Avenues toward Interdisciplinarity in the Classroom

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***Abstract*—This work-in-progress paper in the research category presents a case study conducted in an advanced undergraduate course that is part of an interdisciplinary minor in innovation. Our study investigates student collaborations in a cross-disciplinary course spanning engineering, business, and industrial design approaches to creativity and innovation in commercializing technologies. We examine whether instructor methods, course structure, and curriculum contribute to interdisciplinary collaboration. Our study included faculty and student interviews to present multiple perspectives regarding interdisciplinarity and creativity.**

Keywords—creativity, interdisciplinarity, qualitative research

I. Introduction

In educational settings, interdisciplinarity is often conflated with multidisciplinarity, in that the collaborations conducted across disciplines do not extend beyond insular combinations of disciplinary content. The way students and even instructors engage in work comprising multiple disciplines often follows a 'divide and conquer' approach to problem-solving, in which those with certain disciplinary knowledge only work on coinciding aspects of the problem without integrating disciplinary perspectives [1], [2]. This approach reduces the depth of interactions that occur between disciplinary boundaries– actors are not required to leave the comfort of their own discipline and are not exposed to different ways in which to view or understand problems [3], [4]. These spaces of interdisciplinarity, in which knowledge is integrated across disciplinary boundaries, are often spaces that cultivate creativity; thus, without successful interdisciplinary learning, teams can have difficulty in aspects of their work that require creative skill [4], [5]. In collaborative work, there is a difficulty in achieving interdisciplinarity, for integrating disciplinary knowledge requires more communication and coordination between actors with different priorities and values [7]. When a team's ability spans beyond the sum of their individual knowledge to include the integration and generation of new approaches, the team is better positioned to synthesize skills and to find, define, and solve problems in novel and useful ways [2], [3].

II. Background

The shift from multidisciplinarity to interdisciplinarity can be difficult to implement in practice. According to Klein, projects that facilitate an integration of knowledge and practice across distinct disciplinary domains are defined to be interdisciplinary [8]. With the integration of knowledge, there can be a more complex understanding of how seemingly unrelated knowledge is interconnected [1].

Team projects are one method in which courses aim to engender interdisciplinarity. Yet, a 15-week semester course is a short amount of time for students to adopt the role of team members to effectively collaborate, overcome inherent biases, navigate disciplinary language, and synthesize new methods that integrate their different disciplinary experiences [9]. Moreover, interdisciplinary collaboration cannot be sustained unless the students' disciplinary identities are valued by underlying institutional structures [5]. These can take the form of multiple faculty members from different disciplines or of one with a multi-disciplinary background and opportunities for student teams to be rewarded for their projects.

Varying approaches and values across different disciplines also add to cultivating an understanding of creativity in these team interdisciplinary contexts for "creativity is precisely the kind of problem which eludes explanation within one discipline and demands such sustained cooperative ventures" [10, p. 22]. Real-world problems span more than just one discipline [11], and thus can be highly effective in providing a space to foster knowledge integration across disciplines. There is a level of creative ability inherent in the "drive to reshape the boundaries of knowledge" [12, p. 5]. These skills are critical for students to "thrive in contemporary knowledge societies"; however, even with the increase in multidisciplinary programs at institutions, there are still gaps in opportunities for student to practice interdisciplinarity [13, p. 215]. This study is intended to shed light on facets of creativity that surface when faculty and students engage in interdisciplinarity in courses exploring innovation and entrepreneurship. This study has been guided by the following research questions:

RQ1 - How does interdisciplinarity manifest in teams composed of students across disciplines?

RQ2 - How is creativity perceived in a course comprised of students from different disciplinary backgrounds?

III. Methods

We used a qualitative case study approach to answer our research questions. The case was bound by one course but included both current participants and faculty involved in its co-design as a required course in a general education "pathway" minor in Innovation. This study was aimed at answering questions regarding interdisciplinarity from the perspective of faculty and students as well as the perceived creativity of the course design and implementation. The study diverges from a traditional case study due to the added

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data collected to shed light on the original development and prior iterations of the course as well as its role in the university's initiative to create coherent interdisciplinary "pathways" that satisfy general education requirements. Former faculty who were involved with the previous course offerings were interviewed to include a historical perspective of the course and how it has evolved. In its current form the course was conceived of in 2015 and implemented in the Fall of 2016. Due to the nature of the course and the manner in which it is affected by those who teach it and enroll in it, we found it necessary to include faculty interviews to provide a historical perspective.

A. Data Collection

Using a semi-structured protocol, we interviewed nine current students in the course and seven current and past faculty instructors. The past faculty interviews were critical in providing data surrounding the initial conception and subsequent iterations of the course. Approval from the Institutional Review Board (IRB) has been obtained for this study.

B. Setting and Participants

The setting for this study is an advanced undergraduate course that is part of an interdisciplinary minor in innovation. The course is cross-listed in three departments from three different colleges/schools including Engineering, Business, and Architecture & Design and fulfills three electives for students. The course is designed and delivered by faculty representing multiple disciplines and is open to all majors on campus. The purpose of this structure is to provide students an opportunity to work in interdisciplinary teams in an experiential learning environment replicating the modern innovation environment, which is by its very nature interdisciplinary and team-oriented. In addition to the teamwork environment, students work on real-world innovation commercialization or entrepreneurial projects. Students' individual experiences and projects in the course involve actual inventions, innovations, technologies, intellectual property (e.g., patents) and market opportunities that could be exploited in the marketplace under the right conditions. The primary learning process and outcomes of the course are related to student teams determining if such market opportunities are worthy of actual pursuit in the real world, and taking the potential steps of working with inventors, scientists, entrepreneurs, advisors, and other collaborators. We situate the case study in this course because it was co-designed by an interdisciplinary faculty team and offers students an opportunity to work in interdisciplinary teams.

Of the 42 students in the course, 22 are majoring in a range of engineering disciplines, with the remaining distributed across other disciplines including the sciences, business, industrial design, and architecture. The faculty engaged in co-designing and teaching the course include members in departments across engineering, business, humanities, education, and industrial design.

C. Data Analysis

The interviews were audio-recorded and transcribed by a professional service. These transcriptions were analyzed in parallel with the course, with the use of the qualitative coding software, NVivo12. The analysis portion of the study was completed in parallel with the course to allow for follow-up questions and a deeper exploration of emerging themes; following the advice of Miles, Huberman, & Saldana to "cycle back and forth" between the data analysis and collection to reduce blind spots [14]. We employed an iterative inductive coding strategy that highlighted key themes from the data. The key themes were compared across faculty and student interviews until no more themes emerged. The two high-level themes are creativity perceptions and working across disciplines, which comprise smaller themes shown in Table 1. As this is a work-in-progress, our next step will be to interpret these themes against foundational work on creativity and interdisciplinarity in undergraduate education, thereby expanding their definitions and further detailing their interpretation [15]–[17].

IV. FINDINGS

A. Creativity Perceptions

For creativity perceptions, we took note of how students and faculty described creativity in relation to the course. This theme highlighted any mention of creativity and how it has played a role in their coursework. Responses were grouped into four categories shown in Table 1.

TABLE I. THEMES OF CREATIVITY PERCEPTIONS

Code	**Creativity Perceptions**		
	Definition	***Operationalized Definition***	***Example***
Broader conception of creativity	Students or faculty explaining processes of learning knowledge outside their own discipline	Mention of learning, working with content outside their own.	"*my understanding of creativity has broadened a little bit*" Initial thoughts: "*we're not going to use creativity much in the business school. It's going to be more focused like … that's for art students*"
Focus on the process	Students caring about the process equally or more than about the product	Mention of value of process. Shifting focus away from their products.	*"if we get to a product or service, …that's fine, but that's more icing on the cake. We're trying to learn how do we actually go out and talk to customers and how do we actually ask good questions and make good hypotheses and then analyze that data and allow us to refine this process all over again and do that weekly*."
Issues with ambiguity	Students navigating open-ended nature of course.	Mention of ambiguity, open-ended, discomfort, struggle with	One student specifically pointed to the open-ended nature of the course as a way to "*make it more open to creative*

Code	Creativity Perceptions		
	Definition	***Operationalized Definition***	***Example***
	Faculty coaching them through discomfort.	the course expectations.	*solutions*," but then expressed her concern with the lack of constraints; "*I think constraints actually make it easier to be creative… when it's too open-ended, you go, "I just don't get it... and then stop at the minimum."*
Real-world engagement	Projects extending beyond learning outcomes, assessment, class content.	Mention of students taking their work outside of the classroom and course deliverables.	A student points to an 'official' way in which the team has taken ownership: "*my team knows .. this is their baby too. I extended them offer letters and everything."*

B. Working across Disciplines

As the class was cross-listed with industrial design, engineering, and business, students had many opportunities to engage with students and knowledge outside of their discipline. This theme is broken into smaller categories that provide instances in which students and faculty engaged in cross-disciplinary work and their experiences in these spaces. Emerging themes were grouped into four categories shown in Table 2.

TABLE II. THEMES OF WORKING ACROSS DISCIPLINES

Code	Working across Disciplines		
	Definition	***Operationalized Definition***	***Example***
Seeing the value of disciplines	Student speaking of the value their cross-disciplinary peers add to the team's work. Faculty coaching to this.	Mention of different perspectives and experiences adding to the overall project.	Student: "*from an engineering background ...I really understood the technical components of 3D printing […but have] very little experience with marketing"* and valued her group members' *"perspectives from business and marketing."*
Challenges of working with those from other disciplines	Students navigating disciplinary differences in group work.	Mention of wrestling with conflicting expectations or work styles.	A business student expressed how he's "*gotten the impression from the engineers* [he's] *working with* [that] t*hey're a little more used to having more of a concrete plan."*
Common Language	Student learning how to communicate across disciplinary boundaries and faculty helping them through this.	Mention of learning the language of disciplines and becoming more comfortable expressing ideas in	Instructors noted observable communication: "*if we think they're in a context where they're just not communicating well--we're all using the same words, but they mean different things to different people, then we've got to try to help them understand*
		newer domain spaces	*this is what we mean when we say this."*
Interdisciplinary work as real-world engagement	When students exhibit interdiscplinary learning through an understanding of real-world problems.	Mention of students engaging in interdiscplinary work through the context of real-world experiences.	Bringing in professionals from the community as "*mentors or advisors or guest speakers … helps students get out of their 'I'm a mechanical engineering' or 'I'm a marketing major*'" headspace and to the realization that "*this stuff doesn't exist in a vacuum.*"

V. DISCUSSION AND IMPLICATIONS

The blend of disciplines that comprised this course yielded several paths for the cultivation of creativity through the lens of interdisciplinarity. Creativity is a largely context-dependent term and it is often difficult to reach a consensus on its meaning [18]. For some students who were less familiar with open-ended prompts, the expectation of creativity yielded adverse results, in that students performed the bare minimum they saw as required. But for students who had a firmer grasp of their project and were able to connect it to real-world situations, the ambiguity of prompts acted as a freeing push for creativity. The differences in student disciplines meant that students would connect with this ambiguity at different stages of the course and that the faculty had a role to play in coaching them through the discomfort that may have surfaced initially. A primary finding was the variability in how students reacted to the open-ended nature of the course and how their discipline or engagement with their project informed that process.

As students broadened their understanding of creativity through a shift of appreciation from the product to the process, their rather rigid expectations began to subside. Many students came into the course with a focus on the end result of their work, but as they became more comfortable engaging in the process they began to value it more. This shift took heavy involvement from the instructors to meet each team where they were, such that students learned to value the process, to refine it, and then to fit it to their needs. Students came into courses with expectations that the instructor is in control of their learning, but through the course they began to understand that they were "*developing this project*." They were "*the one creating whatever it will be at the end, the end product*." But from the faculty perspective, students are still *"afraid to be creative* [and] *still look for those concrete outcomes."* The importance of acknowledging student trepidation with open-ended prompts throughout their process is clear through this work. The current model in traditional learning environments engenders a sense that the instructor has all of the answers and students are tasked with figuring them out [19].

Departing from this learning environment is a process for both faculty and students and requires ongoing efforts that seek to establish trust between them, such that students are not left searching for the 'correct answers.' One way to overcome this challenge would be for students to identify their own deliverables and to structure their learning processes so that they feel more in control and are not trying to satisfy what they think are the professor's expectations.

Through the context of real-world application, we can dispel some of the concerns that students come into the course with. Project work that extends beyond the classroom supplies a platform by which students can conceptualize the practicality of working with those from different disciplines and in domain spaces outside of their own. One of the major commonalities that bridge creativity with interdisciplinarity is the application of projects to real-world situations. These opportunities become tangible learning experiences for students as they begin to see how disciplines do not typically function in silos outside of the university environment. Moreover, because students have less experience as to what different disciplines comprise, they need guidance bridging the gaps that stem from learning in single disciplinary environments. Instructors have used scenarios as activities for students to become more familiar with and ultimately recognize the value of disciplines outside of their own.

In addition to recognizing the value of different disciplines, another challenge is acknowledging the different types of course structure that come with a diversity of disciplines. Aside from new disciplinary content, students are also exposed to the different levels of comfort their peers display in response to ambiguity. Scaffolding teams through this potential tension is important in helping them build tools for interdisciplinary collaboration, especially when some students may be at different levels of their studies. Interdisciplinarity can be a difficult goal when students are only newly enculturated in their own disciplines, but maintaining a collaborative environment that still values those with less disciplinary experience is important.

The acknowledgment of disciplinary differences is an important aspect of cross-disciplinary collaboration for it is one of the first ways to bridge gaps across disciplines to create a common language. Establishing a common language may be easier when it is rooted in real-world applications that include disciplinary experts as resources to learn across disciplines. However, the delay that students experience before building a common language can induce discomfort, which surfaced as a recurring theme across the faculty and student interviews. Building that common language requires time and commitment which brings about the conversation regarding why students enroll in the course. This theme was not explored in this paper but will be included in the future investigations.

The commonality that emerges when identifying themes regarding creativity and interdisciplinarity is that of real-world engagement. For the student teams who extended their projects beyond the course requirements, their engagement with the open-ended structure of the course led them to more creative explorations that took advantage of different disciplines. Real-world situations that students connected with helped to drive their learning process and turn cross-disciplinary collaborations into meaningful interdisciplinary work.

VI. Limitations and Future Work

Our study has several limitations. First, as a work-in-process, the study does not reveal longitudinal insights. It is hard to identify the impact a course has on students as we only followed students, teams, and projects for a 15-week semester. It would help to contextualize what they learned from the course and how they transfer their interdisciplinary experience in their other courses or in their professional work. Second, our case study was not bound by time and space, in that we included interviews from past faculty involved with the course rather than relying on the perspective of one instructor. These past perspectives provided a more comprehensive understanding of the course's development and its original premise, which we regarded as valuable data that strengthens the study. Thirdly, interviewed students were only from one class with a certain composition– 22 engineering-related majors and 20 in disciplines across business, industrial design, and architecture. This uneven representation of disciplines, as recognized by faculty teaching the course, results in the course "taking on the flavor" of the disciplines of the instructors and the students who enroll. Completing student interviews with past students or students from future course offerings would offer insights regarding the iterative nature of the course. It would also have been helpful to interview students from when the course was co-taught by multiple instructors. Finally, because the instructor influences each offering of the course, it can be difficult to talk about what students have said in the current course and compare that with what has been said by past instructors.

VII. Conclusion

Interdisciplinarity is a difficult learning objective in a time restricted course, especially when it is comprised of students from different disciplines. Through the context of real-world applications, students begin to cross disciplinary boundaries and expand their preconceived notions of what an engineer or business major does in practice. When students connect to their work, these boundaries are easier to overcome, but with short course periods, the level of engagement necessary for interdisciplinarity can be a challenge to reach. Through this work, we hope to convey that students have pre-existing expectations and values that are instrumental in how they navigate through interdisciplinarity. The creativity that stems from integrating content requires an understanding of existing student disciplinary presuppositions, where we intentionally prepare them for interdisciplinarity rather than being sufficed by multidisciplinarity.

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