Full Paper: Paying it Forward: How Current Students Advised Future Students in an Engineering Design Course

Introduction

This Full Paper shares our method and results for exploring feedback from students about their learning experience in a foundational, project-based engineering design course Students were prompted to provide advice to future students with strategies for academic success. Their responses provided the data for this study.

Instructors in engineering and other STEM-based courses eagerly advise their students about how to successfully meet or exceed the expectations of a course [1], but students may not necessarily heed their recommendations [2]. However, students may be more likely to listen to similar advice given by former students [3], as students will tend to place more value on feedback from peers who have gone through the same experience [4].

Advice from students to students can be considered as a form of peer learning or collaborative learning [5], even though the advising students might not have direct contact with their recipients [6]. Such "collaboration" exists in the form of a common experience divided by time. Motivated by these perspectives from prior work, we gave our students an opportunity to engage in a "lessons learned" type of activity to tell future students what worked for them.

Seeking and sharing advice from students about learning experiences and success in a college-level course have been previously reported for content-based, concept-heavy STEM courses during the middle years of an engineering program [2], [6]. We used a similar approach in our first-year project-based course, expecting to find both similarities and differences in the type of responses from our students as compared to responses reported in the literature for content-based STEM courses [2], [6].

The purpose of this work is twofold - to develop a framework that will utilize a request for student-to-student advice to evaluate and improve a course and b) offer an example of how this strategy can be implemented in practice in an introductory project-based learning environment. Our study is guided by the following research question:

> *What kinds of peer advice for success do students give in a team project-based introductory engineering course?*

Our data generated responses that were structured as statements of "lessons learned" and loosely resembled results from one of our institution's end-of-semester student evaluations of teaching survey prompts about what our students thought that they could have done to be better learners, a finding that is in keeping with current literature [1].

Background

Perspectives from literature. There has been interest in exploring how student to student advice might be leveraged towards fostering student success, including efforts in STEM programs (e.g., [2], [6], [7]). While students regularly seek and receive advice about academic success in higher education, there is a shortage of studies about the types of advice that students share with each other, how students receive and utilize this advice, and the impact of such advice on success.

One such study asked biology and engineering students enrolled in high structure courses [8] to give advice to students who will take these courses in the future [2]. They found that students primarily gave advice related to *study strategies*, such as "do the homework" or "do not procrastinate." Other feedback included *interactions* between the instructor and their peers and *course expectations* (e.g., how difficult the exams are, what the learning environment is like), results in keeping with those from other similar studies [6]. Another study provided students with the advice given by students who had previously taken the course [7], and confirmed that students read and heeded the advice of their near peers, utilizing this resource more than those provided by the professor that semester, such as office hours. Peer to peer advice in the context of sharing students' experiences across iterations of a course, such as those described in these previous studies, have been linked to improved student performance [9], [10].

Course Description. For this work, data came from students enrolled in the second course of a two-semester sequential introduction to the engineering profession, required of all students who intend to pursue engineering degrees. The course objectives are as follows:

1. Demonstrate the ability to use various engineering skills and tools to solve design problems.
2. Demonstrate proficiency in implementing an engineering design process:
    - Collect, analyze, and interpret data.
    - Use systematic methods to develop solutions for problems, and
    - Identify all relevant stakeholders, constraints, and needs.
3. Communicate engineering decisions to technical personnel.
4. Contribute effectively to an engineering team.
5. Evaluate the ethical implications of engineering decisions.

Our students begin their academic journeys as general engineering students, regardless of whether they are first-time in college or transfer students; these students comprise the population in this course. The course is primarily project-based, in contrast to the mostly high structure courses from previous studies; it thus presents an interesting opportunity to examine peer advice from students in a project-based learning environment, where some general tips such as "read the textbook" may not apply.

Research Methods

This study contains an exploration of the types of advice that students finishing a project-based introductory engineering design course would give to prospective students. The responses were analyzed qualitatively according to common emergent themes and the number of responses were tabulated for each theme.

Study Context and Participants. Our project-based design course is typically taken during the second semester of college, as the second half of a two-semester sequence in the foundations of engineering at our large, R-1 state university. Students worked individually with technical and professional development topics, and in teams of six on a semester-long design project. The project consisted of the design and construction of low-cost musical instruments to provide the educational benefits of playing music to students who might not otherwise have access to commercial instruments due to high cost, geography, or other factors.

Data Collection. Our data were collected near the end of the course, through a prompt in one week's required exit survey for which all participants received full credit. However, exit survey participation, or lack of it, had no influence on team or project evaluations or grades. We collected 270 non-frivolous responses, which represented 94% of all students for whom this survey was made available. Participants responded to the following prompt: *Based on what you now know about our course, what advice would you give to students who will take this course in the future?*

All data were deidentified and frivolous responses were omitted from analysis. The survey did not collect identifiable information, keeping responses anonymous. Responding to the exit survey does not impact how the teams' semester projects are evaluated. The data were screened for incomplete responses and general observations to yield approximately 270 useful responses, representing ___% of students enrolled in the course (270/total number of students).

Data Analysis. We used emergent coding to explore themes pertaining to learning strategies and team-based interactions that the participants believed that future students should heed. All coding and theme development was performed by the first author. Analysis began with familiarization, during which the researcher read through the responses. Next, they did a round of open coding, then focused coding to refine the patterns and ideas [11]. The codes were grouped and developed into themes. The researcher then coded each response by the themes. Each response could represent multiple themes. Responses in our dataset demonstrated no more than two themes.

Results

Our emergent coding process resulted in six major themes that the participants believed that future students should follow. From 270 responses, we interpreted a total of 370 different representations of the themes. The themes are presented in Table 1 with the percentage of coded excerpts representing each theme. Sample responses for each theme are shown in Table 2.

Table 1: Response Themes and Percentage of Representations

Theme	***Percentage***
Keeping on top of the work	17%
Planning ahead	20%
Engaging with the course	8%
Project-related advice (musical instruments)	16%
Team communication	15%
Team cohesion	19%
Advice for students in the prerequisite course	6%

Table 2: Sample Responses for Each Theme

Theme	Sample Responses
Keeping on top of the work	• Make sure to stay on top of your work. • Make sure to do all work on time and follow instructions. • Start working on tasks early in advance! As soon as you get the assignment!
Planning ahead	• Put the assignments in your personal calendar and schedule time to complete them. • Stay ahead of the assignments, don't procrastinate. Ask the instructor questions if you need help. • Plan your work out and don't try to cram it.
Engaging with the course	• Come in with an open mindset and be sure to continuously ask questions and stay engaged. • Work hard in the beginning. • Definitely have a good relationship with the teacher and TAs.
Project-related advice	• Learn to use hand tools, e.g., drills, screwdrivers, etc. • Make sure that you start building your project early, so you have more time for it. • Make something you're passionate about and it will be a lot more fun and rewarding.
Team communication	• Make sure you and your team have good communication and time management. • Get to know your team. • Communicate clearly with your team and don't be afraid to take action if there is an issue in your team affecting productivity.
Team cohesion	• It's pretty easy as long as your team works equally. • Try to develop a good relationship with all of your team's members • Prioritize meeting with your team to discuss the project often. If not, the parasites will take advantage of the members that actually put in the work.
Pre-course preparation	• Try your best • Become familiar with Computer-Aided Drawing (CAD) • Be prepared to do a lot more work in the next course

Discussion

The kinds of peer advice that our students gave aligned with what we might expect for a project-based introductory engineering course. We found a roughly even distribution of advice relating to planning ahead, keeping up with the work, succeeding on the project, communicating with a team, and keeping the team cohesive. These match our experience with the challenges students most consistently face in our courses. We noted somewhat fewer students giving advice for engaging with the course, which instructors might consider necessary for academic success.

The advice given by our students was similar to the advice reported by other studies that collected data from non-project-based learning courses [2], [6]. The other studies that we found had categorized advice by generic individual study skills, tips regarding specific skills and

strategies for course content, and general advice about attitudes that were identified for success in the course. We found individual responses that could apply to each of these themes throughout the dataset, particularly with respect to advice about individual learning strategies, such as keeping on top of the coursework, learning from mistakes, and seeking help when needed. In addition, themes of tinkering and working incrementally in content-based courses [2], [6], [7] loosely resembled the advice from our students about iterative design and optimization.

Thematically, we note that our results align with the challenges we tried to create in the course. We wanted students to experience and succeed at a long-term, team-based project. In doing so, they gain experience with team building, teamwork, coordination, and planning ahead of deadlines.. While most class sessions are designed to include active learning, students need to engage more intentionally in both individual and team-based activities.

One of our motivations was to explore ways of comparing student experience and challenges with our intent as instructors. As we designed our course content, we focused on learning outcomes related to team function, iterative design, and the use of engineering tools. These results do suggest that student experience aligns with our intent.

We wondered whether this set of advice would give us some insight into how to improve the design and facilitation of the course. We found that much of the advice was repeating things we said directly to the students (e.g. scheduling is hard). Some of our guidance also involved referral to campus-based support services and hands-on equipment training at our dedicated makerspace.

We did not find any advice that suggested that students were struggling with something unexpected. However, we had imagined the possibility that advice would involve workarounds for friction points or identify areas that left students frustrated with us. While we did not find any such advice this time, in future deployments of this exercise in this or other courses, instructors may be able to gain unexpected insights into the kinds of struggle their students might experience. By tallying advice related to an instructor's chosen themes, it may be possible to find overrepresented struggles that require additional attention as courses are refined.

For instructors interested in repeating this work, we suggest similar simple short-answer reflection questions. After collecting data, read through and code or organize the data. For a similarly structured first-year engineering course, one may wish to start with our themes, but should be open to others. Each program has its own context, history, and quirks. Taking these themes forward to the start of the next semester can help in offering students useful advice.

Conclusions and Recommendations

This paper describes a process for categorizing and examining peer advice for students in team project based first-year engineering design courses. This is useful both in helping students understand how to succeed in a course, and for instructors seeking better understanding of the struggles students face in their courses.

Future exploration may involve a comparison of our current results with those from prior class years at our institution, or with courses of a more product-based or knowledge-based nature. We might also be able to collaborate with other engineering programs at other institutions to compare student feedback about similar courses. Finally, our results might be applicable to formative assessment for the improvement of student learning in first-year engineering and other STEM courses.

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