

## **A Real Report from the Trenches of a PhD Dissertation: Exploring the Inherent "Messiness" of Engineering Education Research Through an Audit Trail**

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Rachel Anderson recently earned her PhD in Engineering and Science Education from Clemson University. She is now the Assistant Coordinator for Clemson's Peer Assisted Learning program. Her research interests include cross-disciplinary teamwork, student development, and program assessment. Rachel received a M.S. in Mechanical Engineering from Clemson University and a B.S. in Physics from Baldwin-Wallace University.

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Julie P. Martin, Ph.D. is an associate professor of Engineering and Science Education at Clemson University. Her research agenda has focused on diversity and inclusion in engineering education. In particular, her NSF-funded CAREER work has investigated how social relations—operationalized as social capital—influence student academic decisions and success, especially for underrepresented and underserved students. Her CAREER research supports the need for continued proactive outreach, educational and support systems that have the potential to form "resource-rich" networks in which students receive information and resources in routine exchanges. Dr. Martin's current projects evolve her prior research on social and cultural capital away from a "normative" state that requires students to conform to the mainstream institution of engineering education. In addition to research, she is deeply interested in STEM education policy, and held a Science and Technology Policy Fellowship with the American Association for the Advancement of Science (AAAS) in 2012-2013. Dr. Martin has held a variety of national leadership positions during her decade-long involvement in ASEE and Women in Engineering ProActive Network (WEPAN). In 2016, she won the ASEE Educational Research and Methods Division Distinguished Service award.

# **A Real Report from the Trenches of a PhD Dissertation: Exploring the Inherent "Messiness" of Engineering Education Research Through an Audit Trail**

## **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.

## **Introduction**

Research publications show the clean, tidy version of the research process. Researchers write and edit their reports 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<sup>1-4</sup> in first person, active voice, following the American Psychological Association (APA) guidelines<sup>5</sup>. 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<sup>6,7</sup>, 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<sup>4,7,8</sup>. 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.

### **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<sup>9,10</sup>, 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 1.

Educational research generally follows one of three main methodological traditions: quantitative, qualitative, and mixed methods research<sup>9</sup>. Quantitative researchers often utilize surveys or other numerical measures to make inferences or identify correlations that are generalizable to a larger population<sup>9</sup>. Qualitative researchers collect *textual data* through interviews, observations, documents, or other methods in an effort to understand the lived experiences of individuals or groups<sup>9</sup>. A mixed methods approach combines qualitative and quantitative approaches in a specific way which best answers the desired research question(s)<sup>9,11</sup>. 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<sup>4,7,8</sup>. Qualitative research is therefore inherently interpretive<sup>6,7</sup>. The researcher must carefully make decisions to build the validity and reliability of the work and establish its trustworthiness<sup>6-8,12,13</sup> 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’<sup>6</sup> qualifying research quality framework. Another approach involves reflexively reflecting on preconceptions and potential biases brought to the study<sup>7,8,14</sup>.

Qualitative research takes into account the context surrounding a phenomenon or experience<sup>9,10</sup>. 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<sup>9,10</sup>. 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/context<sup>7,14</sup>. Qualitative findings include “thick, rich” descriptions of aspects that are salient for the participant(s)<sup>7,14</sup>. 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 <sup>7</sup>.

Table 1: Definitions of common terminology in qualitative research.

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

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 <sup>6,15,16</sup> 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 (Q<sup>3</sup>) framework specifies six categories of quality. The following categories and definitions were taken directly from Walther, Sochacka, and Kellam <sup>6</sup>:

- *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 Q<sup>3</sup> workshops, conferences, and in subsequent publications <sup>15,16</sup>.)
- *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 Q<sup>3</sup> framework recommends the use of each of these six category in two main stages of the study; “making the data” and “handling the data” <sup>6</sup>. 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<sup>3</sup> framework by including the appropriate category of quality in parenthesis at the end of the sentence.

### **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), also bolstered my interest in cross-disciplinary experiences. As the graduate research assistant for CI, I speak with faculty and students from different disciplines about their research projects and find their different research approaches and terminologies appealing. Many Creative Inquiry 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<sup>17</sup>. 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<sup>18-20</sup>. 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*<sup>20</sup>.

Adams and Forin<sup>20</sup> 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<sup>17</sup>. 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 research question: *In what ways do undergraduate students progress through the stages of cross-disciplinary development while working on a cross-disciplinary project?*

### **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.

### **Decisions Made in “Making the Data”**

My qualitative research study followed an emergent<sup>7</sup> design combining methodological traditions in ethnographic<sup>21-23</sup> and case study<sup>24-26</sup> research. My data collection process closely followed an ethnographic approach, where I was a “participant observer”<sup>10,21</sup> 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<sup>23</sup>. Following ethnographic and case study methodologies, I collected data from multiple sources (observations, interviews, and documents) and triangulated<sup>7,14</sup> 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 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 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 1 to my final implementation in Figure 2.

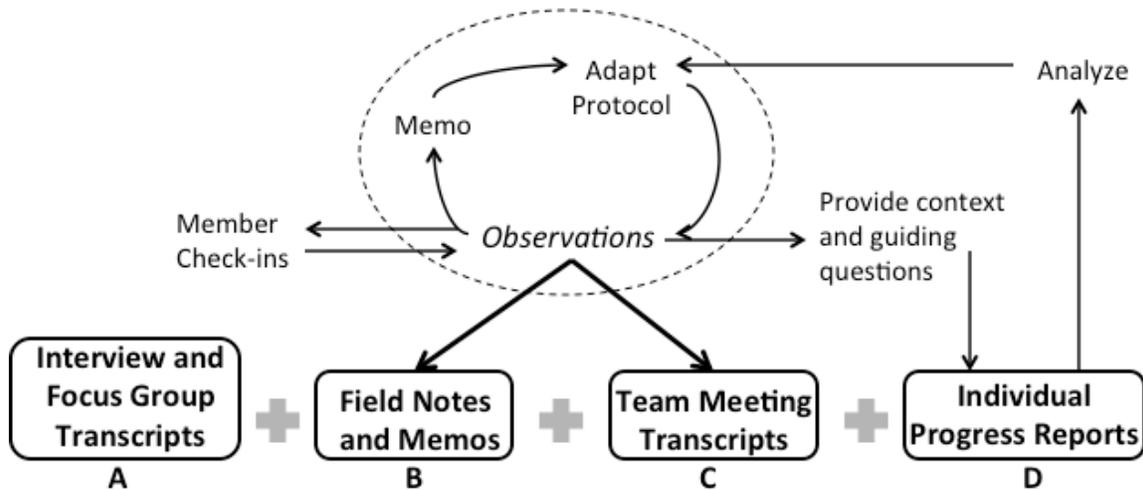


Figure 1: Illustration of my *initial* data collection plan including interviews, progress reports, observations, and a focus group.

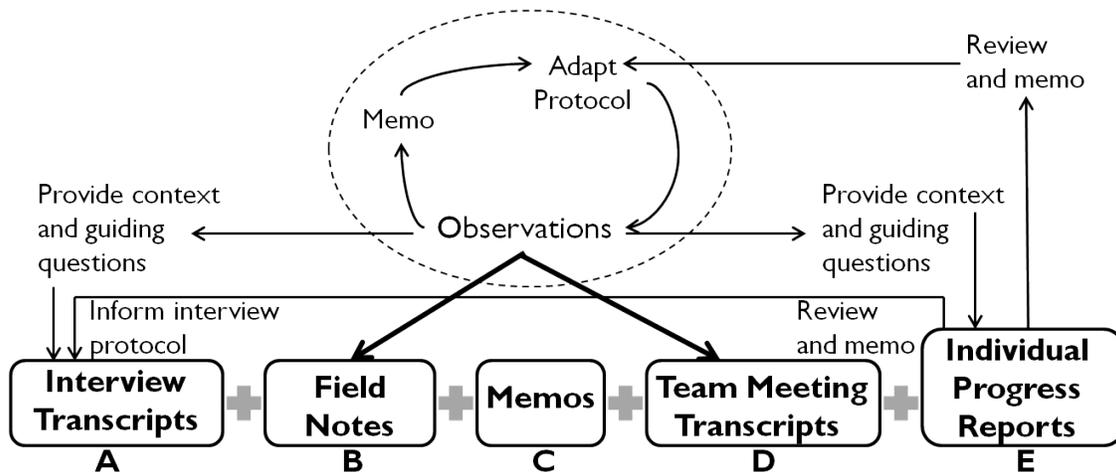


Figure 2: A representation of the *final* data collection plan that I carried out during my study.

### *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. 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.

My first opportunity to build rapport<sup>7,27</sup> 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*).

### *Interviews*

I conducted semi-structured interviews<sup>4,7,10</sup> (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<sup>7,27</sup> 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, data type B and D) and each student's progress reports (Figure 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<sup>6</sup> 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.

### *Observations*

In addition to multiple interviews with each student, I observed<sup>4,7,10</sup> weekly team project meetings throughout the semester (Figure 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<sup>20</sup> 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, 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 did not have access to on their own. 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.

### *Memos*

Memoing is a common research technique in qualitative research<sup>8,10,28</sup>. 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"<sup>29(p162)</sup>

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<sup>23</sup>. 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"<sup>23(p192)</sup>. 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 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.

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.

### *Progress Reports*

Students were required to write periodic reports (Figure 2, data type E) as part of their course grade associated with the makerspace project. These written documents <sup>7,10</sup> 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. 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 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*).

### **Decisions Made in "Handling the Data"**

After "making the data," Walther, Sochacka, and Kellam<sup>6</sup> 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.

#### *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 (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 the project management software (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*).

### *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 <sup>7</sup>.

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 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.

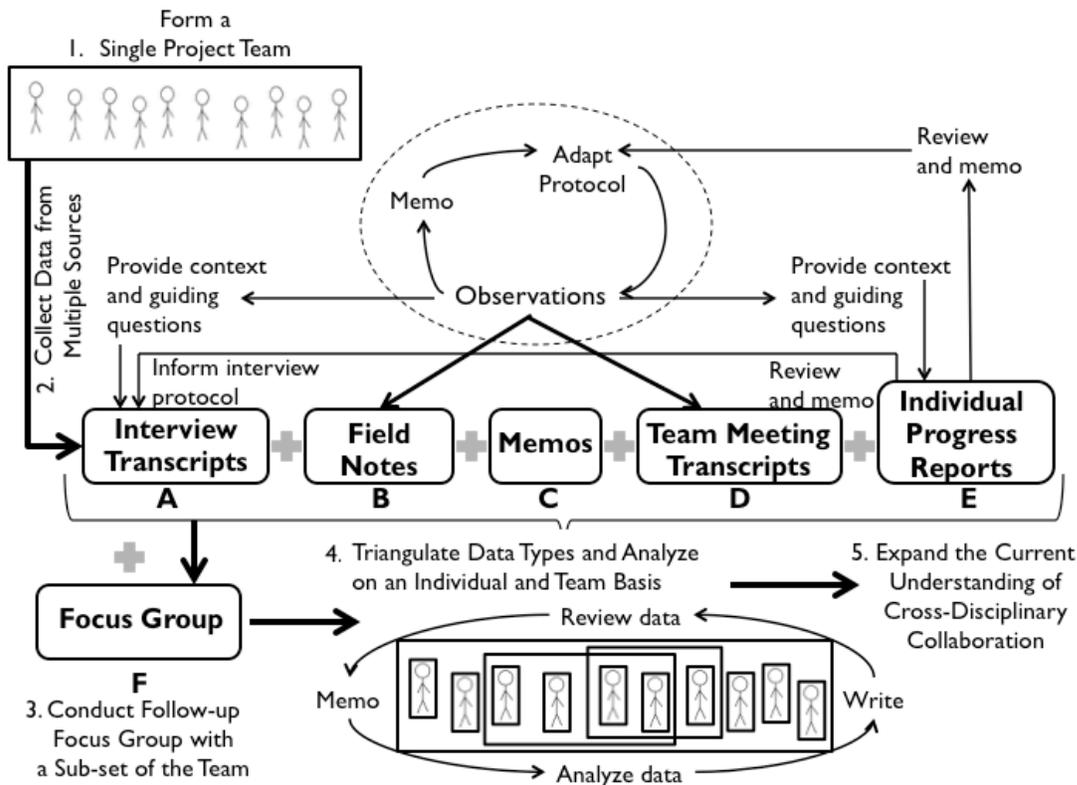


Figure 3: A diagram representing my overall data collection and analysis process with the final goal of expanding the current understanding of cross-disciplinary collaboration.

I decided to construct ethnographic narratives<sup>21,30,31</sup> 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<sup>32</sup>. I drew upon Nathan’s work and the work of other ethnographers such as Bucciarelli<sup>33</sup> to develop a plan to accurately and meaningfully present my findings. I focused on the restorying<sup>34</sup> 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<sup>4,10,14</sup> 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*).

#### *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 serves as a key data source for one chapter of my dissertation. I would have the thick, rich descriptions of these three students' cross-disciplinary development without this additional data source (*Procedural Validation, Communicative Validation*).

## **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 don't 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.

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