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Transformative but Not Easy: Students' Experiences of an Interdisciplinary, Project-based Capstone Course

Alice S. N. Kim*
Teaching and Learning Research In Action; University of Guelph-Humber, alice.kim@tlraction.com
Danielle Robinson*
York University, drobin@yorku.ca
Celia Popovic
York University, cpopovic@yorku.ca
Alecia Carolli
Teaching and Learning Research In Action, alecia.carolli@tlraction.com
Brad Jennings
Teaching and Learning Research In Action, brad.jennings@tlraction.com
Franz Newland
University of Ottawa, fnewland@u0ttawa.ca

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Transformative but Not Easy: Students' Experiences of an Interdisciplinary, Project-based Capstone Course

Abstract
In this study we explored the experiences of students who completed a project-based, interdisciplinary capstone course that was offered at a large university in Southern Ontario, Canada. To do so, we interviewed students after they completed the course, adopting a constructivist perspective and a phenomenological approach. Interview transcripts were analyzed, resulting in four themes: (1) communication, (2) group dynamics, (3) successes, (4) differences between program requirements. In addition to revealing tension between fostering student autonomy and providing students with support, our findings also demonstrate that students valued the capstone course for the knowledge and experience gained from learning to work as an interdisciplinary unit rather than the tangible output of a given project.

Dans cette étude, nous avons exploré les expériences des étudiants et des étudiantes qui ont suivi un cours de synthèse interdisciplinaire basé sur un projet, offert dans une grande université du sud de l'Ontario, au Canada. Pour ce faire, nous avons interrogé les étudiants et les étudiantes après la fin du cours, en adoptant une perspective constructiviste et une approche phénoménologique. Les transcriptions des entretiens ont été analysées et ont permis de dégager quatre thèmes : (1) la communication, (2) la dynamique de groupe, (3) les réussites, (4) les différences entre les exigences du programme. En plus de révéler une tension entre la promotion de l'autonomie des étudiants et des étudiantes et le soutien qui leur est apporté, nos résultats démontrent également que les étudiants et les étudiantes ont apprécié le cours de synthèse pour les connaissances et l'expérience acquises en apprenant à travailler en tant qu'unité interdisciplinaire plutôt que pour le résultat tangible d'un projet donné.

Keywords
capstone course, interdisciplinary, multidisciplinary, collaborative learning; cours de synthèse, interdisciplinaire, multidisciplinaire, apprentissage collaboratif

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Capstone courses enable students to integrate what they have learned throughout their program of study (Durel, 1993). They prompt students to draw on and apply the knowledge and skills that they have acquired throughout their university experience (Hirsch & Parihar, 2014). All capstone courses, no matter the overarching discipline, aim to provide students with enriching experiences that enhance their ability to think, communicate, and apply theory to practice (Lee & Loton, 2019). Though all capstones have this common purpose, they come in different forms (e.g., Hovorka & Wolf, 2019). Some courses require students to work independently under the guidance of a mentor, whereas others involve collaborative teamwork. In the latter scenario, team members may come from the same discipline or from various disciplines, resulting in a multidisciplinary team. The term 'multidisciplinary' indicates the involvement of multiple disciplines, however, the nature of this involvement may differ. Multidisciplinary work stems from different disciplines working in parallel. In contrast, interdisciplinary work requires integration, which includes fostering connections between disciplines into a coherent whole (Choi & Pak, 2006; Gouvea et al., 2013; Stember, 1991). In this study, we explored the experiences of students who completed a project-based, cross-faculty interdisciplinary capstone course and we offer recommendations to others who are teaching in similar contexts based on the lessons we learned.

Project-based capstones afford the benefits of high student engagement and motivation while being conducive to the high impact practice of collaborative learning (Cabrera et al., 2002; Kilgo et al., 2015). More specifically, past research shows that when students select projects based on interests, this promotes high levels of student motivation and engagement, particularly when the projects are connected to their career aspirations (Fedoruk et al., 2014; Schwering, 2015) or when they believe that the project contributes to the greater good (Jones et al., 2013; Layman et al., 2007). Moreover, project-based capstones offer the possibility of having students work in teams that involve multiple disciplines. Given that one of the objectives of multiple disciplinary approaches is to solve "real-world" or complex problems, and that this approach is being emphasized increasingly in various sectors, including health and education (Choi & Pak, 2006), working in teams involving multiple disciplines provides students with invaluable experience for the workforce.

In this study, we investigated the experiences of students who completed the first offering of a collaborative, project-based capstone course that involved working in teams composed of members with different disciplinary backgrounds: the Cross-Campus Capstone Classroom (C4). C4 spans across multiple faculties, departments, and majors, providing a disruption to academic structures within our university, which by design supports separate faculties, departments, and majors. The main goal of C4 is to provide students with a safe and supportive space to hone the skills needed to work effectively as part of an interdisciplinary team, integrating the views and skills of multiple disciplines towards their project solution. In this way, C4 marks a departure from traditional approaches to capstone courses which "cap off" the learning typically at the end of a single program.

Overview of the Cross-Campus Capstone Classroom (C4)

Course Delivery

C4 was first offered at York University during the 2019/2020 academic year and was delivered by a collaborative team of course instructors from Arts, Engineering, Science, Health, and Liberal Arts Faculties. 77 students from 23 different majors, which in turn were spread across 7 different faculties, were enrolled in C4. The class met in-person for three hours every two to three weeks across the year for a total of 13 class meetings. The classes were led by two instructors, with some in-class teaching support from members of the C4 Leadership Team;

this team was composed of eight course instructors from five faculties who met weekly to collaboratively plan classes and make curriculum decisions. In C4, students work in teams on projects that are designed to have social impact and are proposed by partners. Each partner that offered a challenge for a student team to work on provided at least one representative to support the students on project development throughout the course. However, students were encouraged to define the project as they saw fit and were not beholden to the wishes of the partner. The projects were led by the students, with partners serving as mentors, not supervisors.

In early September 2019, students who were enrolled in the first offering of C4 chose from 41 projects, which were referred to as "challenges" given their framing as open-ended questions. These projects were pitched to the students by partner organizations. The projects fell into one of the following nine themes: Environment and Sustainability; Health and Wellness; Technology and Design; Social Justice and Community Engagement; Thinking Globally and Acting Locally; Education and Mentorship; Business and Industrial Markets; Digital Communication; and Arts, Media, and Culture. The 77 students were organized into 11 teams based on their top five project choices. The partners for these 11 projects included 3 on-campus units; 5 non-profits; 1 start-up; and 2 established businesses. The 11 projects shared thematic emphases on learning, sustainability, youth social justice, health, and technology.

The COVID-19 restrictions started about six weeks before the end of the course, presenting challenges for many teams to complete their projects as planned. The original plans included ending the school year with a Capstone Celebration Day event, in which teams would have publicly presented their projects and competed for awards and prizes. However, due to the restrictions of the pandemic, in place of the Capstone Celebration Day, the final online class became a celebration of the teams' distinct project journeys. Each team presented and took questions and comments afterwards. In addition, the teaching team presented a video to the class that captured their own project journey of creating and delivering C4 for the first time as an interdisciplinary team. Despite the absence of a public capstone day, there was still an opportunity for student projects to be asynchronously judged for prizes. A Capstone Award Committee created awards for Interdisciplinarity, Social Impact, and Knowledge Mobilization. Teams competed for these awards by submitting their project portfolio to the committee, which included two or three external judges for each award.

Administrative Logistics

At our institution, faculties consist of multiple departments, which in turn consist of multiple programs. Programs consist of one or more majors that share courses, including capstones. Since courses at our institution are offered by departments within faculties, there wasn't any precedent for a pan-faculty course like C4. Consequently, to enrol in C4, students had to register in a course offered by their home department that gave them permission to complete C4 instead of following the original syllabus for the "home" course. Through these "gateway courses," students were able to receive credit within their major or as an elective for completing C4.

Three programs that offered gateway courses to C4 required their students to also meet additional requirements of the "home courses." One of these programs was the Engineering program, which also required students to complete its own set of assignments and to attend its own classes, apart from C4, due to their program accreditation process. This differentiation in classes and assessments seems to have resulted in some challenges among Engineering students and the other students in their teams, in terms of both course work and group dynamics in general. As discussed further below, these issues, among others, were raised in the interviews we conducted with students to learn more about how students can be better supported in C4.

Method

Participants

All students enrolled in C4 were invited to participate in this study after the final grades for the course were submitted to the university. Students were emailed information about the study, as well as the link to the informed consent form that they were instructed to fill out if they wanted to participate in the study. The 70 students who were enrolled in the course came from the School of the Arts, Media, Performance and Design (7%), as well as the Faculty of Education (1%), Environmental and Urban Change (11%), Health (4%), Liberal Arts & Professional Studies (36%), Science (4%), and Engineering (26%), as well as the School of Business (9%) and the French campus (1%). Eight students participated in the study (approximately 11% of students enrolled in the course). As mentioned above, the course ended after the start of the COVID-19 pandemic lockdown during the Winter 2020 semester. More students may have chosen to participate in this study had it not been for the pandemic and the corresponding restrictions.

The research plan was approved by our institution's Ethics Review Board. Of the eight students who participated in this study, seven were completing the final year of their undergraduate program, and one was a master's student; they represented four programs and one was an international student. To ensure students' anonymity, we did not collect demographic data about the participants.

Interview Protocol

Students were interviewed after they completed the course. All the interviews were conducted by the same member of the research team who has conducted and published interview studies previously and was not involved in any way in the delivery of the course. The interviews were semi-structured (please see the Appendix for the interview questions) and conducted remotely using a teleconferencing platform (Zoom) that enabled both video and audio communication. On average, interviews were approximately 60 minutes in length. Although both video and audio were recorded, only the audio component of the interviews were transcribed for subsequent analysis. The interviews were transcribed by a research assistant, which were then checked for accuracy by another member of the research team.

Qualitative Approach

We adopted a combination of positivist (small q) and non-positivist (Big Q) qualitative approaches in this study. Specifically, we conducted the present study with the notion that our findings would be specific to our context as opposed to being generalizable across all contexts, aligning with a non-positivist approach to qualitative research (Clark et al., 2015). However, our thematic analysis procedure included consensus coding, as described further below, aligning with a positivist qualitative research approach (Braun & Clark, 2023). Although we agree with the non-positivist qualitative notion that coding data is an interpretative and subjective practice, our data were analyzed by multiple coders with the aim of producing findings that reflected multiple perspectives, which we believe adds additional strength to our study.

Thematic Analysis

We conducted a thematic analysis on the interview transcripts (Clarke et al., 2015; Vaismoradi et al., 2013), specifically in relation to students' experiences of the course. We used a constructivist perspective and a phenomenological approach, which is commonly applied and offers valuable insights into the subjective experiences of individuals. According to the constructivist view, knowledge is not discovered but rather socially constructed and emphasis is placed on the participants' perspective of the phenomenon being studied (Mackenzie & Knipe, 2006). Phenomenology focuses on the essence of experiences and seeks to uncover the meaning of lived experiences from the perspective of the individual (Creswell, 2018; Vaismoradi et al., 2013). This approach prioritizes the participant's voice and seeks to understand their experiences in their own words (Creswell, 2018), providing rich, in-depth insights into the subjective experiences of individuals.

Three members of the research team, including the interviewer, took steps to ensure inter-rater reliability. Firstly, data were analyzed both inductively and deductively through a consensus coding process whereby team members individually read through a subset of the interview transcripts to generate themes. They then compared their coding of the transcripts and continued to discuss the findings until they achieved consensus on the meaning of each theme. The resulting themes were then used to code the remaining transcripts. Where necessary, themes were modified based on consensus by the research team. Representative quotes were chosen for each theme using the same approach.

Results

The following themes were extracted from the interviews: (1) communications, (2) group dynamics, (3) successes, (4) differentiation between programs. Each of these themes are described below.

Communications

Communication was a recurring theme in the student interviews. These findings are categorized as communication among students within a team, communication between students and instructors, and communication between students and their project partners.

Students within a Team

Our student respondents regarded communication as key to teamwork, "We need to communicate. If we don't do that, we are not a team" (S8). They also commented on how working on their C4 project required more communication amongst members of their team than other projects that they had completed:

> We had to figure out when to meet up, how long the meetings would be, it was all our own work … what kind of online communication we prefer as a group … we had to figure that out ourselves, we didn't really know the best way … It was a lot of team communication… compared to other group projects and courses, this needed a lot of engagement and initiative from ourselves. (S2)

Students also noted difficulties in communication due to the communication style of the members of their group, including how frequently they used their phone, and differences between how students in their group communicated in-person versus using technology:

> I know I keep going back to communication, but I still think that's probably, that is the factor that may have hindered our success a bit, because people have different ways of communicating. So, for example, I am always on my phone, so I am always replying to messages and acknowledging them, but other people might not do that. Maybe it doesn't come natural to them or maybe the way that they use technology is different. So, the way they talk in person is different from the way they use their technology. (S3)

On a more basic level, students also identified a lack of communication in the early stage of the project: "I think in the beginning it was a bit difficult with communication. People would go off and do their own thing. We obviously knew everyone was doing work, but we were unsure what" (S3). They also noted that "it took a while for us to vocalize in our group and talk about our concerns" (S4).

Students and Instructors

Generally, the need to address instructor/student communication was linked to the challenge of getting to know and feeling comfortable with an instructor from another faculty. As a student commented, with courses offered by their home faculty, students get to know the course instructors, "So when you have someone from your own faculty, you feel like somebody from home is here" (S8). Students commented on the value of talking with their course instructor, someone who was not a member of their team but linked to the course, especially when it was necessary for teams to have difficult conversations. Students shared that these challenging conversations were made easier when they were facilitated by someone who was not part of the group. Here a student describes the positive impact made by an instructor: "he was facilitating the conversation and we were just able to talk really about each other's concerns and try to find a solution together by setting up rules and expectations on each other" (S4). Our respondents also indicated a desire for instructors to spend more time with their teams in class, providing more guidance in project management: "We needed more guidance with project management, … some people took too much work and the work didn't get distributed very well" (S1). While project management was addressed in class, instructors had encouraged students to engage in their own supplementary investigations on the topic.

Students and Partners

As mentioned above, in C4 the projects were led by the students and the partners served as mentors for the students, but not supervisors. This seemed to cause issues for some teams, because it either took the team some time to realize the control they had over the scope of the project, or there were challenges in communicating a change of direction to the partner. In other cases, students commented on how periods of disconnection with their partner and confusion relating to how much the partner should be involved led to wasted time:

> We got an idea that we have to do their project….we kind of just cut off from them [project partner] and we started to do things, our own stuff… everybody was like you are no longer doing anything with them and they are no longer in connection with you. So first we were told we had to do the things, our own stuff and not their project, it is going to be ours. But, then they feel like we are disconnected from them… So then we changed, and we involved them into our project… We wasted our time and energy. (S8)

Group Dynamics

Students identified several aspects of group dynamics when discussing their C4 experience. These are presented here as a) group cohesion; b) the value of interdisciplinarity; and c) challenges of specialization.

Group Cohesion

Our student respondents acknowledged the need to work together and to meet regularly as a team, more so than in other courses. Regular meetings were regarded as being necessary for group cohesion: "I feel like one time a week was not enough; we needed two times a week to be moulded and like connected as a team" (S2). Students also indicated the importance of meeting with their team, even when there was not much to discuss, to maintain feelings of connection with members of their team: "Over the time we really discovered that even if we didn't have a lot to talk about it was very important for us to take the time to connect with each other" (S4). Lastly, a key issue linked to group cohesion was that some students had different expectations and levels of commitment to the course.

> It was really hard to have the full attendance... Even having two meetings per week, not everyone attended still. Yeah so like half the group wouldn't make an effort, or have a consistent attendance and then the other half would be there. I didn't feel like, half of the team was not committed to the project. (S2)

Students also commented on the importance of trust and interdependence among members of their team. This included trusting others to do their assigned work, and supporting each other when there were challenges with schedules for example:

> … even from the beginning if a group member had like some travel thing that they had to go to, we would say go and we will do your part. And it wasn't that someone was taking advantage of another person, it was just like the person would come back and say look I missed this one, let me do more work in the second assignment. (S6)

Our respondents also noted the importance of having empathy for the members of their team, and adopting a positive approach to conflict management, "As soon as there is a conflict if you have empathy towards the other person, you're like let me put myself in their shoes, or what can I do to fix this situation, rather than vilifying the other person." (S5)

The Value of Interdisciplinarity

Our respondents indicated that working successfully as an interdisciplinary team was directly related to growth, and they specifically highlighted the benefits of being open to multiple viewpoints with respect to problem solving, as in this example:

> And there is a group of students who can help provide you with different viewpoints and can help you solve your own problems. Being open to other people's viewpoints, so like you can like do your part better and contribute better to the project. (S2)

Several of our respondents shared the view that working effectively as an interdisciplinary team led directly to a better project solution and to greater innovation: "My opinion after working on the project, is that is how the world's problems are going to be solved, through interdisciplinary collaboration" (S3). In general, having an opportunity to work with individuals with different disciplinary backgrounds and learning how to shift one's own perspective to a different disciplinary lens was valued highly by our respondents:

> C4 does provide you with this opportunity to work with different people from different backgrounds, so the biggest thing you can take out from that is how you can change your perspective or approach your problem from their point of view. (S6)

Challenges of Specialization

At the same time as valuing interdisciplinarity as a key characteristic of C4, students also brought their specializations to the mix. Students mentioned the high degree of homogeneity they were accustomed to within their majors, leading to shared understanding with each other, as they had common reference points:

> I think in other courses in undergrad … you are kind of like everyone else in your classroom. Everyone has been going through the same educational experiences…the way in which we communicate with each other is a little bit more homogeneous. (S6)

They connected this with frustrations that arose while working within diverse teams. For example, one student noted, "I guess people know that having more opinions are better, but I think there becomes a point having too many people from different disciplines kind of over balances the efficacy of team working." (S5)

Students commented on how they were not accustomed to working with other students from different disciplines, and that it took some adjustments: "It was different because people were doing it in different disciplines and they were doing it with different skills and we had to combine our skills into, actually, our project, and not just a small assignment" (S8). Our respondents also noted difficulties in integrating the perspectives of others from different disciplines (faculties), "Yeah, how to take different viewpoints, consider different viewpoints from like different students from different faculties … a big issue in our team was that some people didn't really want to take other people's perspective" (S2). It seems that students are more likely to be willing to put in the additional effort if they appreciate the value of interdisciplinary work. For instance, one student said, "I also knew that interdisciplinary work is very important but it is not going to be easy" (S6).

Successes

Our respondents identified two factors that contributed to the degree of their personal success and team success in their C4 journey: a) personal and professional development; and b) accomplishments.

Personal and Professional Development

For many the key to success is understanding what skills they need to develop and improve, exceeding their own goals and expectations, overcoming challenges, and learning

about themselves while developing new skills and knowledge. Team assignments and classroom activities provided opportunities for self-reflection in relation to skill development: "We were able to discuss our skills within the group and what they individually needed to do in order to develop skills" (S4). Three students commented on goals:

> You just set up some goals for yourself, for your team... I think if you think that 70% or 80% of the goals are targets, you just thought you would do, and you were able to do it, then I think you are successful. (S8)

One student reported finding success by overcoming personal and team challenges:

> I think in terms of the project, success is when you are able to overcome an obstacle that you are facing in the development process... you don't necessarily have to come to the best conclusion or result of your project, but I think if you're able to make some sort of progress in overcoming a challenge ... that is an indicator of success. (S3)

Many students defined success as learning more about oneself and learning new skills:

> I would say that a student is able to achieve success when they learn something new, not just tangibly like skills, but, also, maybe even about themselves. Even if the project didn't turn out exactly the way they wanted it to, it could still be seen as a success if they were able to learn something about themselves in the process. (S3)

Students also noted that C4 gave them opportunities to develop public speaking, teamwork and communication skills. Moreover, students commented on the need to take the initiative in this course, declaring that it is unwise to rely on someone else to sort out the project; instead, every team member must accept responsibility for addressing problems and challenges--for gaining skills or knowledges needed by the team: "Even if members of the group were shy, they need to practice their public speaking" (S1). They also referred to teamwork as a skill, and a set of skills needed to counter the challenges of working on a team project, which is very different from the individual assignments that were more commonplace in their home program. One student noted, "I learned how to listen to different viewpoints from different areas of knowledge" (S2), and another student commented that they noticed that "People have different ways of communicating" (S3).

Accomplishments

For some students, success was based on the awards and grades accomplished individually and as a group through the project. For example, one student noted that "The project I would say was successful, I mean we got an award … I was really happy with that" (S5). Another student shared that "The final grade tells you about the quality of your project…It's the people you work with that makes your project successful" (S2). Our respondents also valued the relationships that were formed:

> But I think getting to meet people from different disciplines was honestly the one thing that I really, really appreciated because I made friends outside of the disciplines. I made pretty good friends in my group actually … it turns out I guess just that the team was the thing that was most memorable. (S5)

Differences between Program Requirements

Aside from challenges of specialization reported earlier, students shared that diverse requirements of the home programs led to internal divides within the teams. Differences between program requirements were most obvious between Engineering and non-Engineering students, due to having a different set of classes, assignments and deadlines:

> So, I think the tension in the beginning was that we were saying that we [Engineering students] have the right to push because we have due dates, but at the same time they were saying are you sure you are just pushing for the due dates and you are not trying to take over the direction of the team. (S6)

Our respondents highlighted challenges related to students within a single team having different assignments, timelines, and marking expectations. They described how this segregated the teams from within, set up opposing sub-teams, and created internal power struggles. This misalignment was repeatedly identified as an enemy of good teamwork:

> …part of the challenge in like organizing our team … it was quite confusing in satisfying both of our capstone requirements. So, I feel like that was, that hindered our success because it was something to work through. (S2)

In terms of perceived differences attributed to discipline specific approaches and expectations, one Engineering student expressed the following opinion:

> I think the challenge came in like we already have that stereotype [of] engineers … And engineering is always known to be like oh you know it all … they tend to be very, you know, elitist to some extent. And we were conscious about that, even in the first class we were like we may have this problem, so we have to be wary of that... it was just the case of [the Engineering course] was so fast, that at times we were kind of pushing the C4 team. We were like okay we got to move on to the next thing and they didn't have that pressure because the course was different, the deliverables were different, we had to be careful. (S6)

Here a non-Engineering student describes their experience of the disconnect:

> I guess they [the Engineering students] never really asked for our opinions. Like the way they would ask us to do something … we really were just pushed to the back. You know they really always took on the lead of the project, like "this is how we are going to do it." It was never "how do you guys want to do it?" It was always like "this is what we want to do. What can you guys sprinkle on top of it?" (S7)

However, despite any challenges that arose in groups that included Engineers and non-Engineers, students still expressed general concern for the success of their teammates. In the following passage, an Engineering student describes how it was important to them to stay on top of assignments that non-Engineering students in their team, but not themselves, were being assessed on:

> So, it was interesting in a sense because usually in Engineering we work hard to meet all the deadlines but this time we had to worry about two deadlines but then the other deadline we weren't really being [assessed] - we knew it was for the bigger picture of the project, we had to be on point. Even if you weren't being assigned for that because ... the C4 section of our team was being marked for those things. (S6)

Our findings may have been influenced by social desirability bias, which can occur when respondents are led by a desire to portray themselves in a positive light rather than reporting their actual behaviours or attitudes (Fisher & Katz, 2018). This tendency can lead to over-reporting of desirable behaviours and under-reporting of negative ones, which can affect the accuracy and validity of research findings (Kreuter, Presser, & Tourangeau, 2018). We were also careful, however, to mitigate against social desirability bias. As mentioned above, all participants were interviewed by the same member of the research team who was not involved in the delivery of course. Additionally, we did not collect demographic data about the participants to help ensure students' anonymity and to encourage our respondents to speak openly and truthfully about their experiences (Johnson & Van de Vijver, 2003).

Discussion

Our findings from this investigation reveal tension between fostering student autonomy and providing students with support, and that students valued C4 for the opportunity to learn how to work effectively as a member of an interdisciplinary team as opposed to the tangible output of their project. The findings of this study help to inform the continued improvement and expansion of the course; just as C4 proved to be a meaningful learning experience for students, many lessons were also garnered by the instructors and members of the C4 Leadership Team who helped support the classroom activities. With the hope of helping others who are working or planning on working in similar contexts, we share lessons we've learned and our recommendations below.

At times, there was confusion and even a degree of conflict between (1) the instructors' aim to provide students with a learning experience in which the students are able to apply their skills with independence and (2) the students' wish for direction, guidance, and support. Our findings suggest that students in C4 were both proactive and passive in the course. For example, students were proactive in assigning themselves positions within their teams and then followed through to take on the responsibilities for these roles. However, students wanted more guidance than they were already receiving on project management, which made it difficult for the instructors to balance providing this guidance to students while also supporting students' autonomy. In C4 the goal is to give students as much autonomy as they can handle, while also making sure they feel firmly supported along the way. Interestingly, in C4, where students were left to make their own decisions, some students appeared to have felt a sense of ownership for their project, whereas others felt disempowered and uncertain about their ability to be successful in the course. Along these lines, in the context of another interdisciplinary project-based learning context where students studying Civil Engineering, Industrial and Engineering Management, and Applied Mathematics worked together towards enhancing traffic to and through a hospital, MacLeod and van der Veen (2020) described that students "felt like they lacked both guidance and various constraints they could work with at the outset, which affected their motivation and ability to participate in any deep way in an inter-disciplinary process." Past research shows that the amount of support students receive from advisors can either enhance or hinder students' motivation in a capstone project (Henry et al., 2012; Jones et al., 2013). Multiple factors likely influence the optimal level of support in any given context,

including the task at hand, students' level of study, and individual differences, making it difficult to assess what the optimal level of support is before meeting students in the course and even afterwards, when they are working within a team.

We found that students in C4 expected the instructors to intervene and help resolve conflicts that arose within their teams, which we interpret as an element of passivity. The tension here is between (1) integrating conflicting disciplinary viewpoints and (2) a desire to have the conflict resolved by another party. This may indicate a lack of communication strategies and comfort on the part of students for addressing such challenges. Among other things, this could lead to feelings of frustration, which we discuss further below. Interestingly, the ability to integrate conflicting insights from two or more disciplines has been regarded as a cognitive ability specifically associated with interdisciplinary learning (e.g., Repko, 2008). Also, past studies suggest that students are hesitant to openly express constructive criticism of their team because they are not used to this kind of professional interaction with their peers (Friess & Goupee, 2020). Together, these findings highlight the importance of intentionally supporting the development of students' ability to integrate conflicting insights from multiple disciplines through constructive and collaborative communication with the members of their team.

Students in C4 indicated that they felt frustrated at times, especially when they believed that their time and efforts were wasted due to miscommunications and misunderstandings about the goals of the course or the roles of the student teams vs. partners. This sentiment is consistent with the general finding that changes in teaching practice and the roles and expectations of students and teachers in a learning context may give rise to a sense of uneasiness among both students and instructors (Lindvig & Ulrksen, 2019). However, all the students in this study agreed that the course was invaluable in terms of what they learned and, in time, came to realize about themselves and their disciplines, working in interdisciplinary teams, as well as all of the skills they gained throughout their program of study. The students were guided by instructors to view the inevitable setbacks, failures, pivots, and conflicts involved in projects as opportunities for discovery rather than roadblocks. We suspect that the students gradually shift their mindsets in this way and in their own time, and that allowing students to sit with complexity and discomfort helped them to appreciate the process-oriented perspective on which C4 is founded. Warr and West (2020) have described similar student experiences relating to teamwork, group function, and interpersonal skills, as have Van den Beemt et al. (2017) in terms of challenges as well as reported benefits.

An unintended consequence of offering a pan-faculty capstone course was the need to assess different groups of students based on different grading schemes and due dates, which contributed to conflicts and even fractures within student teams. As mentioned above, although C4 had its own syllabus and assignments, three programs that participated in the course required their students to also meet additional requirements of their own gateway courses. The intention was not to create more work for the students, but to align C4 with program requirements. In the case of two of the programs, the gateway course expectations served as a means of delimiting and clarifying the contributions their students might make to their team. In the case of the third program (Engineering), students had to complete a separate set of assignments and attend a separate set of classes for their gateway course in addition to the work of C4.

In both of the scenarios described above, there was a significant negative impact on teamwork and thus the final project. In the first scenario, where the expectations of the gateway course delimited the students' contributions to the C4 projects, the students chose to focus their contributions to their team project on what was specified by their "home program" rather than doing what the team most needed. They waited until it was time for them to do "their part," rather than seeing themselves as core team members whose perspectives enhanced the whole

project. In effect, they acted like consultants rather than full team members. In the second scenario, where students had to complete a separate set of requirements for their home program, the relevant teams fractured despite the attempts of the instructors to facilitate stronger cohesion amongst its members. Students from this program struggled to keep track of and keep up with what was expected of them in C4 alongside the expectations of their gateway course. Most of these students stayed active within their C4 project teams, but almost never came to the C4 classes, nor did they complete the assignments that were unique to C4, which we suspect were seen by the students as being extra, unnecessary, or outside their major. This type of "fracturing" of a team has also been reported elsewhere. For example, Shakila et al. (2021), note that "students prefer to bring their own expertise leading to disciplinary division of tasks," while Sortland (2019) describes the needs for explicit support approaches to avoid such challenges "including interaction rules, mutual expectations of one another's contributions and providing rules and methods for how to deal with conflict."

Our findings align with past work reporting that group interactions allow members of a capstone team to form caring relationships and enjoy their capstone experience together, and that students feel comfortable working together when all team members respect each other and are committed to maintaining a functional group dynamic (Jones et al., 2013). The effect of working with peers from a range of disciplines encouraged our students to realize that while disciplines may foster diverse ways of viewing the world, understanding each other as people helps when dealing with conflicting viewpoints. Students specifically spoke about having empathy for members of their team when conflict arose so that they would be better positioned to work productively towards a solution as opposed to resorting to vilifying those with whom they were in conflict: a powerful lesson that can be applied to any setting. Our students also acknowledged that widespread communication differences across individuals, especially with respect to the use of technology, and not necessarily disciplines led to major imbalances and disconnections within teams, highlighting further the importance of developing mutual understanding within a team in the face of both disciplinary and individual differences. Key to this were lessons related to relationships, teamwork, and communication skills.

Lessons Learned and Recommendations

Based on the lessons learned, in the sections that follow, we share our top two recommendations for individuals working in similar contexts that involve working in interdisciplinary teams in project-based courses.

Explicitly Provide Students with Timely Tools and Resources to be Autonomous

As mentioned above, it was challenging for C4 instructors to balance fostering student autonomy with also providing students with the support that they needed and the support that they expected. In C4, it was important to make it explicit to students that they were expected to work autonomously, and to also provide students with as much autonomy as they could manage, while also making sure they felt firmly supported along the way. From the perspective of instructors throughout the delivery of C4, students were in the best shape to work productively in their teams when they were provided with lessons, tools, and resources that were explicitly linked to the current stage of their project process. For the instructors, taking a student-centred approach meant that they had to be both adaptive and flexible regarding the content covered in class each week, as well as the class activities and the distribution of class time in general, so that classes aligned with the work that students were completing in their teams. This did not come easy for all the instructors, requiring them to work outside of their comfort zones and in contrast to how they had grown accustomed to directing their own

courses. It is also important to keep in mind that since interdisciplinary capstones separate students from the safety and community of their own disciplines and set a very high bar in terms of critical thinking skills (synthesis), not all students will be ready for it at the outset. For this reason, it is important to provide explicit disciplinary supports within the classroom, and to work steadily towards interdisciplinary synthesis as a class and within individual team consultations. This is in line with what Van den Beemt et al. (2017) describes as "a set of resources to help conceptualize interdisciplinarity in more concrete terms" that help students to become more aware of the contextual factors relevant to working in teams reflecting multiple disciplines.

Value Interdisciplinary Teamwork over the Project Outcome/Deliverable

In addition to students working autonomously in the course, the C4 instructors have also come to recognize the importance of explicitly and continuously communicating to students the value of interdisciplinarity, and that working in this way requires additional effort compared to working alone or within one's own discipline; the instructors found that it was important for students to hear this message continuously affirmed. They also found that it was helpful to be forthright in discussions of difference across the course and how to optimize its value, particularly in relation to problem solving, so that students are motivated to work through differences rather than around them. The instructors explicitly highlighted that developing skills to work productively as an interdisciplinary team is more important than the project itself, and found that students fared best when the value of interdisciplinarity was modelled for them to help them stay motivated to do the extra work required. Past research has linked challenges to interdisciplinarity with instructor bias (Self et al., 2018), highlighting the importance of instructors modelling effective interdisciplinary mindsets. Similarly, Shakila et al. (2021) similarly noted the importance of role-modelling the value of other disciplines and integrating other disciplinary perspectives. Overall, it is important to recognize that it is not enough for faculty involved in interdisciplinary teaching to be disciplinary experts; instead, they, too, must possess and model these skills. Based on the findings of this study and the extant literature, we recommend explicitly teaching teamwork skills, especially through modelling by the instructor(s), and emphasizing the process in all that the students do in the course while resisting the urge to focus on the project itself as the goal or outcome of the course.

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Appendix
Interview Questions

1. Compared to other undergraduate courses you've taken to date, how did C4 compare?

2. Compared to other undergraduate courses you've taken to date, did you find that C4 required you to take a different approach? Can you share what approach(es) you took for C4?

3. What were your expectations for C4? What did you expect C4 to require of you?

4. How would you describe your C4 journey? For example, did you go through different phases or were your experiences consistent throughout the course?

5. Can you describe your C4 team?

6. What do you think success looks like for students in C4? (How does a student know if they have achieved success in C4?)

7. What factors do you think contributed to your degree of success in C4? What factors do you think contributed to your team's degree of success in C4?

8. What factors do you think hindered your success in C4? What factors do you think hindered your team's success in C4?

9. What would you like to see more of in C4? (What do you think was most helpful to students in C4?)

10. What would you change about C4?

11. What is most memorable about C4?

12. Could you please elaborate on what you learned in this course that really matters?

13. Can you please elaborate on your future plans?

14. What advice would you give to future C4 students?