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DESIGNING AND ITERATING FOR INTERDISCIPLINARY, CREATIVE RESEARCH IN GRADUATE TEAMS

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Two graduate-level courses were designed to advance creative, interdisciplinary teamwork among graduate students. Over three years the two courses underwent three iterations largely focused on refinements to teamwork, which led to high-quality student products. The case study presents the three course iterations, how course design decisions were made, and the kind of results that were achieved. The paper concludes with reflections for designing higher education courses focused on creativity, interdisciplinarity, and teamwork.

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INTRODUCTION

Interdisciplinary curricula have dramatically impacted higher education (Denikina, 2021). In concept, interdisciplinary education provides students with opportunities to explore multiple disciplinary perspectives around one topic or issue. In practice, creating and implementing an interdisciplinary curriculum requires overcoming many challenges from faculty, students, and the institution (see Perignat et al., 2022). The case presented in the following sections describes the creation and implementation of two interdisciplinary graduate courses focused on creativity and teamwork, spanning from the inception in 2017 to 2022. Here, the team describes how they designed several iterations of the courses aiming to meet the pedagogical goals and increasingly to improve upon low student enrollment.

BACKGROUND FOR THE DESIGN CASE

Creativity is widely considered one of the most important skills for the 21st Century; educators within a variety of contexts are encouraged to teach students creative thinking and problem-solving skills in preparation for success in a fast-paced, ever-changing environment (Jingfang, 2017). Creative thinking is considered a higher-order cognitive skill required across disciplines, yet the American educational system has repeatedly been critiqued for failing to prepare students for the rapidly changing job market by not graduating students with creative thinking skills. Higher education's past is embedded within the 2,000-year-old Greek model of master and apprentice (Rudolph, 2021), which often teaches disciple-based skills while leaving students struggling to develop creative thinking skills on their own.

A literature review combined with an internet search of programs that teach creativity in higher education shows that such programs are rare. Of the existing programs, most are embedded within specific departments or schools, particularly within education and psychology. The program described in this paper emerged specifically from a lack of general creativity training, especially in graduate programs where the thesis's merit is heavily weighted toward the impact on the field.

The two creativity courses were conceived as part of a graduate minor, Interdisciplinary Team-Oriented Creativity (ITOC), for students in any discipline; the graduate minors consist of four, interrelated courses intended to enhance the graduate experience. Specifically, the ITOC program was aimed at addressing the increasing need for creative research teams who face complex, interdisciplinary problems requiring innovative, comprehensive solutions. In the case of ITOC, students take the two designed creativity courses described in the paper and two elective courses at least one of which must be outside the student's home department. The minor was open to any graduate student and could be tailored to any discipline. Teamwork was an integral component of the approach because creativity can be enhanced in groups with the potential for more innovative solutions than those developed by individuals working independently. The importance of teams has led to the emergence of team science to discern and leverage the efficacy of teams (Cooke & Hilton, 2015).

The decision to launch ITOC came after the university's Graduate College implemented the graduate minors program. As part of the proposed graduate minor, letters of support were obtained from the Business School, the College of Engineering, the College of Entrepreneurship, the School of Design, the School of Education, and the College of Arts and Sciences. A market analysis was performed which found that the graduate minor addressed high-value student skills such as communication and interpersonal collaboration; the skills are highly valued by employers, but rarely taught in graduate programs. On the student side, three informational sessions with graduate students were organized before launching ITOC, to gauge interest from the students themselves. The minor was proposed and easily passed by the university senate.

SETTING

The ITOC interdisciplinary program was anchored in two core creativity courses designed for an R1 research institution, a large university located in the Mid-Atlantic United States. The university is structured around a quarter-term system, with 10-week terms that make up the academic year (fall, winter, spring, summer). The fast-paced terms result in intensive courses and time constraints for both faculty and students. Shortly before the development of the creativity program, the university established a strategic plan with a core goal of graduating innovative students capable of impacting research in health, education, business, and the sciences. Inspired by the strategic initiative, several specialized programs and certificate courses were implemented within colleges and schools at the university. Although some programs addressed interdisciplinarity and creativity, few provided opportunities for students to practice with interdisciplinary teams or experience interdisciplinary research; no prior programs at the institution modeled interdisciplinary teamwork through co-instructing faculty teams. The faculty team who designed and implemented the courses had primary appointments in the disciplines of education, design, business/psychology, and chemistry.

THE DESIGN TEAM

The interdisciplinary design team was composed of two chemistry professors, a visiting professor specializing in social psychology and business consulting, a design research professor, an education professor with expertise in creative mindsets and creative self-efficacy, and a postdoctoral researcher (see Figure 1). The first postdoctoral fellow participated in the 2019-2021 window, the second in 2021-2022. All team members shared an interest in creativity, research, and graduate education. The five faculty members worked together in partnership to acquire funding and develop the initial courses. Three members of the team led the course instruction (the "Instructional Team"), and one member was a guest instructor, with the postdoctoral fellow leading the research data collection and analysis. See Perignat et al. (2022) for more details on how the design team collaborated.

GOALS SET FOR THE COURSES

The overall goals of the two courses were fourfold.

- Provide students with a deep understanding of creativity in research.
- Equip students with strategies and tools to develop their creative processes.
- Provide students with practical experiences to understand different disciplinary approaches to research and to draw from different disciplines in the design of their own creative research project.
- Equip students with the tools to work in high-functioning teams and to understand the challenges and benefits of working in interdisciplinary teams.

The four goals remained constant throughout, though some of the approaches and content changed considerably during the course iterations. The goals are discussed next.

Provide Students with a Deep Understanding of Creativity Research

The design team envisioned the courses would provide a nuanced understanding of creativity that emphasized the ways in which research is inherently a creative endeavor. Namely, creativity is a skill that is continually developed over a person's lifetime and applied to a wide variety of contexts that extend beyond the simplistic generation of ideas by brainstorming. The focus on promoting a creative growth mindset, believing that creativity is malleable and improved through practice, was an important goal and design element because of research correlating a creative growth mindset with an increased likelihood of producing creative work (Dweck, 2006; Karwowski, 2014; Katz-Buonincontro et al., 2020).

The design team incorporated theories of creativity to provide students with a rich understanding of creativity, particularly as manifested in research. Topics included: (a) exploring different definitions of creativity, (b) learning and completing creativity and mindset profiles, and (c) exploring historically influential examples of creative research processes. The theoretical grounding in creativity was emphasized more in the first course, *Creative Interdisciplinary Team Research: Principles and Practice* (Course I), which served as a valuable prelude for the second course.

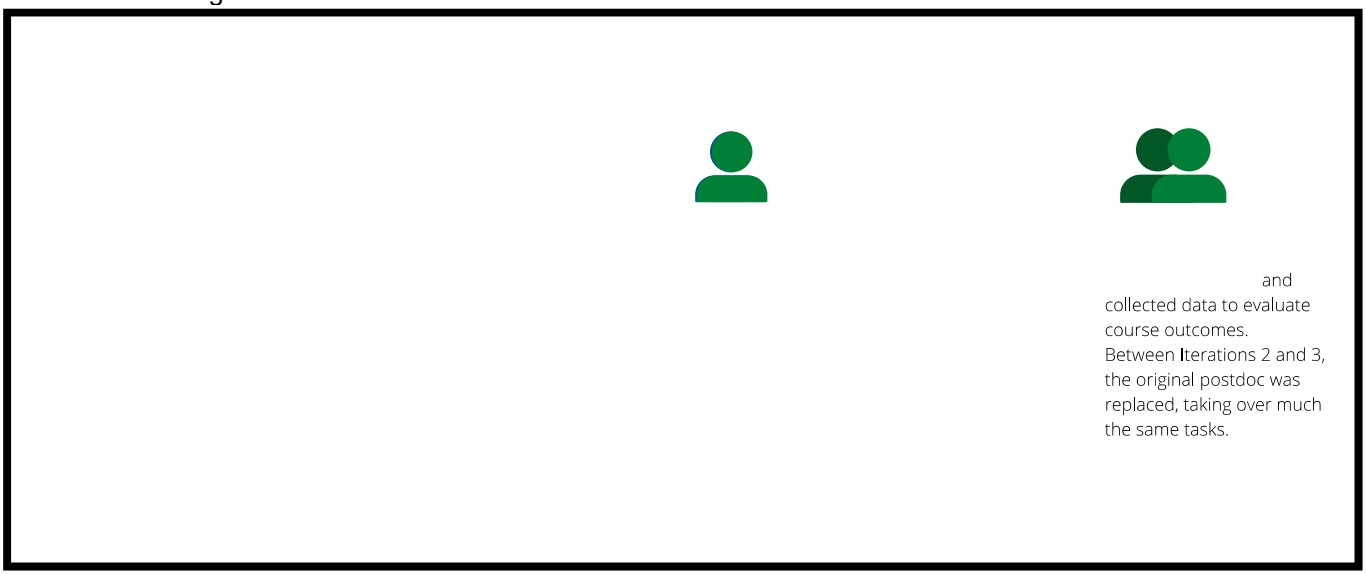

Figure 1. Members of the design team and their roles.

The second course, *Enhancing the Creativity of a Research Project* (Course II), focused on helping students develop and/or refine a project while simultaneously providing strategies to increase creativity while designing the research project. However, because students were able to enroll in the second course without a prerequisite, the design team included a theoretical lesson on creativity at the start of the second course. Additionally, students were required to write reflections on their creative abilities as researchers several times throughout the course. Students were prompted to report to what degree and in what ways the course was/was not empowering them to be creative researchers.

Equip Students with Strategies and Tools to Develop Their Creative Processes

Among the variety of activities, strategies, and approaches to teaching and fostering creative thinking, the team selected *Zig Zag: The Surprising Path to Greater Creativity* by Keith Sawyer (2013) as the required text for Course I. Course II, which focused more specifically on infusing creativity into a research project, was taught using selections from a variety of texts, including *Zig Zag* (more thorough descriptions of Course I and Course II are provided in the description of the first iteration of the courses). The choice of texts was guided by needing a research-based text that was accessible and relevant across all disciplines, which eliminated most books that target business and innovation. *Zig Zag* was ideal because of an emphasis on practical strategies such as: asking the right questions, deliberate practice, viewing through fresh eyes, and preparing your mind. The design team's approach was to teach a wide array of strategies to facilitate creative thinking followed immediately by practice through in-class exercises or by using the strategies on the course project. An integral aspect of both courses was not only familiarity with creative practices but also choosing appropriately between creative strategies and recognizing that when working creatively there are likely to be several beneficial strategies. Some creative skills that were taught include design thinking, ideation, storyboarding, and "fail fast-fail often" (Babineaux & Krumboltz, 2013).

Design thinking was utilized as an engine for in-class ideation and conveying the value of iterative thinking (Cross, 2011; Luma Institute, 2015; Owen 2008; UK Design Council, 2020). Each course was graded primarily on a team project presentation that documented how creative strategies were employed to arrive at a creative solution. Coaching throughout the course ensured that the students understood that documenting a familiarity with, and the impact of, the creativity skills was at least as important as the projects themselves; from a pedagogical perspective, the project was only the vehicle used to practice competency and teamwork.

Provide Students with Practical Experiences to Understand Different Disciplinary Approaches to Research

Interdisciplinary approaches are required to generate the types of creative solutions to address complex problems, such as environmental destruction, urban disparity, and poor public health (Ardila et al., 2016; Buchanan, 1992). The design team employed two strategies to encourage diverse, interdisciplinary encounters. First, carefully curated groups were formed in both courses to maximize representation from different academic disciplines. Second, the courses were co-taught and guest taught by an interdisciplinary group of academics. The diversity of the core team included chemistry, psychology/business, and design; and was supplemented by guests from electrical engineering and education. Diversity was further emphasized through panel discussions in which the panelists, from both industry and academia, shared the unique ways their field approached asking research questions, designing research projects, and describing the epistemological frames from which they operated. Discussions with panelists aimed to encourage reflection on the differences across the different academic disciplines by considering how strategies more commonly observed in academic fields other than their own might be applied to a student's research.

Help Students Understand the Challenges and Benefits of Working in Interdisciplinary Teams

Teamwork and collaboration – particularly interdisciplinary teamwork – is a foundational skill for much creative scholarship. Teams are increasingly prevalent in virtually all fields where they produce more highly cited research than individuals (Wuchty et al., 2007). Solutions to many pressing global and societal issues, such as designing sustainable housing, require teams of experts who can draw from a wide array of fields (see Ardila et al., 2016). While much remains unanswered when considering the impact of interdisciplinary collaboration on a student's creativity (Brodin & Avery, 2014; Mullet et al., 2016), some early studies have demonstrated that courses employing interdisciplinary learning and collaboration have fostered creative solutions in students' research (e.g., Fenge, 2012; Lee, 2022).

Despite the benefits of teamwork, the American education system remains highly individualized. STEM-based teaching rarely takes advantage of the possibilities of team-based cooperative learning (National Research Council, 2015). Often, when students *do* work collaboratively in teams, they prioritize individual success, interpreted as a good grade, over the team's success (Mosvick & Nelson, 1996).

The design team set a goal of not only teaching teamwork best practices but also ensuring an environment for students to experience the synergy of working in a high-functioning team; the context was teamwork on a group project designed to enhance creative ability. Each course organized students into carefully curated teams that maximized disciplinary representation, gender, and their Basadur creativity profile (Basadur Foundation, 2021). Basadur profiles were employed because the profiles succinctly provide individuals with a readily understood profile of their approach toward problem-solving that can change over time *and* how all four types contribute to the health of a high-functioning team (Basadur, 1994; Basadur et al., 1982). For example, generators have strengths in generating ideas whereas implementers excel in bringing abstract ideas into the real world. Teams were comprised of individuals whose profiles best spanned a diverse range of profiles balanced against constraints such as discipline and gender to create teams who were well-equipped to create innovative solutions to a project of their choice.

The focus on teamwork in the two courses directly benefited from Author 7, whose academic training as a social psychologist combined with his industrial expertise as a consultant provided the experience needed to teach and coach best practices with interdisciplinary teams. The impact of teaching about teams coming from a group of faculty members from disparate disciplines was not lost on the instructors and was often brought into class discussions. Each weekly class included time specifically devoted to teamwork. Author 7 worked with each team to create a team charter defining the norms of behavior, agreement on measures of success, roles, and responsibilities, and the process of arbitration to mediate dissent. Team exercises were fostered with good practices, such as utilizing "yes, and" in conversation and having students experience the difference with "yes, but." The design team additionally addressed diversity, expectations, and teamwork by incorporating a class on diversity from *Diversity and Creativity in Work Groups* (Milliken et al., 2003) and having teams reflect on diversity in their project goals.

METRICS USED FOR THE TWO COURSES

The design team's goals and course outcomes were evaluated in several ways. First, the instructional team developed and utilized rubrics to assess student work and assignments (e.g., presentations, written reflections, teamwork). In such assessments, the metric was based on evidence of collaborative student work and the application of skills and techniques taught in class. Second, student feedback provided through the focus groups, student course evaluations, and student self-evaluations were surveyed for evidence of meeting course learning goals and instructor and student expectations. The combined metrics were used to evaluate the course and inject changes to optimize the course goals.

ITERATION ONE

Courses I and II on creativity and interdisciplinary teamwork were designed with the expectation that students would take them in sequence; however, Course II was framed sufficiently independently such that Course I was not a prerequisite. The first course provided the fundamentals of interdisciplinary collaboration while the second course focused on strategies used during the development of a research project (literature searching, topic selection, hypothesis identification, and problem-solving) with an emphasis on creativity. Each class included time to apply the recently learned ideas to a research project of the student's choosing, typically their graduate thesis.

In Course I, the student teams worked on a ten-week, interdisciplinary project with two deliverables, a 15-page report, an oral presentation, and a description of how the course content was applied in developing the project. Content taught within the first course focused on general strategies to improve creativity and teamwork, such as asking the right questions, design thinking, and how to create a team charter.

Course II similarly employed interdisciplinary teams to provide feedback and support to each individual's research project, described to students as a "think tank" environment. The implementation of interdisciplinary think-tanks was done to provide an environment where students would develop and explain an individual project to non-experts, thereby gaining feedback that included learning about how other disciplines may approach problems differently; the course design was specifically aimed to raise an awareness of discipline-specific methodologies and epistemologies. The goal was to have students consider adopting methods outside their own discipline while the practices and experiences would provide a robust, experiential toolbox of creative

approaches to solving problems. See Tables 1 and 2 for the weekly course topics.

The instructional team (see Figure 1) met thirty minutes prior to each class to confirm the format, make any accommodations required due to deviations from the previous class plan, and converse on the progress of the course relative to the set goals. Topics discussed by the team included ensuring that props and technology for that evening's class were ready, discussing student needs, considering experts to invite to an upcoming class panel, and preparing the syllabus for the next course. The meetings facilitated communication among the instructional team about immediate and emerging learning needs as well as time to informally exchange valuable information about teaching style and content; the pre-class meetings were maintained throughout all iterations of the course.

Unlike the instructional team, once the two courses were designed, the design team met less regularly—around once or twice every term. Topics discussed by the design team included a general appraisal of the courses and any challenges or successes that merited attention, such as low enrollment or research awards received by students enrolled in the courses.

Course I was initially taught in the summer of 2018, and Course II was taught in the winter of 2020. The extended break between the courses was due to the team focusing on writing a grant for, and receiving, NSF funding to fully develop the courses into a graduate minor and to implement and refine the program. See Figure 2 for a timeline.

REFLECTIONS ON STUDENT WORK

The instructional team identified three areas for improvement in student work. The areas emerged from numerous discussions stemming from observation of students in class and from grading the presentations and final reports:

1. Improving students' understanding of how to survey and incorporate the research literature into the proposal.
2. Improving students' integration of the creative toolkit into the research project, for example: concept mapping, stakeholder mapping, affinity mapping, and strategies, such as looking at a problem with "fresh eyes."
3. Improving students' deployment of team processes to improve the overall creative outcome.

Students were found to be less adept at finding and evaluating research literature than anticipated. Most students exhibited a significant gulf between broad searches using internet search engines on the one extreme, and a very narrow area of expertise within the primary discipline on the other; often even these skills were lacking. The issue was effectively addressed in Course II through a library-oriented class session in which library staff from different disciplines showed search techniques that students then modified for their own use; students had access to library computers or could connect their own devices.

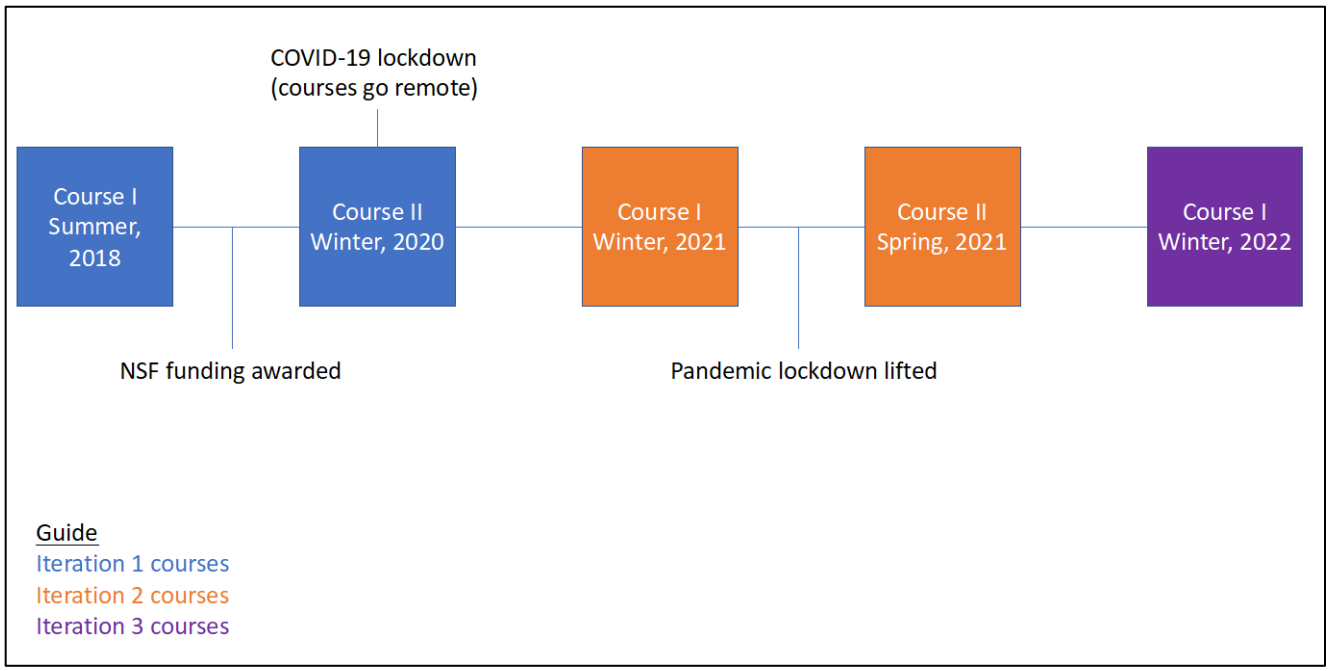

Figure 2. Timeline depicting course iterations and other important events.

The faculty instructors then demonstrated research searches in their own areas while verbally explaining how they were evaluating the search results to refine and pare down the answer sets. The presenters stressed the necessity for breadth and depth in literature searching to provide insight into whether new research areas were likely to be novel or routine.

A second area in which students' work could be improved was their high-level integration of the creativity skills that were initially evident from reflective writing and poster presentations. In the first class, the instructors observed that linking the skill description to the class topic reinforced skill usage and understanding. For instance, instructor 1 introduced a sequential process that students needed to consider in creative work, and then instructor 2 asked the students to journey map that sequential process (see Figure 3). These pedagogical linkages reinforced the use of tools by showing the thought process that experts used to capture ideas that students could then adopt in their projects.

A third area to improve student work was in forming high-functioning teams. Students were encouraged to use the team charter to optimize their teamwork and were coached to reflect on optimizing the team process to best achieve the team goals. In the first iteration, teams that met over a meal or worked on issues other than those related to the class were observed to have a stronger team culture. Teams with strong cultures were observed to have a greater willingness to delegate and to wrestle with opposing views. Instructors continued to iterate ways to foster a strong team culture while stressing the need for teams to diligently evaluate and even seek out opposing ideas to avoid groupthink.

The extended break between teaching the first two courses and the subsequent courses was caused by the design team using the experience to refine an NSF proposal to develop the courses and begin a university proposal for the *Interdisciplinary Team-Oriented Creativity* graduate minor. The process led to deep reflection on the challenges and successes, which aided in identifying areas for improvement. In several cases, improvements in the course design came from team members sharing insights arising from their disciplinary expertise.

The NSF-funded project included a strong emphasis on course evaluation followed by a revise-and-repeat cycle. The design team gained student feedback through focus group interviews, course evaluations, and analysis of the student reflections, which, combined with the design team discussions, could be grouped into five main areas.

First, there was often insufficient time at the end of class for teamwork. After the first iteration, there was a greater appreciation among the design team for the role of teamwork in facilitating the assimilation of the skills and ideas central to the pedagogical approach.

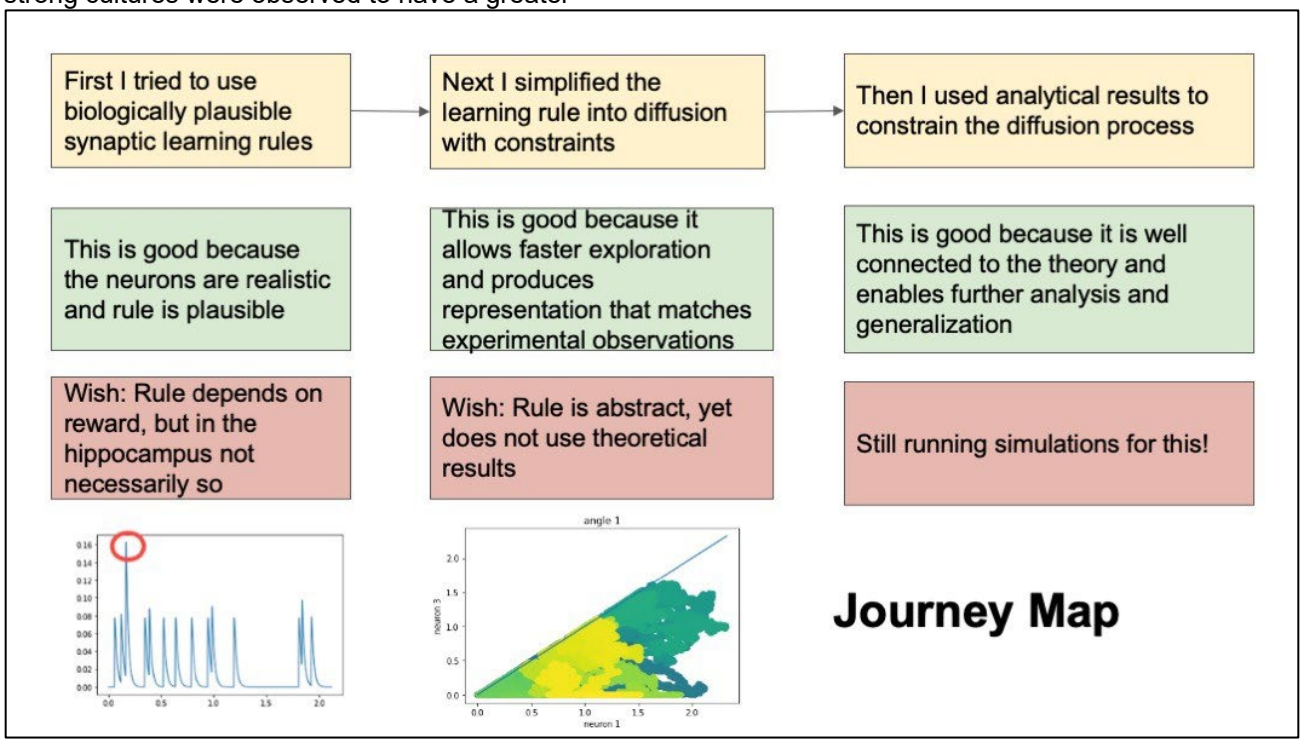

Figure 3. Journey map of the sequential creative process generated by a team in the first iteration of Course II.

Partially as a result, the courses were changed from two 90-minute classes to one three-hour class with the anticipation of better ensuring time for in-class teamwork and coaching; throughout all the classes there was a tension between teaching concepts and providing class time to practice and/or reinforce the concepts. Meeting beforehand to review the content helped to ensure that all the instructors were clear about the time allocation for the class.

Second, students reported a desire for a more consistent group of instructors, particularly for Course II, which included several guest instructors and panelists. Consequently, the team of two lead instructors with four visiting instructors for Course I was replaced with a team of three lead instructors and one visiting instructor. The three lead instructors attended every class, regardless of whether they were scheduled to teach. The fourth instructor attended only the classes they were scheduled to teach plus student presentations.

Third, students complained about a lack of clarity regarding expectations for grading. Discussions among the design team led to the realization that the faculty approached the grading with norms from their own disciplines; ironically, the benefit of an interdisciplinary instructional team in designing and delivering the course led to challenges caused largely by grading differences between education, STEM, and studio disciplines. The issue was resolved through a combination of discussions on disciplinary grading practices, agreement on appropriate evaluation metrics of student competency, and by Author 2 spearheading the creation of standard rubrics. Grading the student's work against rubrics provided quicker agreement among the design team during shared grading that had previously led to significant grading differences. Providing the rubrics to the students created a standard against which they could develop and evaluate their content.

Fourth, focus group interviews at the end of the course revealed a hesitancy among many students in their initial decision to enroll because of the emphasis on teamwork. The course description used terms such as "group work," which the students were averse to because of prior negative classroom experiences with group work. The students uniformly reported positive experiences of the group work after completing the courses, becoming advocates of using team skills. In response to the dichotomy, the design team rebranded the teamwork involved in Course II as working in a think-tank environment and lessened the description of teamwork in Course I advertising.

Finally, students reported that some of the material used in the first course was either too generic – and perceived as simplistic – or too specific to a discipline outside of a student's area. The challenge was, in part, because of a dearth of material for teaching creativity in higher education beyond the context of creative arts and the considerable literature developed around innovation and disruption in the business sector. Conversely, few instructional materials are available to teach techniques intended to boost the creative output of students in STEM. As a result, the instructional team placed more emphasis on class discussions using their own experiences to teach content that would have otherwise been read in a text that seemed topically distant to students; in some instances, the reverse approach was taken to demonstrate how material read in a particular text was applicable across several disciplines.

Overall, the design team found that the changes made between the first and second course iterations were highly effective. While many changes were made to the first iteration of the first course, little was done to change the first iteration of the second course (see Tables 1 and 2).

Challenges with Student Enrollment

The design team was disappointed by the low student enrollment because student surveys performed before the course development along with faculty feedback indicated strong support for the ITOC program. While the team had aimed for classes of 15 students, attendance hovered around 10 students, a number that was inflated by the enrollment of several students who were studying with members of the faculty design team or within their college or school. The design team expended much effort, particularly by the lead PI and the post-doctoral associate, in trying to recruit students from across the university. Recruitment included: advertising through electronic newsletters targeting graduate students, email blasts, presentations to graduate advisors, mini-presentations at the start of graduate student extra-curricular events, targeted emails through departments and schools, recruitment through past students, posting flyers in high-traffic areas and near the labs of professors whose research interests included research in creativity, posts on social media, personal emails to more than 70 faculty with graduate research, time spent by postdoc in the graduate student lounge to talk with potential graduate students and informally promote the courses.

The design team realized that while the courses were designed to be electives open to graduates from across the university, students were often unable to take electives outside the scope of their school or department curricula. The problem was three-fold: lock-step curricula provided a very limited window in which students were available to take an elective; taking courses outside some departments came with issues of providing course credit, and some advisors saw less value in training students to be creative than

in having them engaged in research. The feedback on timing was additionally part of the reason for moving the courses from two weekly 90-minute sessions to one three-hour session. Another change made by the design team was to secure cross-listings for the courses across various programs so that the courses were offered as electives *within* students' programs.

THE COVID-19 PANDEMIC

After the ninth week of the second course, the University moved courses online due to government-mandated COVID-19 lockdowns. Prior to the lockdown, COVID-19 was already beginning to make an impact, such as social distancing with panelists during the ninth week (see Table 2 for the Course II syllabus). However, because the ninth week was the final time the class was meeting, lockdown did not pose challenges to reaching the pedagogic goals set by the design team and syllabus. However, pandemic lockdowns created challenges for the team during the second iteration of the courses, particularly because the courses were specifically designed to be an interactive, team-oriented, in-person experience.

ITERATION TWO

Metrics from the first iteration of the two courses indicated that the overall design and structure of the courses met the curricular goals. Most of the changes to the two courses were improvements within the existing course structure as opposed to addressing a major oversight or deficiency. Examples include deciding to teach a topic earlier or later in the term, explicitly teaching students how to collaborate on the final project presentation, or topic adjustments due to instructor changes. Smaller changes in the syllabus are evident in Tables 1 and 2, which show the weekly lessons in the first and second iterations. The two challenges facing the design team on the second iteration were the low enrollment and determining how to best move online due to COVID-19 lockdowns.

REFLECTIONS ON STUDENT WORK

The assessment of the final student projects was made by the entire design team for Course I; for Course II the assessment was assisted by an evaluation of student output by outside panelists with creativity expertise. Compared to the first iteration, the student final presentations in the second iteration were more polished and more clearly explained how creativity skills and teamwork influenced the project development. For Course II, an increased emphasis on incorporating different disciplinary viewpoints was evident in the broader and richer literature review of several projects. In the second iteration, an increased emphasis on the midterm presentations led to output like that observed in the first iteration for the *final* presentation. As a result, the team decided to include explicit instruction during the third iteration on how to develop polished team presentations prior to the midterm presentation.

Lessons Learned for the Third Iteration

The two main challenges facing the implementation of the two courses for the third iteration were low enrollment and, as experienced nationally, how to provide a rich educational experience during the pandemic.

Challenges with Student Enrollment

The expectation was that over time the courses would gain a reputation as a valuable experience because the content benefited students in the creation, design, and implementation of high-impact, creative research projects. Instead, enrollment remained low and, if anything, became more challenging as the design team's direct recruiting pool became depleted. The enrollment challenge was certainly affected by the pandemic despite the team's best efforts to recruit students using the suite of approaches developed in previous iterations.

THE COVID-19 PANDEMIC

Moving courses online due to ongoing COVID-19 led to an intense series of discussions on the viability of creating an online environment in which discussion and personal coaching could be as effective as the in-person experience. Reflection by the design team identified two elements that facilitated the vibrant in-person development that was important to replicate: many topics were designed to morph into class discussions with students and often led to input from instructors who were not the primary presenter; and secondly, the instructors coached teams by tacitly listening in to student discussions and then contributing to the team's development. Neither element would be possible in an asynchronous manifestation.

The design team decided to offer the course as a synchronous online class despite the inconvenience to students living in different time zones (students were mainly across time zones in the US with one in India). The instructors made liberal use of breakout rooms, dropping in to be available or provide input as needed and providing at least some time for the teams to work unsupervised. The synchronous, online format with much the same curricula seemed to work well with a mix of advantages and disadvantages over the in-person experience. While interactive break-out experiences, such as in-person, Post-It interactive exercises were not possible, there were opportunities to use interactive, online platforms that were not previously part of the course, such as digital

Week	Topics: Iteration 1	Topics: Iteration 2	*Changes made*
1	Understanding Creativity Profiles How to Create Teams that Function Well	Creativity Profiles How to Create Teams that Function Well	*[None]*
2	Creative Mindsets Asking the Right Questions	Enhancing Imagination Leading innovation in teams Concept/mind maps	*Moved "Leading Innovation," previously in week 9 to week 2.* *Added concept/mind maps, taught by the new lead instructor.*
3	Deliberate practice Where to look for answers	Methods of Creative Thinking [combines asking the right questions, deliberate practice, and other methods] Sketch noting	*Consolidated methods of creative thinking into a single lesson.* *Added a lesson on sketch noting.*
4	Design Thinking Team Dynamics	Design Thinking Effective Presentations	*Replaced lesson on "Team Dynamics" with "Effective Presentations" to prepare students for midterm presentations.*
5	Strategies for Generating Ideas	Student Midterm Presentations	*Instead of instructors teaching, students presented. Instructors noted progress and helped student groups as needed.*
6	Identifying Barriers to Thinking Forcing New Perspectives	Generative Strategies	*Consolidated two lessons on generating new thoughts into a single lesson, allowing for other strategies to be taught.*
7	Fail Fast How to Free Your Mind	Innovation, Ideation, Incorporation Diversity and Creativity in Work Groups	*Replaced two lessons with two new lessons due to the difficulty students had in understanding the previously more subtle topics given, evidenced in their lack of synthesis on these concepts.*
8	ExCITe Center site visit How to Pick the Best Ideas	How to Pick the Best Ideas and Implement Creative Ideas	*Due to COVID-19 lockdowns, there was no trip to the ExCITe Center.* *Moved the lesson "Implementing the best ideas" from week 9 to week 8.*
9	Leading Innovation in Teams Implementing the Best Ideas	Student Final Presentations and Reflections due	*Courses went from being held Mondays and Wednesdays to only Mondays. Because one Monday in the term was a holiday, finals had to be moved to Week 9*
10	Intuitive vs. Logical Thinking	[No Class]	

Table 1. Differences between the first and second iterations of Course I.

whiteboards. Similarly, panelists were easily recruited because travel to campus was not required, though the student interactions were necessarily less interactive and spontaneous in the breakout rooms.

When the lockdown was lifted prior to the second course, the instructional team, like many other university instructors, was faced with the question of the best format to offer future courses. On the one hand, students from many disciplines were eager to return to classes in-person, as were professors. Instructors were especially eager to return to campus where practical instruction, such as in labs and studio performance, constituted a key component of the student learning experience. On the other hand, remote offerings are beneficial for disciplines such as Education, for which a cadre of the student body had a distance learning modality as a part of their program. The course emphasis on interdisciplinary collaboration and teamwork, coupled with recruitment challenges and a desire to have the most diverse

Week	Topics: Iteration 1	Topics: Iteration 2	*Changes made*
1	Class Structure, Expectations, Teamwork, Evaluations, and Framing the Research Problem Typologies Teamwork	Class Structure, Expectations, Teamwork, Evaluations, and Framing the Research Problem Introduction to Creativity Teamwork	*Typologies class moved to Week 7, replaced with an introduction to creativity. This change accounted for most students taking Course II without having taking Course I beforehand.*
2	Faculty Panel at Library: Background, Literature, and Scope Librarian Panel Students refine their projects with librarian and staff guidance	Faculty Panel at Library: Background, Literature, and Scope Librarian Panel Students refine their projects with librarian and staff guidance	*Session tightened up so that students could further concentrate on information given*
3	Creative mindsets and learning Flow Teamwork	Creative mindsets and learning Flow Teamwork	*[None]*
4	[Human-centered] Design [and process] Project tuning, preparation for midterm presentations	[Human-centered] Design [and process] Project tuning, preparation for midterm presentations	*[None]*
5	Student midterm presentations	Student midterm presentations	*[None]*
6	Hypothesis/Objective of the Research Question Teamwork	Hypothesis/Objective of the Research Question Teamwork	*[None]*
7	Panel: Professors Who Teach or Study Creativity Using Logic Models in Research Design	Panel: Professors Who Teach or Study Creativity Typologies	*Typologies lesson, previously taught in week 2, taught this week in place of logic models. Course evolution was due to the desire to have typologies introduced at a more appropriate time.*
8	The Role of Logic and Intuition in the Creative Process Teamwork and coaching for final presentations	The Role of Logic and Intuition in the Creative Process Teamwork and coaching for final presentations	*[None]*
9	Panel: Creativity in Industry Student final presentations	Panel: Creativity in Industry Student final presentations	*[None]*

Note: The ExCITe Center is a research lab that combines computer and electrical engineering with music. The trip included a tour of ongoing research projects, an opportunity for the students to meet with the lab's director to discuss creativity and interdisciplinary collaboration, and to discuss their projects.

Table 2. Differences between the first and second iterations of Course I.

student body, led the design team to decide on offering future courses in a synchronous hybrid mode.

ITERATION THREE

The course metrics indicated that the changes previously made to the syllabus resulted in both courses largely fulfilling the original course objectives. Consequently, changes made during the third iteration primarily involved fine-tuning the order and content. See Table 3 comparing the syllabi of the second and third iterations of Course I and Table 4 for a comparison of the second and the (untaught) third iterations of Course II.

Challenges relating to student enrollment persisted during the third iteration. For the first class, only five students enrolled, leading to a less-than-optimal course with only one team; however, the student output was exceptional. Only one student enrolled in the second class, leading to the course's cancellation.

REFLECTIONS ON STUDENT WORK

The enrollment of only five students during the third iteration was a concern because of the emphasis on discussion and teamwork. With only five students, one course-wide team was created, whereas prior classes were organized into more teams comprising groups of 3-4 students. Consequently, the group was created by chance – those who enrolled in the class were grouped together by default - instead of through an intentional selection to create a group with diverse disciplines, demographics, and Basadur problem-solving approaches. The absence of an "implementer" profile from the team was stressed at the outset of the course and observed by the instructors to have an impact on the project development. Observationally,

the team was excellent at generating ideas, broadly and in detail, but found coalescing around goals to be a challenge. The instructional team shared the observation with the student team who specifically assigned the role of implementer, which had a noticeable impact on the project development. The students described the experience in the final presentation as an illustration of how their creativity and teamwork skills impacted the project.

Toward the end of the term, there was a consensus among the instructional team that the student project was of exceptional quality. Instead of an external panel, the team presented the final project on food insecurity to several university administrators, including the Dean of the Graduate College, and to leaders in the neighborhood working to address food insecurity. The enthusiastic feedback on the high quality of the project led the students to present the project to the Alumni Board and enter a competition, ultimately successfully, to connect undergraduate and graduate student innovators with resources to implement the program. The external experts' evaluation validated the instructors' evaluation that the student's work was of exceptional quality.

OUTCOMES FROM THE THIRD ITERATION

Ultimately, the students' continued successes in and out of class support the curricular development for teaching a program in interdisciplinary team-oriented creativity. However, the failure to achieve a sustainable enrollment led the course to be discontinued for the foreseeable future.

Challenges with Student Enrollment

The constant challenge of enrollment was an ongoing issue that the instructional team continued to explore throughout the teaching of both courses. The enrollment issue was found to be a common challenge among creative teaching initiatives at the graduate level (Innovation in Graduate Education (IGE) Acceleration Hub Meeting, June 29, 2022).

Responses from students who were asked what led them to enroll in the course shared a common theme: recommendation from a mentor, advisors, or professors in prior courses. Many students were personally interested in learning from the interdisciplinary instructional team.

For some students, a mentoring professor explicitly recommended the course. At other times, the course was one of several that a professor shared with their students as potentially beneficial. Conversely, when departments outside that of the instructional team were contacted to promote the course, a common response was that information about the course would be shared with students but: "[Students] have only 1 elective in our program and most students use this to take [one of two advanced research methods courses offered by the department they belong to]."

DESIGN INSIGHTS

The design team had set out to create a program to benefit any university student's creative development as novice researchers and academics. Through three iterations of two courses, the approach was refined with an emphasis on increasing the effectiveness of teamwork, creativity, and interdisciplinary communication and collaboration. As the approach was refined, not only was the content changed but a commonly agreed upon series of metrics were developed as standards to gauge the quality of the student output *and* their assimilation and understanding of the material (see the end of the "Design Insights" section). The team's experiences also highlight the unique issues in designing graduate courses to teach creativity and interdisciplinary collaboration.

WHAT WAS LEARNED ABOUT DESIGNING TO TEACH TEAMWORK?

Teaching effective teamwork requires time. Faculty have an innate desire to stress content in class, which represents a challenge, especially for faculty teaching conventional classes rather than discussion-based or studio courses. Hermetically assigning time for teamwork allowed for supervised feedback and coaching during class and provided structure for effective team meetings outside class.

Many students enrolled in the classes reported doing so *despite* an emphasis on teamwork. Changing the language of Course II to emphasize "think tanks" instead of "teamwork" may have helped motivate students. The challenge is that overcoming students' prior bad experiences in teams fundamentally requires enrollment in a course with teamwork. Strategies to address the enrollment challenge remain unclear.

Week	Topics: Iteration 2	Topics: Iteration 3	*Changes made*
1	Creativity Profiles How to Create Teams that Function Well	Creativity Profiles The History of Creativity	*Added a lesson on the history of creativity, charting the evolution of the how creativity was conceived and researched over time.* *Moved the lesson on creating teams that function well to week 2*
2	Enhancing Imagination Leading innovation in teams Concept/mind maps	Enhancing Imagination How to Create Teams that Function Well	*Moved Concept/mind maps to Week 3 homework.* *Leading innovation in teams moved to Class 10*
3	Methods of Creative Thinking [combines asking the right questions, deliberate practice, and other methods] Sketch noting	Methods of Creative Thinking Sketch noting	*[None]*
4	Design Thinking Effective Presentations	Design Thinking Flow	*Added a lesson on Flow*
5	Student Midterm Presentations	Student Midterm Presentations	*[None]*
6	Generative Strategies	Generative Strategies	*[None]*
7	Innovation, Ideation, Incorporation Diversity and Creativity in Work Groups	Visit the ExCITe Center	*Lifting of lockdowns and the return to in-person instruction allowed for a visit to the ExCITe Center.* *Innovation, Ideation, Incorporation moved to week 8.*
8	How to Pick the Best Ideas and Implement Creative Ideas	Innovation, Ideation, Incorporation Growth and Fixed Mindsets	*Innovation, Ideation, Incorporation taught this week.*
9	Student Final Presentations and Reflections due	How to Pick the Best Ideas and Implement Creative Ideas	*Moved the lesson from week 8 to Week 9 which, in the first iteration, was taught in week 9 (at least in part)*
10	[No Class]	Topics in Creativity: Individualism vs. Communalism and Creativity Leading Innovation in Teams	*Added a lesson on topics in creativity and leading innovation.* *Moved final presentation to finals week to create more time to teach the course*

Note: The ExCITe Center is a research lab that emphasizes computing, robotics, and electrical engineering. The trip included a tour of ongoing research projects at the center as well as an opportunity for the students to meet with lab researchers who spoke on creativity and interdisciplinary collaboration and discussed the individual projects.

Table 3. Differences between the second and third iterations of Course I.

Week	Topics: Iteration 2	Topics: Iteration 3	*Changes made*
1	Class Structure, Expectations, Teamwork, Evaluations, and Framing the Research Problem Introduction to Creativity Teamwork	Class Structure, Expectations, Teamwork, Evaluations, and Framing the Research Problem Introduction to Creativity Teamwork	*[None]*
2	Faculty Panel at Library: Background, Literature, and Scope Librarian Panel Students refine their projects with librarian and staff guidance	Faculty Panel at Library: Background Literature, and Scope Students refine their projects with librarian and staff guidance	*Due to a smaller staff of librarians at the university, there was no librarian panel scheduled, nor would librarians be available to help students with their work*
3	Creative mindsets and learning Flow Teamwork	Flow Teamwork	*As the team member with expertise in creative mindsets was unavailable, students would not be taught about creative mindsets and learning*
4	[Human-centered] Design [and process] Project tuning, preparation for midterm presentations	Human-centered Design and Process Project tuning, preparation for midterm presentations	*[None]*
5	Student midterm presentations	Student midterm presentations	*[None]*
6	Hypothesis/Objective of the Research Question Teamwork	Hypothesis/Objective of the Research Question Teamwork	*[None]*
7	Panel: Professors Who Teach or Study Creativity Typologies	Panel: Professors Who Teach or Study Creativity Typologies	*[None]*
8	The Role of Logic and Intuition in the Creative Process Teamwork and coaching for final presentations	The Role of Logic and Intuition in the Creative Process Miro and team feedback using the preparation-incubation-illumination- verification model	*Final presentations were an additional week away, so an additional session was provided for feedback, focusing particularly on Miro (a platform that students and one of the instructors used).*
9	Panel: Creativity in Industry	Science of Team Science Teamwork and coaching for final presentations	*With the extra week, preparation for final presentations was moved to the ninth week. Additionally, moving the final presentation to finals week (instead of the last week of classes) allowed us to plan an additional lesson on the science of team science.*
10	[No Class – University Holiday]	Panel: Creativity in Industry	*The Creativity in Industry panel, previously taught in Week 9, was planned to be taught in Week 10.*

Table 4. Differences between the second iteration and (untaught) third iteration of Course II.

The uniformly positive student experience with teams is contingent upon a course structure that promotes, integrates, and explains how teamwork can be organized for a productive, enjoyable experience. Structuring the course to include team charters, discussions of team members' creativity profiles, and specific directions to self-assign roles based on the profiling directly correlated with the quality of the student output.

WHAT WAS LEARNED ABOUT DESIGNING TO TEACH CREATIVITY?

The course goals were to equip graduate students to be more creative in their research through (a) understanding creativity as a malleable skill necessary for research endeavors, (b) gaining the theory and practice behind strategies to improve creative thinking and output, both individually and in teams, and (c) opportunities to work with and learn from students and experts from a variety of disciplines outside the student's primary academic area. The expectation was that enrollment in Course I would then lead to enrollment in Course II and completion of the graduate minor in Interdisciplinary Team-Oriented Creativity.

Most students did not enroll in both courses in the program, which meant that across iterations changes in the syllabi had to be made assuming that students would only take one of the two courses. Specifically, Course I was designed without pre-requisites with an emphasis on theory and practice where the expectation was for students to build on the foundation in subsequently taking Course II. The original design of Course II, which emphasized how to inject creativity during the evolution of a research project, had only a minimal introduction to creativity, which subsequently evolved to include some creativity instruction like thematerial covered in Course I.

WHAT WAS LEARNED ABOUT DESIGNING AN INTERDISCIPLINARY PROGRAM?

Several challenges emerged that arose from a disconnect between the widely agreed upon benefits of an interdisciplinary experience at the university level and beyond, and the reality of teaching students from disparate disciplines. As an elective, the courses were competing with electives offered to students in their "home" departments. Although faculty, faculty advisors, and administrators from various disciplines and programs were supportive of the program goals and included the courses and the graduate minor in suggested course listings, student enrollment was poor. Despite poor enrollment, the student outcomes were excellent. The interdisciplinary course design was successful in providing students with the capacity to communicate complex, discipline-specific ideas across disciplines.

A profound lesson learned about designing an interdisciplinary program was that teaching the courses with a truly interdisciplinary team allowed the design team to model collaboration across disparate disciplines. The strong bonds developed during the course development, refinement, and teaching meant that the instructors, who were present for all the classes, contributed rich examples from a variety of disciplines in virtually every class. Further modeling the benefit of multiple instructors from a wide array of disciplines was the use of different teaching methods: the humanist often employed the Socratic method, the design expert brought electronic design tools into the classroom, and the business expert demonstrated coaching methods. Collectively, sharing the struggles and successes of the interdisciplinary instructional team with the students, coupled with modeling the processes being taught, provided an excellent connection between knowing and doing that positively impacted student learning.

Figure 4. "Team and Tools Journey Map" created by the most recent class.

Despite the benefits of co-teaching with professors in a variety of disciplines, being able to co-teach classes remains a challenge in many universities. For example, the university determined that because the course was co-taught by three professors on record, the three credits that would have gone to a single professor teaching the course were divided evenly among the three co-teachers. The main driver supporting the team teaching of ITOC courses was financial support through the NSF grant. The intention was that time spent over the summer on effective program design would lead to steady and improving enrollment, which in turn would lead to university support of the faculty through teaching load relief. In one instance, the dean of one of the university's colleges agreed to recognize each co-teacher's efforts as an in-load course. However, that recognition was later rescinded due to budgetary concerns.

WHAT WAS LEARNED ABOUT STUDENT OUTPUT?

Over the course iterations the instructional team became more closely aligned in the evaluation and metrics appropriate to gauge student output. As the courses evolved so too did the evaluation metrics:

1. *Excellence of literature incorporated into a proposal.* Students progressed from viewing literature searches as a necessary component of research to understanding the value of literature searches in identifying a truly creative idea. As students embraced the benefit of literature searching, their searches evolved in increasingly innovative ways, firstly by using tools in other areas modeled by the professors and subsequently by using different creative search tactics.
2. *High-level use and integration of tools into the projects and research, such as concept mapping, stakeholder mapping, affinity mapping, and tools in the* Zig Zag *book.* Designing the course around teaching-then-doing, both in the content-rich sections of the class and during the teamwork sessions facilitated student assimilation of core ideas and techniques. During the pandemic, the professors introduced digital whiteboards specifically prepared to practice newly introduced tools and skills. Students were encouraged to create and ideate uses for individualized whiteboards as part of their project development. The electronic tools proved to be very popular so were carried over to the last hybrid class in which the students very effectively used several different electronic tools to track their research process, develop the project design, and monitor project development.
3. *High-level use of tools and strategies to improve the student team's collective creativity and ability to collaborate.* Students in the final course created a "Team and Tool" journey map showing how they integrated the tools and process into the development of their outcomes (see Figure 4).

In their final presentation, the last group of students was able to provide examples of how different creativity and implementation tools were used as they designed an "Engagement Box" to address food insecurity on campus (see Figure 5 for an example of how they presented their ideation process; see Figure 6 for an illustration of students' proposed "Engagement Box," including a list on the bottom of three strategies applied during the creative process).

CONCLUSIONS

The design and development of interdisciplinary courses create unique but surmountable challenges. The biggest challenge for this project, and probably for most truly interdisciplinary courses, is the enrollment of students from disparate disciplines. The team-taught nature of this program and the courses provided a great learning experience but created barriers to enrollment. The two courses were designed to enhance graduate student creativity, which, by the metrics employed, indicated that the courses were particularly effective in fostering students to become more creative.

Running the three iterations of two courses over three years refined several aspects of the curriculum and the teamwork that led to high-quality student products. The lessons learned include incorporating strategies to ensure students understand how to create high-functioning teams, modeling interdisciplinary teams by teaching with an interdisciplinary instructional team, working through challenges caused by a diverse instructional team to improve the course, and navigating enrollment challenges. The syllabi, experiences, and insights are shared for people to learn from and successfully implement similar courses and programs.

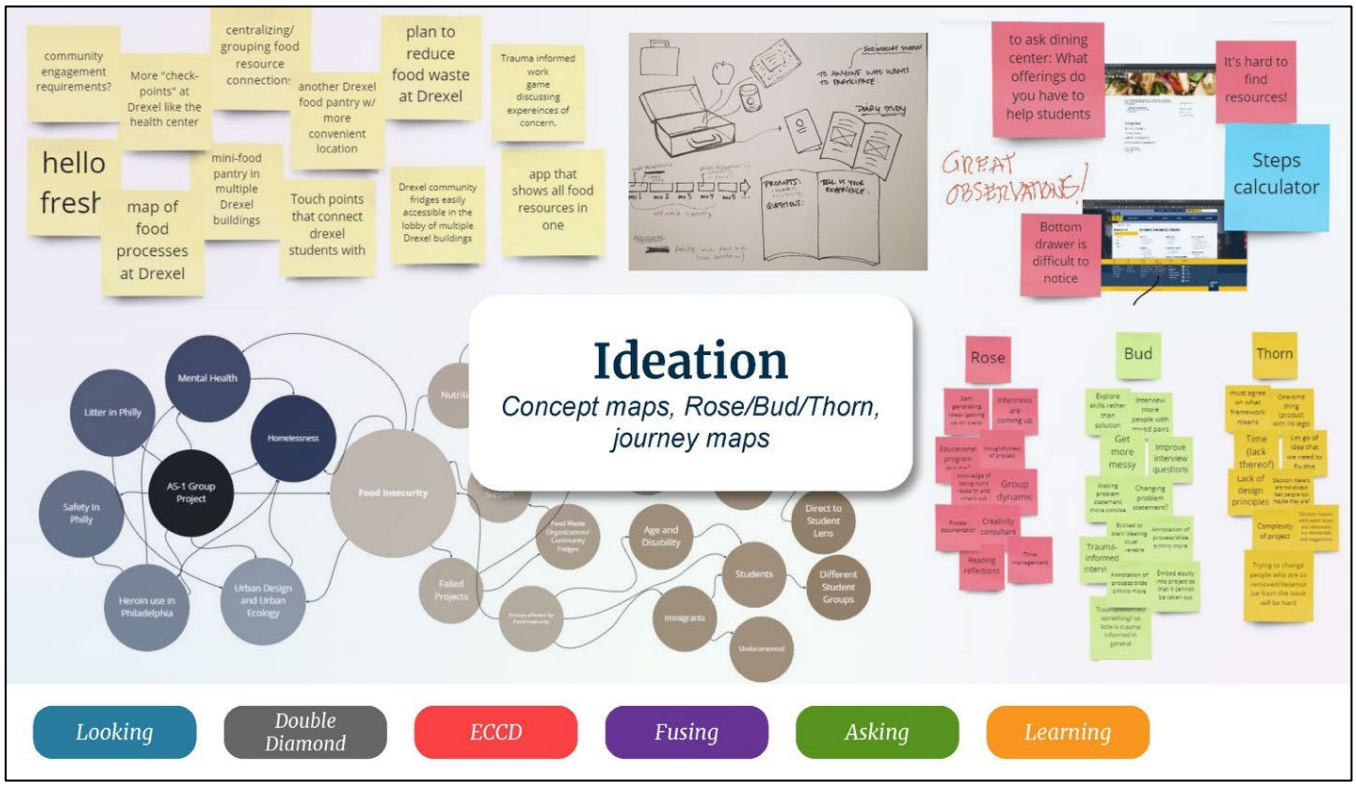

Figure 5. Slide created by students in the third iteration explaining their ideation process using the "Team and Tools Journey Map".

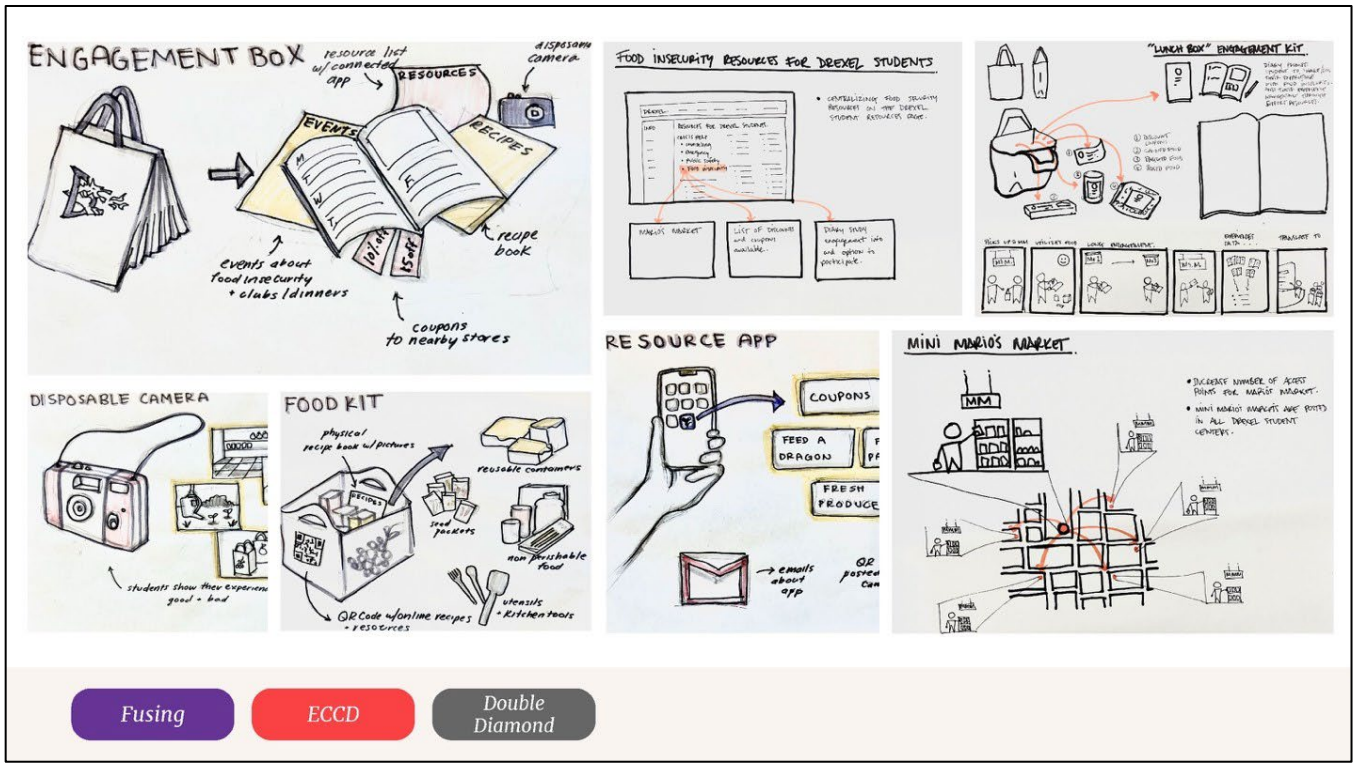

Figure 6. Illustration of students' proposed "Engagement Box".

With the conclusion of NSF funding and the continued enrollment issues, the future of the courses is uncertain. The recruitment challenge led Authors 4 and 7 to survey industrial contacts to see whether ITOC could be repackaged as a professional development course. In response, the company representatives indicated that they expect their employees to learn creative problem-solving in their academic degree programs. Additionally, while there was support for turning ITOC into a micro-credential, the design team felt that turning the minor into a micro-credentialling program would not solve the recurring issues. Currently under development are several resources to better package the courses and program for dissemination and marketing, including a pitch deck to take the accomplishments across the university and region. In addition, new strategies for moving the program forward, along with institutional changes and restructuring that are part of the higher education post-pandemic landscape are being examined. One such strategy is relocating the program to better align with topic areas in the university, such as design, that are considered centers of this type of coursework.

Despite excellent student outcomes and strong endorsement from some faculty supervisors and administrators, the ITOC graduate minor has not been able to overcome the institutional obstacles to make the program sustainable. The design team remains committed to interdisciplinary collaboration, teamwork, and the graduate minor in *Interdisciplinary Team-Oriented Creativity* and hopes there is an opportunity to continue this project.

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