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Cross-disciplinary Teamwork During an Undergraduate Student Project: Results to Date

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Abstract

This paper presents results to date from a dissertation study on undergraduate student cross-disciplinary teamwork. The study focuses on a team of undergraduate students from technical and non-technical disciplines such as, engineering, management, economics, architecture, and psychology, working together on a cross-disciplinary project. The project was primarily student-led, and was facilitated by two faculty mentors in mechanical engineering and management. The team spent the semester working together to develop a business plan for a makerspace on campus that would allow students access to prototyping equipment, such as 3D printers, at little to no cost.

This study utilized a qualitative research approach, borrowing from ethnographic, narrative, and case study research. Data collection included: observations and audio/video recordings of weekly team meetings, interviews with student team members, and analysis of regular, written progress reports from each student. The real-time approach to data collection provides a rich understanding of how students develop as cross-disciplinary team members while working on a project. The case presented here illustrates one student's cross-disciplinary experience and how she developed from a shy, apprehensive team member to an interested and contributing member of a student project team.

Background

Engineering professional collaborations across disciplines are becoming increasingly frequent. These cross-disciplinary interactions require a unique set of skills necessary for effective teamwork. Cross-disciplinary teamwork skills are most often developed through *first-hand experience* working on diverse teams. Both engineers and non-engineers can benefit from problem solving together, as they can learn skills outside of their discipline and gain a broader perspective on how they approach projects.

In contrast to engineering professional practice, undergraduate engineering curricula typically only offer mono-disciplinary team experiences, such as those in engineering senior-design. These experiences are often insufficient for preparing students to work on cross-disciplinary teams as practicing engineers. Some universities and departments have incorporated cross-disciplinary team experiences into their degree programs, but others have found it difficult to add cross-disciplinary experiences to an already full curriculum.

Offering undergraduate research projects with a cross-disciplinary component is one approach to incorporating cross-disciplinary practice into the student experience without needing to adapt the curriculum. Clemson University has implemented this approach by encouraging cross-disciplinary, team-based research projects through the Creative Inquiry (CI) program. Creative Inquiry is an internally funded, campus-wide, undergraduate research program that promotes student-led, team-based, hands-on research projects for students at all academic levels. The CI

program fosters cross-disciplinary projects by providing flexibility for students of all majors to enroll in project teams.

This paper describes work to date from a qualitative dissertation study investigating cross-disciplinary teamwork through real-time observations of a cross-disciplinary Creative Inquiry project team. The study seeks to answer the research question: ***In what ways do undergraduate students progress through the stages of development as cross-disciplinary team members during a cross-disciplinary team project?***

In answering this research question, this study will illuminate how undergraduate students approach cross-disciplinary teamwork and what these experiences can teach undergraduates about being effective cross-disciplinary team members. This can inform the development and implementation of cross-disciplinary experiences in undergraduate education and help engineering educators better prepare students for cross-disciplinary collaborations within engineering professional practice.

Qualitative Research

This qualitative research paper follows the American Psychological Association (APA) guidelines for reporting qualitative data in that the paper is written in first person, active voice.[1] While readers trained in engineering or science research may find this awkward to read at first, it is an important aspect of qualitative research because the first person (i.e. the use of "I" or "we") acknowledges the researcher(s)' role in the study.[2] Likewise, this differs from laboratory research that typically is written in passive voice. The use of active voice is intended to communicate what or whom is performing the action,[1] thereby emphasizing the active role of the researcher in qualitative research. Hence, the rest of this paper is written in first person, active voice. The study is the first author's dissertation project, so "I" is used; the second author is the dissertation advisor, who contributed to the intellectual development of the project but did not perform the actual research tasks.

This particular qualitative research study borrows from ethnographic, narrative, and case study research. This paper will describe the first author's process for collecting multiple sources of evidence, an important element of all three research traditions, in order to answer the research question.[2–4] The paper will then present the experiences of a single participant as a narrative,[5] including both direct quotes from the participant as well as the researcher's perspective.[6] The inclusion of the researcher's perspective is important in qualitative research because the researcher serves as an "instrument" during the entire research process.[2(p16)] In their handbook on qualitative research, Chism, Douglas, and Hilson 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''.[2(p14)] Presenting a single case is a common practice in case study research;[3] in fact, some readers may be familiar with a seminal paper in the engineering education literature where Foor, Walden, and Trytten exemplified this method by presenting the case of a single student.[7] Here, I present the particular experiences of the unique case of Annie, the only psychology major working on a cross-disciplinary team with mostly engineering majors. Her story is unique and can inform how students from non-technical majors relate to and work with engineers. Investigating cross-disciplinary teamwork from

Annie's perspective can shape how researchers understand teamwork at the undergraduate level and how instructors might develop and teach a similar cross-disciplinary course.

Existing Knowledge on Teams and Teamwork

Researchers and scholars have studied teams and team performance for over four decades.[8–10] However, the array of terminology, such as multidisciplinary and interdisciplinary, makes it difficult to gain a cohesive understanding of research findings in the literature. I have chosen to use the term "cross-disciplinary" throughout this article and, more broadly, my dissertation study. I apply the definition proposed by Adams and colleagues as: "practices associated with thinking and working across different perspectives such as multidisciplinary, interdisciplinary, transdisciplinary".[11(p1)]

My study applies Adams and colleagues' [11,12] cross-disciplinary practice framework as a starting point for my research. These researchers took a phenomenographic approach to investigating individual, cross-disciplinary team experiences within professional settings. They developed a model of cross-disciplinary professional practice from retrospective interviews with individuals who were working in professional engineering contexts.[11,12] The model consists of four main categories of cross-disciplinary practice and provides descriptions of each category. Table 1 details each classification of the cross-disciplinary practice model.

My study aims to expand the existing cross-disciplinary framework by operationalizing this model in a unique way. I move beyond the professional context to explore how the existing model applies to *undergraduate* cross-disciplinary experiences. Using data from a retrospective pilot study with recent graduates who previously participated in a cross-disciplinary student project[13] helped me to confirm that elements of the cross-disciplinary practice model were applicable in the undergraduate context. The pilot study also confirmed that collecting data *during* the team process would provide a deeper, more detailed picture of how undergraduates develop as cross-disciplinary team members compared to a retrospective approach. Therefore, my dissertation work uses a real-time approach to collecting data—that is, I utilized weekly observations of the team, regular, written reflections by each team member, and periodic individual interviews with student team members throughout one semester. This real-time method, common in ethnographic research,[4] provides a rich understanding of how undergraduate students develop as cross-disciplinary team members during a cross-disciplinary team project.

Table 1: Categories and attributes of Adams and colleagues'[11,12] cross-disciplinary practice model.

Working Together

1. Asking questions, challenging assumptions, and listening for understanding.
2. Being comfortable with asking for information that might seem obvious.
3. Knowing what you and others contribute.
4. Recognizing differences in what people know and how they communicate.
5. The need to take personal responsibility to be an effective collaborator.

Intentional Learning

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

Strategic Leadership

1. Making or enabling conceptual connections.
2. Building allegiances and trust.
3. Facilitating systems oriented strategies or frameworks that leverage diverse perspectives.

Challenging and Transforming Practice

1. Critically challenging disciplinary practice and the ways conflict can be transformative.
2. Integrating stakeholders as collaborators.
3. Attuning to the human aspect of complex systems.
4. Advocating perspectives by taking into account the broader context.
5. Embracing cross-disciplinarity as every day practice.

The Cross-Disciplinary Project Team

The participants in this study were members of a single Creative Inquiry team working to develop a business plan for a makerspace on campus. A makerspace would allow students access to prototyping equipment, such as 3D printers, at minimal to no cost. Throughout the semester, students working on the project tested 3D printer equipment, collected data on the market need for a makerspace on campus, and developed a "pitch" of their business plan. The team then presented their pitch to project stakeholders at the end of the semester. The project included students from technical and non-technical disciplines representing seven different academic majors, including engineering, architecture, psychology, management, economics, and parks, recreation, and tourism management. The team was also diverse in grade level as it included students from freshman to senior year. The sample for my study was a subset of ten of

these students, ranging from freshman to seniors, who were active participants in the project throughout the semester.

A Real-Time Approach to Data Collection

The study borrows from elements of multiple qualitative methods including ethnographic, narrative, and case study research. I collected data over the course of one semester; this involved taking field notes of my first-hand observations, conducting individual interviews with team members, and analyzing documents written by participants. Figure 1 below illustrates the multiple data types collected during the investigation and explains how each data source/type interplayed with the others to provide a detailed, real-time picture of each student's experience working on a cross-disciplinary team. Observations, interviews, and document analysis yielded a corpus of data made up of four main data types: interview transcripts (type A in Figure 1), field notes and memos (type B), team meeting transcripts (type C), and individual progress reports (type D).

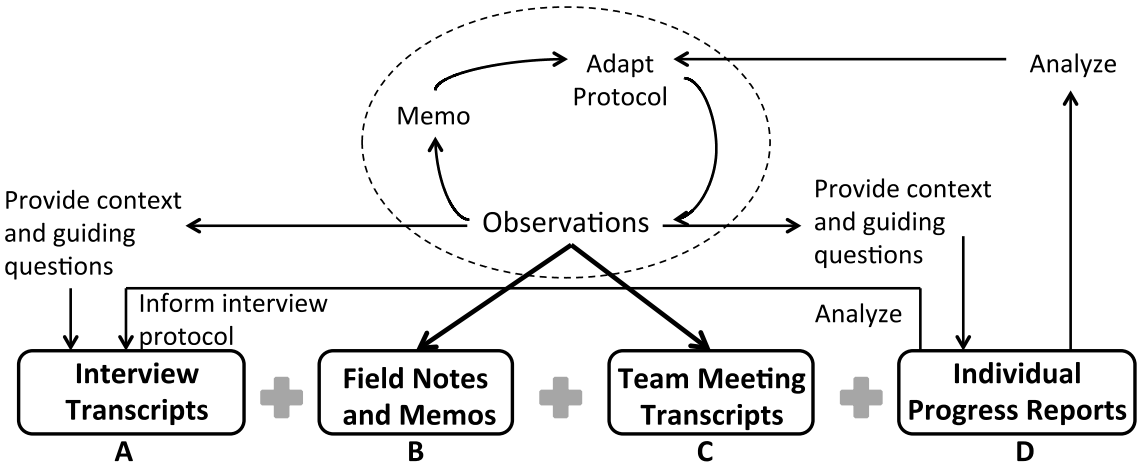

Figure 1: Progression of data collection and the data types generated by my study

This combination of data sources and types provided rich data on how these students approached the project and how this experience helped them learn about being an effective cross-disciplinary team member.

Interview Transcripts (see A above): I conducted individual interviews with each participant three times during the semester. I referred to these semi-structured interviews as "informal meetings." Categories and descriptions from the existing cross-disciplinary practice model informed interview topics. The specific protocols for each participant's interview were based on observations during weekly team meetings in combination with each student's responses to progress report questions.

Field Notes and Memos (B), Team Meeting Transcripts (C): I observed, as well as audio and video recorded, weekly project team meetings where students on the team updated each other on work accomplished over the past week and discussed objectives for the upcoming week. During these meetings, the faculty mentor for the project provided feedback when necessary but allowed the project to remain largely student led. I used video recordings to identify individual speakers on the audio for each meeting. While I was initially unsure of the influence the camera might have on students' behaviors, students revealed in later interviews that after the second or third meeting, they forgot the equipment was there. I sat during the team meetings with the rest of the team and observed. I refrained from contributing to the conversation unless the team requested resources for their project to which I had access, such as mailing lists or potential contacts. These observations informed the context and questions for progress reports and future interviews with team members.

Individual Progress Reports (D): Students enrolled in the project completed written, individual progress reports as part of their grade. Reports were designed to take no more than fifteen minutes to complete and addressed topics related to teamwork, working with people from different disciplines, and individual contributions to the project. These reports proved to be a key resource that informed both my observation and interview protocols. They allowed me to gain individual perspectives on topics related to my research without having to conduct additional interviews with participants.

My Analysis of the Findings – Results to Date

The real-time nature of my data collection allowed me to watch the development of both the team and the individual students throughout the semester-long project. I saw evidence of the existing cross-disciplinary practice framework at both the team and individual levels. I am still in the process of analyzing the data and have chosen to share a single case that illustrates one student's unique experience as the only psychology major working on a team of mostly engineering students. I gave this student the pseudonym Annie. My goal in presenting Annie's case (and the general goal of case study research) is to share the experience of a participant, telling her story in a way that provides insight for the reader to relate to.[14] The following narrative of Annie's cross-disciplinary team involvement illustrates the unique experiences of a student who enrolled in the project to earn credits toward graduation and initially had no personal interest in the project or prior knowledge of the project topic. Students with these characteristics can often be difficult to motivate and engage in projects, but Annie's case illustrates how a cross-disciplinary, student-led project sparked her interest and allowed her to apply her disciplinary skills in a context very much outside her major. By the end of the semester, she felt like a contributing member of the team and voiced an appreciation for the different ways she and her teammates approached the project. Understanding cross-disciplinary teamwork from Annie's perspective can shape how researchers understand teamwork at the undergraduate level and how instructors might develop and teach a similar cross-disciplinary course.

My process for analyzing the corpus of data collected during the study began with having the interview recordings professionally transcribed. I then read through each of the participant's progress reports and tabulated the data, including direct quotes, into individual spreadsheets for

each student. My process for analyzing Annie's interview transcripts began with re-familiarizing myself with the data by listening to each of her three interview recordings and checking the transcripts for errors. During this pass through the transcripts, I also highlighted relevant text and made notes in the margins. I then began writing a chronological account of Annie's experience in the cross-disciplinary team project while including information and direct quotes from her interviews, her progress reports, and my observations. After writing my account of her experience, I took another pass through each of the interview transcripts to ensure I fully understood Annie's experience.

Annie's Cross-Disciplinary Team Experience

Annie is a senior psychology major who joined the team after the start of the project (following the first team meeting). With just one semester until her graduation, she explained that she signed up for the course because she "just had hours [she] needed to fill." Furthermore, her selection of this particular project, she later admitted, was "accidental." That is, a friend had told her about three open project listings that Annie thought were all the same. After signing up for the makerspace project, she later found out that the listings were in fact for three different projects.

Despite the fact that Annie admittedly did not understand what she was getting into, she did say that her goal for the semester was to "challenge" herself and "find out what [she is] interested in doing for the rest of [her] life." Annie's statements about challenging herself and just wanting to fill hours for graduation seem somewhat contradictory. However, Annie acknowledged in her first progress report that this project, coupled with her other courses that semester, brought her "out of [her] major comfort zone," particularly because she was the only psychology major on the team. She described being "excited to see what [she] learned." Annie also talked about wanting to start her own business and hoped that this project would go over some of the fundamentals of building a customer base and creating a functional space for customers to use.

Annie's first meeting with the team was the second time the team had met together that semester. I observed that Annie was silent during the team discussion, and later asked her in an interview what she was thinking during that meeting. She recalled being "terrified" on the first day, and described her thoughts about being different from most of the team members: "These people are all engineering majors, and, oh, I'm a psychology major." She went on to explain, "I didn't even have enough information about what we were talking about to have a question..." Annie recalled thinking to herself "… I could waste everybody's time by asking what a makerspace is… or I could listen and try to figure it out and then look it up later…"

Annie mentioned being worried she would not be able to make a substantial contribution to the team because she had no prior knowledge of makerspaces or 3D printers. She also worried that her teammates would think less of her if she could not contribute to the project. In fact, Annie continued to compare herself to other students on the team during our one-on-one interviews throughout the semester. She often portrayed herself in a negative light when comparing herself to other members of the team. She talked about feeling like a "slacker" compared to her teammates. She decided to "stick with it" because the project "seemed cool," although when a teammate expressed excitement about getting a 3D printer for Christmas, she admitted that she wondered if she had made the right decision in joining the team.

Annie remained quiet and somewhat reserved during the next few team meetings. However, her level of involvement during the meetings, and on the project in general, changed drastically when the team decided to conduct a survey of the student body in order to determine the market need for a student makerspace. Part way through the semester, the team brainstormed about different ways to send out a survey and how to ensure they would get responses. In her mid-semester interview, Annie recalled this meeting clearly, saying:

> "I knew I don't really do much for the group, but when they said surveys, I was like, 'Hello, let me help you! Been there, done that.' So I spoke up because, like I said, if it is my forte; if it is something I'm good at, I'm not going to just sit back and be twiddling my thumbs and be like, 'Nah, I'm a senior. You guys do it.'"

She went on to explain,

> "I knew that their [the other team members'] brains probably didn't work the same way that mine did when it came to that [surveys], so I was like, 'I'm going to speak up because this is a people interaction thing …'"

Contributing to the development and distribution of the survey was a turning point not only in Annie's role in the team project, but also in how she perceived herself as a member of the team. She wrote in a progress report,

> "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. From my first meeting being *so* confused about what we were talking about, I feel that I have a better understanding and am more interested in what we are working towards."

The terminology she used to describe herself and her role on the team changed from "slacker" to "a nice outside mind" able to bring a new perspective to the project. There was also a change in how Annie thought about the project and what she would be able to take away from it. She enjoyed seeing how each of her teammates "work so differently" than her. She reflected,

> "…it's definitely been cool to learn about people. I think it's going to be a major takeaway. It [the team project] is definitely more about how people interact than it is about 3D printers, because I still don't really know anything about them [3D printers]."

Aspects of Cross-Disciplinary Practice in Annie's Case

On an individual level, each aspect of the cross-disciplinary practice model resonated differently with each participant, based on his or her personal experience. Annie's experience exemplifies specific aspects of the existing model, the most interesting of which is "being comfortable with asking for information that might seem obvious" (*working together*). Annie initially refrained from asking questions during her first team meeting even though she admittedly did not know

what others were talking about. However, she believed that she could easily look up some of the terms she did not know on her own rather than having to interrupt the meeting.

Some additional aspects of the existing model that were particularly salient for Annie include:

- Recognizing differences in what people know and how they communicate (*working together*) – Annie regularly talked during our one-on-one interviews about her perceptions of her teammates and the nuances she noticed about how each of them acted and communicated. She believed that she noticed these differences because of her psychology background and interest in how people think.

- Making or enabling conceptual connections (*strategic leadership*) – Through working on this project, Annie realized that developing a makerspace on campus involved a lot of marketing and sharing the idea of a makerspace with others which she recognized was "similar to a lot of things" in her psychology education.

- Embracing cross-disciplinarity as every day practice (*challenging and transforming practice*) – Early on, Annie seemed to understand and appreciate the benefits of networking with different people. She talked in her first progress report about "creating a wide network" during her professional career so that she could "pick people's brains" and learn from "wiser, more experienced" individuals.

Preliminary Findings of Cross-Disciplinary Practice at the Team Level

During data collection and preliminary analysis, I noticed instances of the cross-disciplinary practice model[11,12] being exemplified by this undergraduate student team. Many of these instances have fallen under the "working together" category of the existing model (see Table 1). During the first few meetings, team members asked questions of each other and about the project topic (*working together*). Three of the team members spent the last twenty minutes of one of the meetings purposefully educating their teammates on 3D printer technology (*intentional learning*). Students on the team were also able to explain, both in interviews and assigned progress reports, what they and their teammates contributed to the project (*working together*). In another progress report, I asked team members to discuss the role of trust on a team and, more specifically, how trust had come into play on this project. Team members had differing opinions as to the level of trust among members of the team, but all believed that trust was an important component of a successful team project (*strategic leadership*).

Based on my preliminary analysis, it is clear that many aspects of Adams and colleagues'[11,12] cross-disciplinary practice model—originally developed from retrospective interviews with professionals—can be applied to *undergraduate* cross-disciplinary teams. In addition, there is evidence that a model for cross-disciplinary practice at the undergraduate student level would require some adaptations and/or expansions to the current model. The difference in the level of disciplinary training between students and professionals as well as the role of the instructor in a student context provide a unique dynamic that is not illustrated by the current model for professional practice. The applicability of Adams and colleagues' existing model and the potential to expand to an undergraduate cross-disciplinary context will become more clear as analysis continues.

This is just the beginning – data analysis will continue during spring and summer of 2016.

Unique Aspects Associated with the Undergraduate Context

Studying an undergraduate team did pose some research challenges that seemed to be unique to the student context. First, the undergraduate student project was more dynamic in terms of team composition over time than most professional team projects. Some students on the team dropped the project part way through the semester, while other students did not regularly attend team meetings, despite these meetings being classified as mandatory in the syllabus. This flux of active team members made data collection challenging as the study sample was not constant, as is generally the case. Second, there was a complex interplay among the individual student ideas and those proposed by the faculty mentor. This interplay will become more important as I continue my data analysis. I suspect that some aspects of Adams and colleagues'[11,12] cross-disciplinary practice model may be fulfilled by the faculty mentor rather than the students on the team.

Conclusion and Future Work

Through my real-time approach to data collection, I have been able to capture rich descriptions of student experiences while they work on a cross-disciplinary team project. This approach provided the opportunity to watch the individual students, and the team as a whole, develop over the course of the project rather that relying on retrospective reports as has been common in past cross-disciplinary team research. The unique case of Annie illustrates how one of the individuals on the team experienced cross-disciplinary teamwork and points to the applicability of various aspects of Adams and colleagues' cross-disciplinary teamwork model in this context. In addition, analysis to date provides some "hints" about the potential to expand the existing cross-disciplinary framework to include additional or alternate aspects related to the undergraduate student context.

The next steps for my dissertation study will include incorporating my field notes from team meeting observations into Annie's case. I will also expand and continue my data pass system as I continue to analyze data for all ten study participants as well as for the student team as a whole.

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