace team’s final presentation caused Mark to disengage from the team and seek out his own solution to the problem. Yet as a member of the tech team, Mark engaged with his teammates and trusted them to complete tasks despite being under a tight timeline for the Game Day project.

Beyond expanding the existing cross-disciplinary practice model to incorporate trajectories of student development, my work also perpetuates Adams’ broader definition of cross-disciplinary as a practice rather than a team structure (R. Adams, personal conversation, February 23, 2017). With this definition comes the realization that effective everyday teamwork hinges on an ability to engage with differences. These differences include disciplinary training but can also manifest as personal experiences, interests, and backgrounds. This broader definition can inform the focus of further research as well as the implementation of student team experiences. Cross-disciplinary research needs to concentrate on how difference is experienced and understood by team members. And practitioners must scaffold team projects to highlight the differences that are “already in the room” (R. Adams, personal conversation, February 23, 2017) regardless of the structure of the team. Defining cross-disciplinary work as an action rather than a structure can shift both research and practice to a consideration of difference and thereby further expand the understanding of cross-disciplinary collaboration in all contexts.
6.2 Opportunities for Future Work

My real-time methods elicited thick, rich descriptions of the makerspace student cross-disciplinary experiences over the course of a single semester. During this time, I witnessed individual students and well as the makerspace team as a whole move through the initial stages of cross-disciplinary development as defined by Adams and Forin’s (2014) existing model for cross-disciplinary professional practice. In a single semester, the majority of the team’s development took place in the first two stages: working together and intentional learning. This existing model was developed from accounts of professionals with years of cross-disciplinary collaboration experience; a stark contrast to the 14 week experience of this undergraduate student team. Over this comparatively short timeframe, my study only shows a snapshot of the student team’s initial progression through stages of the cross-disciplinary model. Figure 6.1 illustrates the makerspace team’s development over one semester and suggests the role of time and faculty support in achieving further development. Further progression through the stages of cross-disciplinary development would require additional time navigating the complexities of genuine collaboration as well as additional support from the faculty project mentor.
Figure 6.1: Diagram of the anticipated trajectory of student cross-disciplinary development past a single semester

Exploring student development over a longer timeframe is an interesting topic for future work. Some potential research questions include: Over an extended timeframe, do students achieve higher-level stages of development? What events influence this further development? Additional research could also draw upon a real-time approach to investigate other contexts and types of student projects, such as senior-level projects or projects with a final objective of creating a tangible artifact rather than a giving a presentation. These opportunities for future work can further expand the theoretical understanding of student team experiences and continue to shape the design and implementation of student projects in the classroom.
Appendices
Appendix A

My Research Study Consent Form with Accessible Language for Undergraduate Student Participants

Description of the Study and Your Part in It

As a PhD student in Engineering and Science Education at [Redacted], Rachel Anderson, is conducting a research study for her dissertation. The goals of the study are to identify the value of multidisciplinary, undergraduate research projects and to determine the level of professional development these experiences provide to students. In order to complete her study, Rachel needs access to a multidisciplinary team of undergraduates working on a current project. She would like to request your participation in her study.

Your participation will involve talking one-on-one with Rachel about your experience working with students from different disciplines on this CI project. You may be asked to talk with her between 2 and 5 times during the semester with each discussion lasting around 30 minutes. You will be asked in advance, whenever possible, to plan a time to meet with Rachel that works into your schedule. These talks will be audio recorded so that it is easier for Rachel to carry on a conversation with you without having to take notes on everything that is said. Part of Rachel’s data collection for her study will also include observing and audio/video recording group meetings during the semester. This process is important for her study as it allows her to better identify how team members work together during the project.

Team members will be assigned progress reports as a course requirement throughout the semester. These reports will be designed to take 15 minutes each, or less, to complete and will make up part of the course grade for this project. Rachel will use these reports as an additional source of data to help her understand how the team is working together on the project.

Risks and Discomforts

We do not know of any risks or discomforts to you in this research study.

Possible Benefits

While you may not experience any direct benefits from participating in this study, your feedback will be essential in identifying the benefits of multidisciplinary projects to undergraduate education. This study will allow you to share your experience as a
member of the maker space CI team and reflect on the skills and knowledge you may develop during your involvement on the team. Your input can inform the development of research experiences for undergraduates at and possibly at other institutions.

Protection of Privacy and Confidentiality

One-on-one talks with Rachel will be audio recorded so that she can later review what was said and have the conversation transcribed (turned from audio files into text files which are easier to analyze). The same process will take place for the recordings collected during team meetings. Video recordings from team meetings will only be used to help identify who is talking if this is unclear from the audio recordings alone. Once complete and accurate text renditions of team meetings have been created, the video files will be destroyed. Audio files will be destroyed after 3 years.

All text files (transcripts) from the project as well as collected progress reports will be “cleaned” of identifiable information. This means that your name, or any information that could be used to identify you, will not be associated with anything you say. A pseudonym will be assigned to your information so that Rachel can keep track of each person’s feedback, but no one else will know who said what. This pseudonym will be used whenever any findings are presented, including in Rachel’s dissertation. Any other names or identifiable information said during meetings, progress reports, and one-on-one talks will be anonymized also. Data will be stored on password-protected computers and will not be accessible by anyone other than Rachel and the other research team members (including her dissertation advisor and other committee members).

You are welcome to request a copy of the text files of which you are a contributor so that you can review the content of the documents. And you have the right to ask that specific information be changed, reworded, or be removed from the documents if you are uncomfortable with what is being reported.

Choosing to Be in the Study

You do not have to be in this study. You can still be a member of this CI team even if you choose not to be a part of Rachel’s study. You may choose to be part of the study, and you may decide to stop being in the study at any time. You will not be punished in any way if you decide not to be in the study or to stop taking part in the study. While Rachel may assist the CI mentors for this project with certain tasks throughout the semester, Rachel will not be part of the grading process. Your responses will not be graded nor will your decision regarding participation in this study affect your grade in any way.
**Contact Information**

Please contact Rachel Anderson with any questions or concerns you have regarding this study. Rachel will do everything possible to insure that you are completely comfortable with your part in the study. Rachel can be contacted at 440-382-1433 or rsundbe@g.clemson.edu.

If you have any questions or concerns about your rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-6460 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC’s toll-free number, 866-297-3071.

You will be given a copy of this form for your records.

Print Name: _____________________________________________

Signature: _____________________________________________
Appendix B

Sample Progress Report

Name: ____________________________ Due: __________

Progress Report #5

1. What role does trust play in a team project?
For example you may want to consider the following prompts to help you get started. You do not need to address all of the prompts, and you are welcome to include additional information beyond these prompts.
   - What does it mean to trust your teammates?
   - How would the team be different if there was no trust among team members?

2. How does a team develop trust?
For example:
   - Where does a level of trust among team members come from?
   - What actions, perceptions, and/or ideas lead do you believe can lead to trusting your teammates?

3. What is the current level of trust within this team? (Please be as specific as you can with respect to this team and your experiences on the team so far this semester.)
For example:
   - Do you trust your teammates (all of them or only some of them)? Why?
   - How has trust, or the lack of trust, influenced team actions and decisions so far?
   - How long did it take for this trust to develop?
     - Give a specific example of trust building that has happened among the team. (an event, an action, etc.)
   - Was it there all along?
   - Is the team still developing a level of trust?
References


