Coordinating Opportunistic Interdisciplinary Projects Across Single-Discipline Capstone Courses

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There is increasing interest in developing interdisciplinary capstone courses in which students from different majors enroll to work together on complex, real-world projects. Creation of new interdisciplinary capstone courses may not be feasible for some departments or institutions, however, due to administrative or funding complexities. As an alternative, the inclusion of smaller numbers of interdisciplinary *projects* engaging students enrolled in separate single-discipline capstone courses may offer the opportunity to undertake interesting projects, or engage with certain sponsors, that would not be possible without the contributions of students from diverse disciplines. The fact that such projects are undertaken by interdisciplinary teams of students who remain in their single-discipline capstone courses, however, does not reduce, and may amplify, the challenges found in full-fledged interdisciplinary capstone courses (e.g., misaligned schedules, differing requirements, and unfamiliar working cultures). This paper provides early lessons learned from a series of opportunistic interdisciplinary capstone projects associated with NASA's Psyche Asteroid Mission involving students from computer science, computer systems engineering, engineering management, industrial design, and graphic design. The findings highlight the importance of close communication and flexibility between faculty and identify a novel and potentially-replicable approach of including project management students on interdisciplinary teams.

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Introduction

In January 2017, NASA selected the Psyche asteroid mission, led by Arizona State University (ASU), as one of two missions in NASA's Discovery Program (https://psyche.asu.edu). The Psyche spacecraft is scheduled to launch in mid-2022 and arrive at the mostly-metal asteroid, known as *(16) Psyche*, in early 2026. Funding for the mission includes development of four efforts to engage undergraduate students, one of which is the creation of capstone projects across a range of disciplines that contribute to science, engineering, or communications related to the Psyche mission. Several capstone projects were piloted during the 2017-2018 academic year at ASU, an institution which offers over 80 capstone or capstone-style courses annually. Additional capstone project opportunities will be available nationally in 2018-2019.

To facilitate broad adoption, this effort is focused on the design and development of standalone capstone projects (rather than entire courses) that may be undertaken by faculty and students in any capstone course (or across capstone courses in multiple disciplines) who feel they have relevant interests and abilities. Given the large variation across institutions in the types of capstone courses offered, the ways in which they are administered, and their principles, objectives, and requirements[1-5], the projects are designed to allow variation and adaptation to local contexts by the participating faculty. Additionally, since the projects are tied to the Psyche mission, which itself requires the skills of a wide range of disciplines, many of the projects conceived to-date are naturally interdisciplinary.

Developing projects that require multiple disciplines, but that can be incorporated into existing, single-discipline courses at (and perhaps even across) a wide range of institutions has the potential to amplify the challenges of interdisciplinary capstone courses that have been documented in the literature[6-10]. The current pilot projects at ASU provide the opportunity to implement existing best practices from the research literature and, where necessary, to develop structures, frameworks, and assessments to guide faculty in implementing interdisciplinary capstone projects in single-discipline capstone courses in the future. This paper describes this pilot effort and lessons learned.

Pilot Projects

The initial pilot projects involved faculty and students from six disciplines (computer science, computer systems engineering, engineering management, graphic

design, industrial design, and public relations) working on four types of projects. Two of the Psyche-related projects involved interdisciplinary teams of students from distinct capstones courses: 1) A competition to create the first Psyche mobile app and 2) the design and manufacture of an imaging system with either a camera or a scanner to image iron meteorite samples for analysis. A third project, the development of an image analysis algorithm for bulk chemical analysis of iron meteorite samples that will be used to create a reference database for use when data are acquired at Psyche, involved only computer science students on the actual teams, but these teams needed to interact regularly with the interdisciplinary imager teams. Table 1 shows the composition of the nine capstone teams working on these projects in terms of academic major and gender. (The fourth project was development of a public relations strategy by a single team but, in its initial iteration, this one-semester project did not include participants from other disciplines and is not discussed here.)

	Male	Female
Computer Science	28	10
Computer Systems Engineering	6	4
Engineering Management	3	3
Graphic Design	1	5
Industrial Design	1	1

Table 1. Academic major and gender composition of Psyche-related capstone teams.

Each of the five teams competitively developing the Psyche mobile app was comprised of approximately five developers from computer science, one or two graphic design students, and an engineering management student. Each of the teams working to build an imaging rig for iron meteorite samples had five computer systems engineering students and one or two industrial design students and the two teams shared a single project manager from the engineering management capstone. The two teams working to develop the algorithm used with images produced by the imaging rigs were made up of solely computer science students and did not have an engineering management student to provide project management, which is an absence we plan to avoid in the future, as discussed below.

Challenges and Solutions

Those who have created interdisciplinary capstone courses or projects know that much of the challenge lies in the fact that interdisciplinary projects "attempt to unite two or more orientations that may (or may not) share any substantial overlap in terms of substantive and theoretical concerns" (p. 10)[4]. As expected, we encountered many of the challenges documented in the research literature, including those related to project administration, student schedules, workspaces, and deliverables, disciplinary cultures and expectations, and assessment. Although it would be ideal to design a completely new course from the ground up to preclude these issues[11], it is not feasible in our situation, so we have adopted/adapted existing solutions or explored new ones.

Project Administration

As Howe, et al., (2016) and others have found, each capstone course participating in our projects is set up and administered differently (see Table 2)[5,13]. Particularly challenging at the beginning of the year was that students who would be the sole team member from their discipline (such as graphic design or engineering management) could select a project or be assigned almost immediately at the start of the semester. For teams consisting of multiple students from the same course, however, it took a few weeks before all the assignments were settled based on students' elections, and this resulted in some of the CS teams being comprised of students from different sections administered by different TAs. Going forward, we will implement team and project selection/assignment processes that are more constrained (particularly in terms of assignment across sections) and streamlined.

	Course Size	Project Assignment	Mode	Project Origin	Funding available
Computer Science	300	Student- selected (but teams formed by instructor)	In-person	Sponsor-driven	No (unless from sponsor)
Computer Systems Engineering	50	Student-selected	In-person	Sponsor-driven	No (unless from sponsor)
Engineering Management	100	Instructor-assigned	In-person and online	Both	No (unless from sponsor)
Graphic Design	50	Student-selected	In-person	Student-driven	No (unless from sponsor)
Industrial Design	16	Student-selected	In-person	Student-driven	No (unless from sponsor)

Table 2. Administration of participating capstone courses.

Student Schedules, Workspaces, and Deliverables

It can be difficult for students within the same major to find times they are all able to meet[6], but this is exacerbated when teams are comprised of students from significantly different majors, such as the Psyche mobile app teams with students from CS, graphic design, and engineering management. To facilitate this, students were allowed to self-organize their meeting times (resulting in some teams that met in the evenings or on weekends) and any sponsor meetings always included a call-in option for those who were online students or who were off-campus for jobs or other reasons.

A special challenge for interdisciplinary teams comprised of students from completely different (non-engineering) departments was finding workspace, especially for teams building something physical. Particularly on large campuses like ASU, student access to secured buildings and workspaces may be limited to majors, so after-hours work sessions with non-major teammates can be difficult. For example, our two imaging rig teams were lent valuable equipment that needed to be secured. Their shared capstone space did not have sufficient storage, nor did it allow entry by non-majors, so in the spring semester they were lent space in a lab offered up by a sympathetic faculty member. Clearly, this is not a sustainable solution, particularly as we expand the projects to other institutions, but a one-size solution to this challenge is not evident at present. ASU is engaged in a campus-wide discussion of how to better provide space for interdisciplinary student projects (both curricular and extra-curricular), but in the meantime such projects rely on the generosity and resourcefulness of faculty and departments. We continue to pursue solutions to this issue.

As documented in other interdisciplinary capstones, students participating in Psyche-related capstone projects were still expected to meet their specific course's deliverables and, as Abdel-Mohti, et al. found, "students who participated in this [interdisciplinary] project put in more effort than those who were involved in a discipline-specific project" (p. 1)[6]. A unique element of our projects that partially mitigated this challenge, however, was the inclusion of a project management student on most teams, who aligned and facilitated the competing deliverables schedules for their teams. Adding project managers to teams of students who had never been actively managed before added to the real-world fidelity of the projects: the content-focused team members learned how to work to a project schedule and be responsive to a manager and the project management students had their first realistic experiences managing different kinds of contributors. As one project manager shared, "It has given me the best idea of what managing an interdisciplinary team is like and I've used knowledge that I've gained in college to do so."

From the sponsor perspective, the project management students (including two online students) were critical to being able to scale the program, facilitating the flow of information and feedback and keeping projects on track without daily monitoring by the sponsor. Given the numerous positive outcomes in terms of student practice, sponsor experience, and project progress, we intend to have one project management assigned to every Psyche-related capstone team in the future, including potentially having ASU online engineering management capstone students provide project management to non-ASU Psyche project teams.

Disciplinary Cultures and Expectations

Of course, interdisciplinary teams do not always run smoothly. By senior year, many students have been steeped in the culture, norms, and work habits of their discipline, and may have had few opportunities to work on projects with students outside their major. This blending of disciplines is one of the ways that interdisciplinary capstones may better prepare students for the workplace, but is also a potential source of strife. As Cooper, et al. (2015) point out, "When students are developed fully within a single discipline program that also offers their capstone, the structure promotes the student, instructor, and advisor expectations…. However, as students are assigned outside of their engineering discipline to support other capstones, the potential for misunderstanding of how their unique disciplinary skills support the capstone outcomes increases" (p. 700).[7]

In some ways, having a project manager on each team helped ease those issues by, for example, assuring that the graphic artists delivered their products when needed by the developers or that the developers provided timely feedback to the artists. However, without a true workplace hierarchy, this occasionally put the project management students into the awkward position of having to scold or cajole their peers without being empowered to reward or sanction individual participants. As recommended in the literature, in the future we will better define team duties, responsibilities, and norms and help the students explore the host of interesting similarities and differences inherent in diverse disciplines' cultures and expectations[12,14].

Assessment

Since the opportunistic interdisciplinary projects represent only a few of the projects in each single-discipline capstone course, in the first semester each course implemented its own assessment processes per its usual syllabus, with different team members being evaluated against different criteria. This challenge is not reserved to projects that mix students from widely different majors, such as engineering and art, but is

encountered even by capstones bringing students together from different engineering programs, with one suggested solution to develop a "common design assessment language"[8]. In the case of opportunistic interdisciplinary projects, however, it is not feasible to implement wholesale change across each single-discipline course. As a hybrid solution, in the spring semester we combined the existing mid-term assessment processes used in engineering management course with an assessment of the project managers as a gauge of team dynamics and progress. Issues identified were addressed with the individual teams.

For the program-level assessment, we used an adapted version of empowerment evaluation,[17] in which students participated in "(a) developing a mission, vision, or unifying purpose [for the program]; (b) taking stock or determining where the program stands, including strengths and weaknesses; and (c) planning for the future by establishing goals and [determining] strategies to accomplish program goals and objectives" (p. 23)[15]. Used successfully with other NASA student programs with distributed participants,[16] this process takes place iteratively as the program progresses, allowing program coordinators to make mid-course corrections and continuously improve.

Conclusions and Future Work

As other authors have concluded, communication, flexibility, and openness to continuous improvement among faculty and departments is critical to the success of interdisciplinary capstones. This is particularly the case for opportunistic interdisciplinary projects, as they do not afford a wholesale course redesign. We are using our lessons learned from this pilot effort (including our novel approach of assigning engineering management students as project managers), the research of many others engaged in this area, and the ongoing evaluation of the program to make process improvements in preparation for expanding this effort nationally. We invite other capstone faculty interested in incorporating Psyche-related projects in their courses in the future to collaborate with us on this development process.

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