AC 2011-2260: OBSERVATION OF CROSS-DISCIPLINARY PRACTICES IN A DESIGN LEARNING CONTEXT

Ming-Chien Hsu, Purdue University, West Lafayette

Ming-Chien Hsu is a doctoral students in the school of engineering education at Purdue University. She received her B.S. at NCTU, Taiwan and M.S. at Purdue, both in electrical engineering. Ming-Chien's research focus is on design learning in the cross-disciplinary context.

Observation of Cross-Disciplinary Practice in a Design Learning Context Using a Phenomenographic Framework

Introduction

Cross-disciplinary practice, "a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to deal with adequately by a single discipline or profession"[1], is required in many engineering problems in order to bring together diverse perspectives and expertise. ABET has listed functioning on multidisciplinary teams as a student outcome [2].

Cross-disciplinarity is a complex concept. For many decades, scholars have been making efforts to find constructs that characterize the topology of cross-disciplinary practice. For example, it has been characterized by the degree of conceptual integration: multidisciplinary and interdisciplinary [3]. Lattuca characterized it regarding the questions that motivated the scholarship: informed disciplinarity, synthetic interdisciplinarity, transdisciplinarity, and conceptual interdsiciplinarity [4]. For the purpose of this paper, we use the term "cross-disciplinary" as an all-encompassing term for working across different perspectives.

There have been efforts to articulate the outcomes of cross-disciplinary learning from the cognitive perspective. For example, prior research argued that some of the cognitive outcomes included cognitive flexibility, creativity and insight, and epistemology development[5] . Lattuca explained the benefits of cross-disciplinarily practice with learning theories such as engaging students' prior knowledge and experience, encouraging effective thinking, and motivating students to learn [6]. All of the above outcomes are complex constructs that might not be readily applicable to the learning context. Instead, Boix Mansilla and Duraising built on a performance view of understanding and constructed a framework to assess students' cross-disciplinary work [7]. The performance framework, while powerful, is more suitable for giving summative feedback, and not during the process of creating and learning. This poses hurdles for facilitating the participatory or situated aspect of learning which is often described as "intellectual integration leveraged socially [8, 9]". The participatory or situated perspective is particularly important to engineering education cross-disciplinary learning often is put into a design team context.

The need to better understand the process of teamwork in the engineering learning context is also articulated by other researchers. Fruchter and Emery proposed classification of cross-disciplinary learning assessment regarding distance from understanding other disciplines (islands of knowledge, awareness, appreciation, and understanding)[10]. Schaffer proposed another model of team learning (identification, formation, adaption) [11].

While the above research provides insight into the different stages of cross-disciplinary learning and team formation, there is a lack of "intentionality" in terms of pedagogy and process in the models. Intentional pedagogical design is important since engineers have been described as not appreciating other perspectives. Specifically, engineers tend to divide work among expert and work separately [12]. Also, Klein believed that "engineering do not engage in critical reflection of problem choice, the epistemology of the disciplines being used, or the logic of disciplinary structures" [13].There is a need to further explore the possible learning models, designed learning process, and observable outcomes in the cross-disciplinary engineering design context with the ultimate goal of being able to facilitate cross-disciplinary learning. In this paper, we ask a research question of:

- How can students' cross-disciplinary practice be observed and described?

This question is one of the many essential steps to allow answering of the overarching question of articulating cross-disciplinary learning outcomes. We would like to be able to:

- recognize team members' current cross-disciplinary behavior, and to
- identify opportunities for helping students develop more sophisticated cross-disciplinary practice skills.

Methodology

Choosing a Framework

To be able to start to answer the question, we have decided to take the approach of identifying frameworks that looks at the developmental pictures of cross-disciplinary learning. The criterion is that the framework should provide languages for us to start describing student practices. We chose to adopt the framework of critical variations in cross-disciplinary practice. The framework was developed by Adams, Forin, & Srinvasan [14] using a phenomenographical method focusing on the variations of how individual practitioners experienced cross-disciplinary practice in engineering settings. The framework included four categories of variations that represent a developmental perspective:

Category 1: working together,

Category 2: intentional learning,

Category 3: strategic leadership, and

Category 4: challenge and transform practice.

Although the framework was developed around individual experiences, it provided languages and a structure upon which we are able to capture instances of cross-disciplinary practice during team process.

Research Setting

We observed design teams in a service learning program in a Midwestern public university over the course of a semester during the weekly meeting time allocated by the program. (Outside of the meeting time, the team members met in small sub-groups a couple of times). The service learning program collaborated with stakeholders in the community to provide real projects for students majoring in engineering and also students outside of engineering. Each project team discusses the major they feel suitable for the current state of the project each semester, and that information is listed on the website. Students wishing to participate but unsure of where their expertise lies can use the website as a resource when making team selection.

In each big project, there could be several sub-teams that work on different aspects of the project. The structure of the program lets students sign up for the team they would like to be in every semester, so, even though some projects are several semesters long, the team members change from semester to semester.

In the beginning of the semester, the researcher, with the help of an administrator of the service learning program, identified five project teams with different “flavors” of cross-disciplinary collaboration: members from different engineering disciplines, from engineering and science disciplines, and from engineering and social science disciplines. We report in this paper observation of a project team that consists of engineering students and audiology students. Within the project team, we have chosen a specific sub-team to observe (The headphone team). The selection is based on the fact that this sub-team was newly formed at the start of observation. A professor in the audiology clinic at the university was supposed to be the “client” or “project partner” of this team, but all the other project ideas provided by the clinic had been claimed by other teams. Instead, the team had a meeting the first day of the semester and discussed project ideas. Based on the suggestion and research of the acoustic engineering student, the team decided on making a headphone limiter that would cap at a safe volume. They made the rationale based on the market research concluding there was no similar device on the market, and also on the concern of losing hearing due to constant use of headphones.

<u>Participants</u>

There were a total of 6 people in the headphone team. Besides 4 members from different engineering disciplines (acoustic engineering- senior[E-acoustic], biomedical engineering- senior [E-biomedical], electrical engineering- sophomore [E-electrical], and first-year engineering[E-first]), there were also 2 second-year graduate students from audiology([A-1] and [A-2]), which is considered a non-engineering discipline but essential for the context of the project. In the topology of interdisciplinary courses derived by Lattuca [4], the team fell into the category of “synthetic interdisciplinarity”, in which it was intended by the course organizer to combine theories, concepts, and methods of two disciplines; but the disciplines remain identifiable.

<u>Data Collection and Analysis</u>

We took an observer without participation stance. Observation notes were taken during each session concerning items such as how the team spent their meeting time, specific activities, interaction, and language used that might be relevant to the guiding framework. After the session, the observation notes were transcribed to a table with format shown in Table 1, which is adapted from Adam’s framework [14]. We are reporting our results based on the field notes. The other data collection methods were not pursued due to restriction of research protocols.

Table 1. Format in which observation notes were mapped into the framework adapted from Adam’s framework [14]

	1. Working together	2. Intentional Learning	3. Strategic Leadership	4. Challenge & transform practice
Thinking				
Doing				
Being				

Results

Using Adams' framework, the observation data were put under three categories of cross-disciplinary practice categories: thinking, doing, and being. The highlighted spaces in Table 2. indicate the team's cross-disciplinary practice during the semester. More detailed qualitative descriptions are given in the following sections.

Table 2. Highlighted spaces indicate the observed team's experience during the semester

	1. Working together	2. Intentional Learning	3. Strategic Leadership	4. Challenge & transform practice
Thinking				
Doing				
Being				

<u>Thinking</u>

The framework of critical variations in cross-disciplinary practice focused on the awareness of collaboration differences, situations, and goals in terms of cross-disciplinary thinking. We were not able to interview individual team members to probe their thinking due to the limitation of the data collection method. Instead, we focused on the big pattern of team collaboration to see how their process matched to the description of the framework.

Awareness of collaboration differences:

The team throughout the semester remained in the "working together" space (category 1) regarding their awareness of collaboration differences. In this space, the members realize the differences between them were disciplinary training, and that differences make collaboration complicated. As early as the third team meeting, the team decided on a "divide and conquer" paradigm. They decided to divide the team into three sub-teams: (i) hardware team that deals with the physical design of the headphone, consisting of the ECE sophomore and BME senior, 2) software team that is responsibility for programming the capping, with the acoustic engineering senior and the first-year engineering student, and 3) testing team, with the two audiology students. They divide the team based on disciplinary training. "So basically, you two [the audiology student] just do testing and calibration after we [the engineering students] have a prototype", said one student [E-biomedical] at the third meeting. This view was also shared by the audiology students [A-2]: "we are the paperwork, calibration type of people.. I think this format [of design documentation] is more for them [pointing to the engineers]".

Four weeks later, at their last meeting before mid-term review, the view is still prevalent when the team discussed who should work on design documents. "Since we [audiology students] don't really design anything, you guys [the engineering students] have to make it happen" [A-1].

Although it is not evident in the framework how cross-disciplinary practice affects design, we can see that the divide between engineering and audiology students based on the divide- and –conquer approach had some effect on the team's design process. The team saw testing as a separate from the design process. It was not until the 7^{th} week that they realized they might have a problem since they have decided to cap the earphone volume at the OSHEA recommended value of 85 dB(SPL), but the testing equipment available is in dB(A) scale. The conversion between scales is not straightforward and directly affects how software should be designed.

Awareness of situation complexity:

The team started out in category 1 (working together) concerning their awareness of situation complexity. They saw design problems as criteria-driven. They readily set their problem parameters to iPod applications and headphones based on the ease of the project, and also decided to divide the problem into three pieces as described above. It was not until later that they realized that there could be emergent problems during design, such as having to reconsider what

They had also realized the limits of their own knowledge as the engineering students started to ask questions about ears, hearing, etc., and the audiology students started to ask questions about how to incorporate their ideas into programming and how hardware worked (category 2: intentional learning).

Awareness of goal:

Teams practicing in the "working together" category sees goal as meeting needs, extending applications, and identifying what is feasible from another disciplinary perspective. However, the team was initially working on a superficial understanding without going into more details of understanding what each discipline could bring to the table. In the course of the semester, they had the opportunities to explore other viewpoints. For example, during the mid-semester review, the project partner offered his insight about the measurement scales that could be taken into consideration; that music has more information in low frequency, so using dB(C) scale might give more low frequency information. However, the team did not go back to visit their decision about scales afterwards. The team had an opportunity to engage in intentional learning from this interaction with their project partner, but this opportunity was not pursued.

<u>Doing</u>

Engagement with situation/differences:

Teams practicing in the "working together" category engage in the iterative communication practice, and take responsibility for being effective communicator. The team with the divide-and-conquer approach did not initially talk a lot about the difference perspectives that they can take, and instead jumped very quickly to implementation. It was not until later when the situation about testing rose did they realize they needed a more integrative approach. They started communicating by trying to learn more about what each component was about.

<u>Being</u>

Identity:

Associated with the previously discussed two pieces of "thinking" and "doing", the team member at first identified what they were capable of and should take responsible for, and divided the design task accordingly. They functioned as team members responsible for contributing their disciplinary training (Category 1). Later, when they realized that there should be interfacing between the different components; they started to take on the roles as learners and educators (Category 2).

Discussions and Implications

Our preliminary results show that cross-disciplinary practice is closely linked to the "thinking", "doing", and "being" of team members. We described the type of activities and interaction that the team engaged in. One limitation of this study is that due to protocols, only observational methods were used. Thus, the thinking and the being part of the description were deduced from actual team behavior.

With reference to the framework, the team members mainly stayed in the "working together" space (Category 1: working together)—"cross-disciplinary practice as working together with people who have different training to effectively find a better solution" [14] . The student team that we observed immediately adopted a divide-and-conquer approach, thinking that the boundary between components and disciplines can be clearly delineated. The team went on to work independently according to this arrangement for weeks without communicating between components or disciplines. Thus, we suggest adding another category (Category 0: no awareness of cross-disciplinary collaboration) in the framework. Category 0 applies when people do not value the potential synergy between disciplines. Note that the situation with this specific team was consistent with the observation other researchers [12].

The team moved into a learning space (Category 2: intentional learning) after the "surprise" expectedly came up when they found out the original parameter they chose to use might not be workable for the testing facility available to them. This instance opened the door for the interaction between people working on different components and they began to ask each other about the part that they are working on.

How this team approached the task implied that there might be a link between how people understand design, approach design, and approach cross-disciplinary practice. The team that we observed didn't see testing as an integrative part of the design process, and the students from the non-engineering discipline were assigned to the testing task. At the beginning of the project, the students thought this arrangement allowed them to work independently of each other. In order to facilitate this approach, the team quickly decided on the problem and the solution. However, design literature suggests that high quality design is usually correlated with constant iteration between problem scoping, developing alternative solutions, and project implementation [15]. The team's approach was simple in terms of project management from their standpoint but might not be conducive to learning.

Revisiting our goals

Our goals were to recognize the team member's cross-disciplinary behavior and to identify opportunity for students to develop sophisticated cross-disciplinary learning. We show that by using a phenomenographic framework, it is possible to gain insight into students' thinking, doing, and being of cross-disciplinary practices. For the specific team that we observed, there were opportunities at the beginning of the semester to encourage them to further explore the problem and solution from more perspective. Also, the divide-and-conquer strategy might be an indication of needing more communication between members from different disciplines. It might be important to encourage students to be more than team members (Category 1: working together), but to be learners of other disciplines (Category 2: intentional learning), or bridges between disciplines (Category 3: strategic leadership).

Significance and Future work

Cross-disciplinary work is challenging but important. Curriculum efforts emphasize service learning projects and other types of design learning. However, students do not learn these skills simply by being in cross-disciplinary teams, as shown by the above results and other research. Our recommendation is to explore the potential use of framework such as Adam's [14]as an assessment tool and as a learning tool. Objectives of using such tools might include prompting students to reflect on their own thinking, doing, and the roles they take when they work with teammates from other disciplines. Furthermore, students should be reflecting on what makes successful designs and how they design.

Moreover, we found that there was a new category (Category 0), "no awareness of cross-disciplinary collaboration", in the phenomenographic framework which warrants additional research. Adams' study recruited practitioners including some with extensive cross-disciplinary experience. In the context of learning, there might be "threshold concepts"[16] that student need to possess in order to be in the cross-disciplinary practice space. In our study, it is the experience of process not turning out like expected that made members realized they need to collaborate more. More research should be done on characterizing those threshold concepts and potential intervention to help students overcome the threshold early in the collaboration process.

Acknowledgement

The author would like to thank Dr. Monica Cardella and Dr. Purzer for their feedback and input. The author would also like to thank members of the EPICS program for granting access to research site and providing assistance during the process: Dr. Bill Oaks, Dr. Carla Zoltowski, Dr. Patrice Buzzanell,Craig Titus, and Shivam Malhotra.

Reference

1. Klein, J. T., *Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities*. University Press of Virginia Charlottesville: Charlottebille, VA, 1996.
2. ABET *2010-2011 Criteria for Accrediting Engineering Programs*; ABET, inc: Baltimore, MD, 2009.
3. Newell, W. H., *Interdisciplinarity: Essays from the literature*. College Board: 1998.
4. Lattuca, L. R., *Creating interdisciplinarity: Interdisciplinary research and teaching among college and university faculty*. Vanderbilt University Press: Nashville, TN, 2001.
5. Ivanitskaya, L.; Clark, D.; Montgomery, G.; Primeau, R., Interdisciplinary learning: Process and outcomes. *Innovative Higher Education* **2002,** 27, (2), 95-111.
6. Lattuca, L. R.; Voight, L. J.; Fath, K. Q., Does interdisciplinarity promote learning? Theoretical support and researchable questions. *The Review of Higher Education* **2004,** 28, (1), 23-48.
7. Mansilla, B.; Duraisingh, E. D., Targeted assessment of students' Interdisciplinary work: An empirically grounded framework proposed. In The Ohio State University Press: 2007; Vol. 78, pp 215-237.
8. Klein, J. T., Evaluation of Interdisciplinary and Transdisciplinary Research: A Literature Review. *American Journal of Preventive Medicine* **2008,** 35, (2, Supplement 1), S116-S123.
9. Mansilla, V. B., Assessing expert interdisciplinary work at the frontier: an empirical exploration. *Research Evaluation* **2006,** 15, (1), 17-29.

10. Fruchter, R.; Emery, K. In *Teamwork: Assessing cross-disciplinary learning*, Conference on Computer support for collaborative learning, Palo Alto, CA, 1999; International Society of the Learning Sciences: Palo Alto, CA, 1999; p 19.
11. Schaffer, S. P.; Lei, K.; Paulino, L. R., A framework for cross-disciplinary team learning and performance. *Performance Improvement* **2008,** 21, (3), 7-21.
12. Muis, K. R.; Bendixen, L. D.; Haerle, F. C., Domain-generality and domain-specificity in personal epistemology research: Philosophical and empirical reflections in the development of a theoretical framework. *Education Psychology Review* **2006,** 18, (1), 3-54.
13. Klein, J. T., *Interdisciplinarity: History, theory, and practice*. Wayne State University Press: Detroit, MI, 1990.
14. Adams, R.; Forin, T.; Srinivasan, S. In *Cross-disciplinary practice in engineering contexts- a developmental phenomenographical perspective*, International Conference of the Learning Sciences, Chicago, IL, 2010; Chicago, IL, 2010.
15. Atman, C.; Chimka, J.; Bursic, K.; Nachtmann, H., A comparison of freshman and senior engineering design processes. *Design Studies* **1999,** 20, (2), 131-152.
16. Meyer, J. H. F.; Land, R. *Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines*; 2003.