New Orleans JAZZED about Engineering Education

Paper ID #16034

A Flipped Classroom Approach to Teaching Transportation Engineering

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A Flipped Classroom Approach to Teaching Transportation Engineering

Abstract: The flipped classroom approach has gained increasing popularity in higher education, particularly in STEM fields. In flipped learning, part or all of direct instruction is delivered through online videos and other media, and the class time is used for engaging students in collaborative, hands-on activities. In order to utilize the benefits of this novel teaching approach, a junior-level, introduction to transportation engineering course was converted into a flipped format. This study, conducted in a major Midwestern university, will present the results of a mixed-method evaluation investigating the effectiveness of the flipped classroom approach. Quantitative data included a pre-course survey, a post-course survey. Qualitative data, on the other hand, included video recordings of in-class sessions and end-of-semester focus group interviews. Analysis of the results indicated students benefited from the flipped classroom approach although it entailed some challenges for both faculty and students. Conclusions are drawn and recommendations are made for engineering education researchers and practitioners.

Introduction

Flipped learning, also referred to as inverted learning, has gained increasing popularity in higher education, particularly in STEM fields. This pedagogical approach extends the typical three-hour learning period beyond the confines of classroom time through the use of online platforms by delivering part or all of direct instruction through videos and other media. The in-class time is instead used for engaging students in collaborative, hands-on activities[1]. The roles of the instructor and students change as a result of this new teaching approach as the instructor facilitates student learning by providing assistance and guidance while students actively participate in the learning activities.

As a relatively new pedagogical model, flipped learning seems to have made its way into many engineering classrooms, an environment for which it appears particularly well-suited because of its potential to "combine learning theories once thought to be incompatible—active, problem-based learning activities founded upon a constructivist ideology and instructional lectures derived from direct instruction methods founded upon behaviorist principles"[2]. Additionally, the flipped learning format provides various benefits for students and instructors. These benefits can include *increased learning gain*[3,4], *flexibility*[5-15], *increased interaction with peers and the instructor*[6,8,9,12,13,16-22], *improved professional skills*[20,23], and *increased student engagement and preparation*[9,13,25,26]. Based, in part, on the potential benefits identified in previous studies, a junior-level transportation engineering course was converted into a flipped format. This paper aims to investigate student perspectives on various components of the course. In particular, the following research questions will be addressed.

1. Are students prepared to take a flipped course?
2. What are student perspectives on a flipped transportation engineering course?

Course Description

CE 355: Principles of Transportation Engineering serves as a junior-level foundational course in the civil engineering undergraduate curriculum at the university. The course provides an introduction to the field of transportation engineering and is organized into a sequence of three

general content modules, which include: (1) transportation planning; (2) traffic operations and level-of-service; and (3) highway design. It serves as a pre-requisite for all other undergraduate- and graduate-level transportation engineering courses at the university, in addition to preparing students for relevant content on the Fundamentals of Engineering (FE) and Principles and Practice of Engineering (PE) exams.

Historically, this class has been taught in a traditional, lecture-style format. Given its high enrollment, with 150 to 200 students per year over two semesters, CE 355 was identified as a promising course for conversion to a "flipped" classroom environment for the Fall 2015 semester. This flipped classroom approach involved delivering approximately 25 percent of direct instruction through online videos and other media. The in-class time was then used to engage students in collaborative, hands-on activities. This format allowed for increased one–on–one interaction with students and better short–term assessment of student learning outcomes, addressing two anecdotal concerns with respect to the existing structure.

Prior to the Fall 2015 semester, a series of ten video lectures were recorded, each of which provided an introduction to a specific fundamental transportation engineering topic. A course introductory video was also developed to familiarize students with the flipped classroom structure. These videos are hosted on a YouTube channel that was developed as a part of this project. Each video was 20 to 30 minutes in length and was produced using a screen recording software application. Direct links to the videos were provided through the course website, which utilized the Blackboard Learn course management system. In advance of each week's class, students were asked to watch the video and complete an accompanying quiz, providing important preliminary feedback on student understanding. Students were allowed take each quiz up to two times, with questions being drawn randomly from pools that were developed for each video.

The face-to-face lecture sessions provide more in-depth coverage of each topic. The class was scheduled to be two 75 minute long periods to provide sufficient time for in-class assignments. Typically, the first lecture session each week provided a brief (approximately 10-minute) review of the video and a subsequent discussion that focuses on finer details within each topic area. For example, this included discussions of limitations associated with the analytical methods the students were introduced to through the videos. The second lecture session utilized team-based learning, allowing students to work through a series of practical, hands-on exercises and group activities. At the end of each week, students submitted solutions to these problems through Blackboard. Moving these activities into the classroom allows for real-time feedback and more extensive interaction with the instructor and teaching assistants. These in-class exercises also involved the integration of iPads and laptop computers, providing exposure to useful transportation engineering apps. Students also worked in teams on a semester project, which utilized real-world data provided by the State transportation agency for the state within which the university was located.

Lastly, students worked in small teams to develop content and learning aids that may be leveraged during subsequent course offerings. These materials included additional short videos, small-scale and practically-oriented design projects, and other tools that could facilitate more effective student learning.

Methodology

The mixed-method approach was adopted in this study to evaluate the flipped learning environment for teaching transportation engineering. Combination of quantitative and qualitative feedback enabled triangulating multiple sources of data to establish trustworthiness and consistency in interpretation of the findings. Following is a description of the research context, participants, data sources, and analysis procedure.

Research Context and Participants

This study was conducted in a Civil, Construction, and Environmental Engineering department at a large Mid-western university. Approximately, 1000 students are enrolled in the department, and about 20% of them are female.

Introduction to Transportation Engineering (CE 355) is a junior-level course required for civil engineering students with a transportation engineering focus, and an elective for other focus areas. During the semester of Fall 2015, 64 students were initially enrolled in the course, but 3 ended up dropping the course. Out of these 64 students, 64 students took the pre-course survey, 50 students took the post-course survey, and 36 students participated in focus group interviews. Table 1 displays detailed information about the participants.

Table 1. Participant information

Gender		Age	Classification	
Male	Female	Average	Junior	Senior
48	16	21.3	38	26

Data Sources and Analysis

Quantitative data included the results of a pre-course survey and a post-course survey. The pre-course survey collected information about student background, learning preferences, and expectations from the course. The post-course survey involved parallel questions to the pre-course survey, allowing for an assessment as to whether the flipped leaning approach met student expectations or influenced students' learning preferences. Additionally, students were asked to evaluate specific online and face-to-face components of the course on a five-point Likert scale. During analysis, answers to Likert scale items were converted to numerical entries, 1 being strongly disagree to 5 being strongly agree. The internal consistency reliability (coefficient alpha) of the pre-course survey was 0.70, and the post-course survey was 0.92. Two open-ended questions were included to provide students an opportunity to comment on aspects of the course that went well, or did not go well, and were not covered in the survey items. Descriptive statistics were used to analyze quantitative data. Mainly, the percentages, mean scores, and standard deviations were included in this paper.

Qualitative data, on the other hand, included video recordings of in-class sessions, and end-of-semester focus group interviews. Five randomly selected student groups were videotaped twice during the semester to analyze peer-to-peer interaction and task engagement. Finally, semi-structured focus group interviews were conducted to further investigate students' perspectives on the flipped format. Thirty-six students, divided into six groups, participated in the focus group interviews. The interviews took an average of 30 minutes. All focus group sessions were audio-recorded and transcribed verbatim for analysis. The transcripts were coded for recurring themes

and categories using a qualitative analysis software application. Triangulation of different data sources (i.e. surveys, interviews) helped to increase the validity of findings and interpretations. Results from the surveys and the focus group interviews are included in this paper.

Findings and Discussion

The first research question investigated students' readiness for and expectations from the course. The second research question addressed student perspectives on the online and in-class components of the course. The findings were discussed in the light of previous studies, and practical recommendations were provided to improve the course structure and to provide and enriching learning experience for students.

Readiness for and expectations from the flipped course

The results of the pre-course survey indicated that only 14% of the participants had taken a flipped class before; 46% knew what the flipped classroom was but had not taken one; 16% had heard the term, but did not now what it was; and 24% had not even heard of the concept of the flipped classroom. Focus group interviews also supported this finding that many students mentioned that this was their first flipped course. This implied that although millenials used technology and online tools excessively in their daily lives, they may not necessarily be prepared to use these ubiquitous tools for learning purposes[27]. Preparing students for a new teaching approach, and clearly explaining what they would be doing and why they would be doing it may decrease resistance from students and create an environment that is more conducive to success. In our case, the course instructor developed an introductory video explaining the course structure and logistics, which was distributed to students the week before classes started. The first day of the class was also used to explain the rationale behind the flipped course design, and what students should do in order to succeed in this particular course.

In order to gauge the technological readiness for a flipped format, students were also asked about the kinds of technologies they owned. All but one participant indicated that they owned a laptop computer. One student, who did not own a laptop, owned a desktop computer, an iPad, and a smartphone. In addition to their laptops, 89% of the participants owned a smart phone; 25% owned an iPad, 13% owned an android tablet, and 8% owned a desktop computer. These results indicated that students owned the technology required for a flipped course, and that technology access was not a problem. The department also had a tablet kit with a charging station available for instructor checkout. Student ownership of laptop computers proved to be helpful when the tablets were not appropriate for certain course tasks (e.g. extensive calculations using spreadsheet software).

Students were also asked to indicate their level of agreement with statements about expectations from the course. The items were based on the benefits of flipped learning identified in previous studies[3-26]. The expectations in terms of flexibility, instructor interaction, learning with and from peers, application-based exercises, and retention of learning were rated generally positively as can be seen in Figure 1. These results indicated that students had appropriate expectations for this flipped course and were ready to do online activities, work on complex problems and projects, and work collaboratively with their peers.

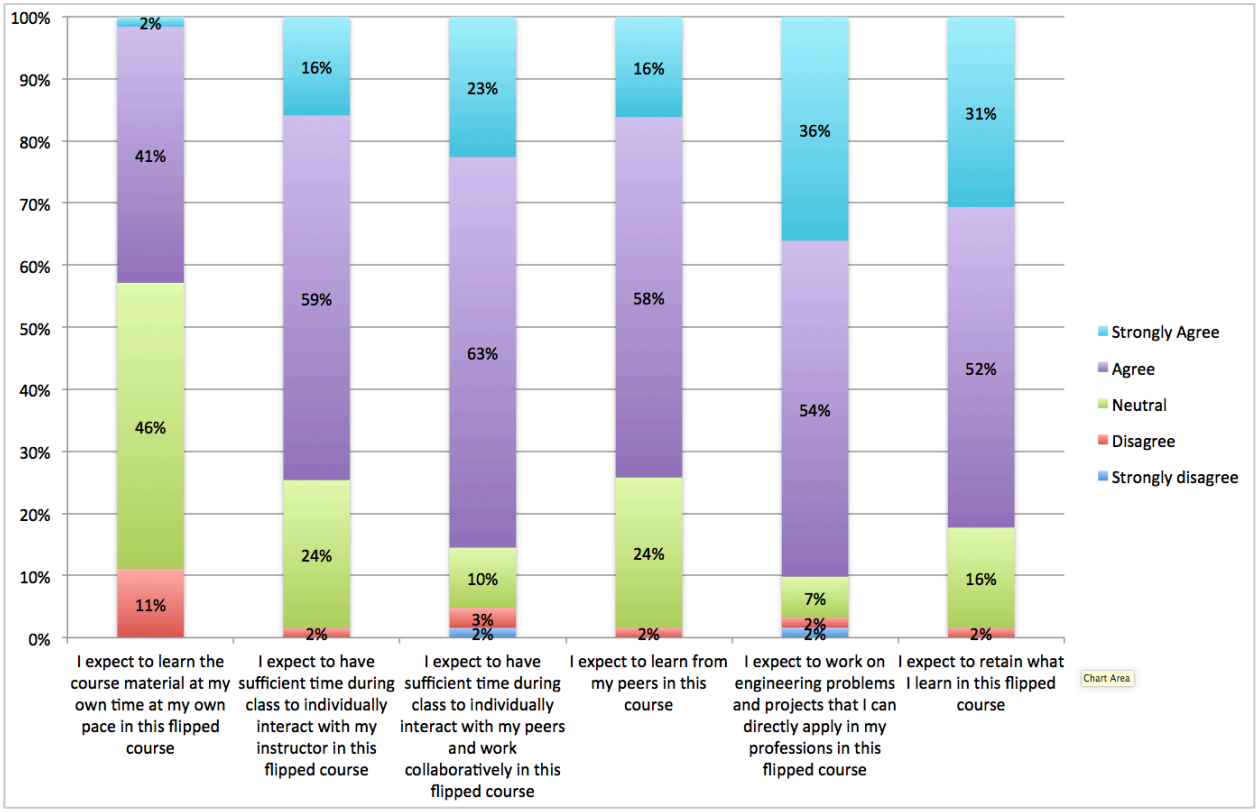

Figure 1. Expectations from the course (N=64)

In the pre-course survey, participants were also asked to indicate their learning preferences to understand if students' preferred learning methods matched with the characteristics of a flipped learning approach. The results indicated that the students thought that they were generally prepared for online tasks as 92% indicated they were good at setting goals and deadlines for themselves and 94% indicated they could keep themselves on track and on time (See Figure 2). This was important because students had to manage their time and finish online tasks to be prepared for the in-class activities. The fact that 64% students responding positively to the statement about learning by listening to a professor in the lecture suggests a need to include some in-person lecture component during the class. On the other hand, a large majority of the participants (91%) stated they learned best when working on problems and projects. This dovetailed with previous findings that suggest in order to create sufficient time for such problems and projects, the instructors might need to reduce the time spent lecturing[2,28]. Student responses were more scattered about learning from the textbook. Only 21% positively rated that they learned from reading the textbook, while 35% were neutral, and 38% were negative. Based on anecdotal experiences, the instructor anticipated this negative reaction to reading the textbook and considered online lecture videos to be an alternative solution to ensure students came to class prepared. Finally, responses to learning from peer collaboration were scattered with 11% negative, 37% neutral, and 42% positive. However, "being able to function on multidisciplinary

teams" is included as an ABET outcome,[29], and it was hoped that students would improve their teamwork skills through this flipped course.

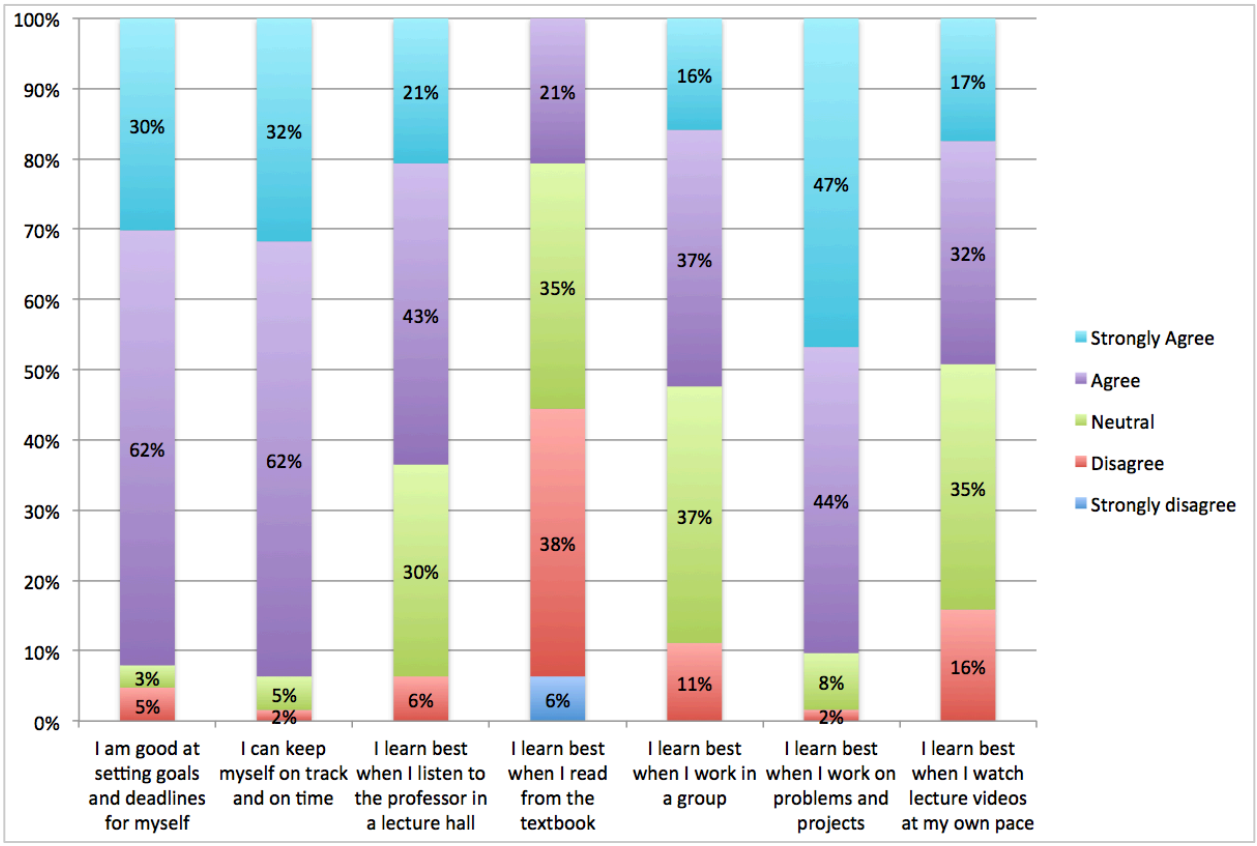

Figure 2. Learning preferences before taking the course (N=64)

Student perspectives on the flipped course

Online Lectures and Quizzes. Student surveys and focus group interviews enabled students to voice their perspectives on the course. The results indicated that students enjoyed the benefits such as flexibility, pacing, and increased understanding, that the flipped format brought to their learning See Figure 3. For example, one student noted

> When I watch video lectures I like to try and write down everything I can, especially all the PowerPoints and things. So, a lot of times I end up pausing it, and then I end up taking just way longer, it's a twenty-five minute video but I took an hour to do it. That was interesting for me, you can't pause a real life lecture (Student 1, Focus Group 1, p. 2)

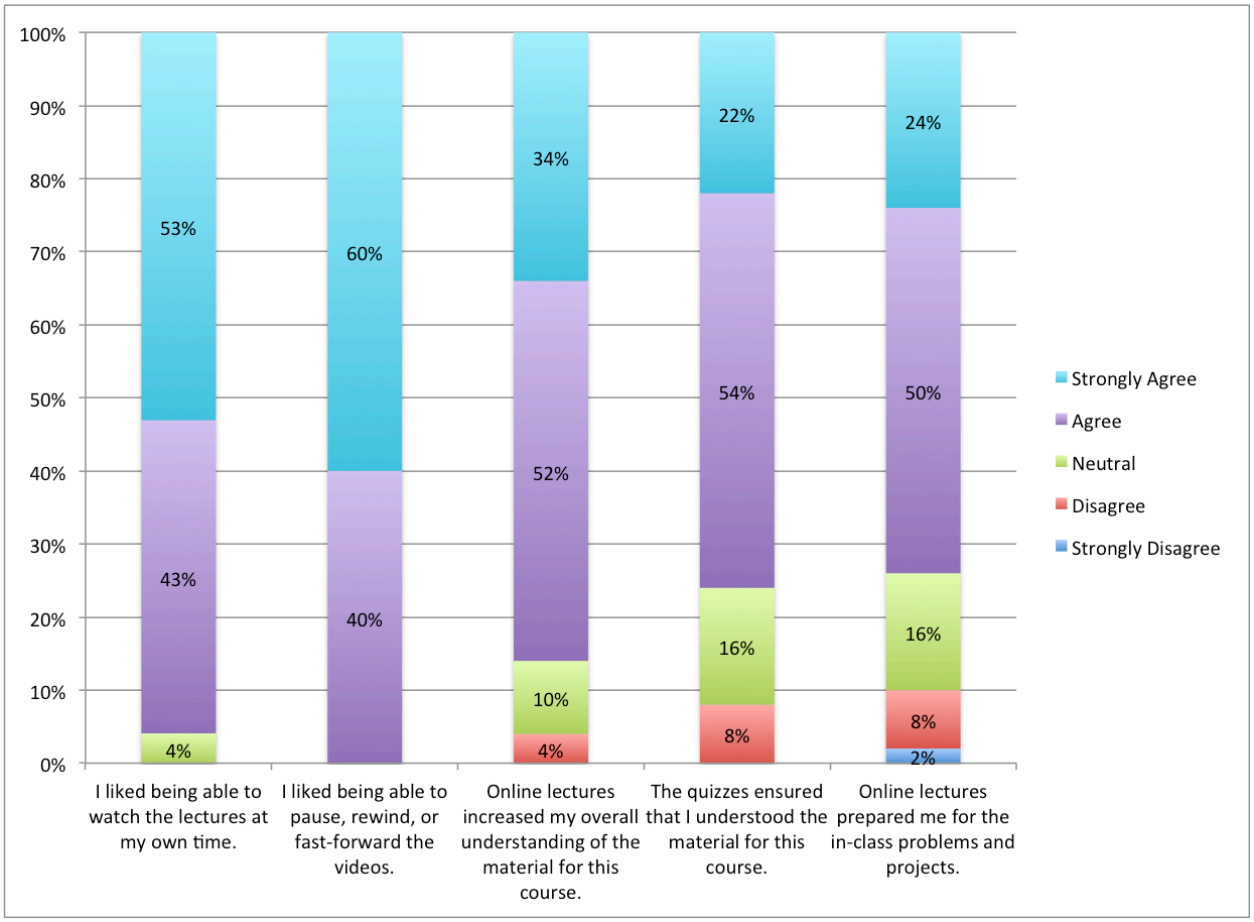

Figure 3. Student perspectives on the online component of the course (N=64)

Quizzes ensured students understood the material for the course according to 76% of the participants. The focus group interviews revealed some issues with quizzes that could be addressed in the future offerings of the course. For example, students commented that timed quizzes stressed them out as they tried to learn new material. They recommended removing the time limit on quizzes so they can focus on learning rather than trying to finish answering questions as one student stated:

> I don't really see the reasoning behind even putting a time limit on the quiz. I think that goal should be to understand the content. I'd say going through the video first and then going back isn't that detrimental as long as someone actually gets the information they need to know (Student 2, Focus Group 4, p. 4).

Similarly, 75% of the survey participants positively rated that online lectures prepared for the in-class assignments. Students felt more prepared for class like one student stated:

> I think the flipped course kind of forces you to review the material before class. All the professors will say, come to class and have such-and-such chapter read, but most people don't do it. If you have a quiz that's due before class and you actually do it and you get exposed to the information already (Student 3, Focus Group 4, p.4).

One concern raised about the online component of the course was to be able to remember to do online tasks. Although it was recommended to finish the online assignments before the in-class sessions, there were not set deadline for the online assignments. The experience in this course has shown that students needed specific deadline to keep themselves on track. For example, one student noted

> It's very, very easy to just say, "You know what, I don't have time for this right now. I'll do it later." Then later just never comes. I don't know if that's a personal issue or not, but having no deadlines kind of hurt me, I think in the long run. They just kind of pile up. (Student 4, Focus Group 2, p.7)

Instructor-student interaction. One of the basic rationales behind flipped course design is to use the face-to-face classroom time for more complex and engaging tasks where students interact with the instructor and with each other in meaningful ways rather than passively listening to the instructor. The findings from this study indicated the flipped course under investigation here provided such opportunities. Figure 4 shows students had sufficient time during class to individually interact with the instructor according to 62% of the participants. One student in the focus group interviews mentioned that communication in the classroom was one of the favorite things she liked about the course. She stated:

> I like the social interaction between student and the professor better. A lot of times with traditional classes you find that the communication between the student and professor is very rigid, very lecture based. Very much you just listen to him. I thought that with the flipped course, at least I don't know if it's just because this is how Dr. X normally runs his courses, but it seemed very discussion based and very interactive which helps me remember the material better. The communication in the classroom is probably one of the favorite things I liked about this course (Student 5, Focus Group 4, p. 5)

Although the majority of participants enjoyed the opportunity to individually interact with the instructor, they raised a concern about how the instructor was not always able to provide the help they needed because numerous groups needed help simultaneously. This concern was raised in previous studies as serving "one-to-many"[6]. Hiring graduate students or undergraduate students who have previously taken the course might reduce the workload for the instructor. However, these assistants need to be knowledgeable enough to answer any questions students might have.

Peer interaction. Being able to function on teams is an ABET[29] requirement, and an essential skill to function in today's global society. Having the opportunity to work collaboratively with peers enable students to not only learn the content but also improve this essential skill. As described earlier, students in this class worked on their in-class assignments as a team. The post-course survey results demonstrated that students had sufficient time during class to interact with their peers (70%) and enjoyed being able to work in teams (84%). Working in a team increased their overall understanding (68%), motivated them to work harder (60%), and helped them become better at problem solving (64%). This positive reaction to team work was also repeated during interviews as one student noted, "if somebody in your group understood, or they understood it better than you did, they can just help you out and you don't even have to ask Doctor X or one of the TAs." (Student 6, Focus Group 6, p. 5).

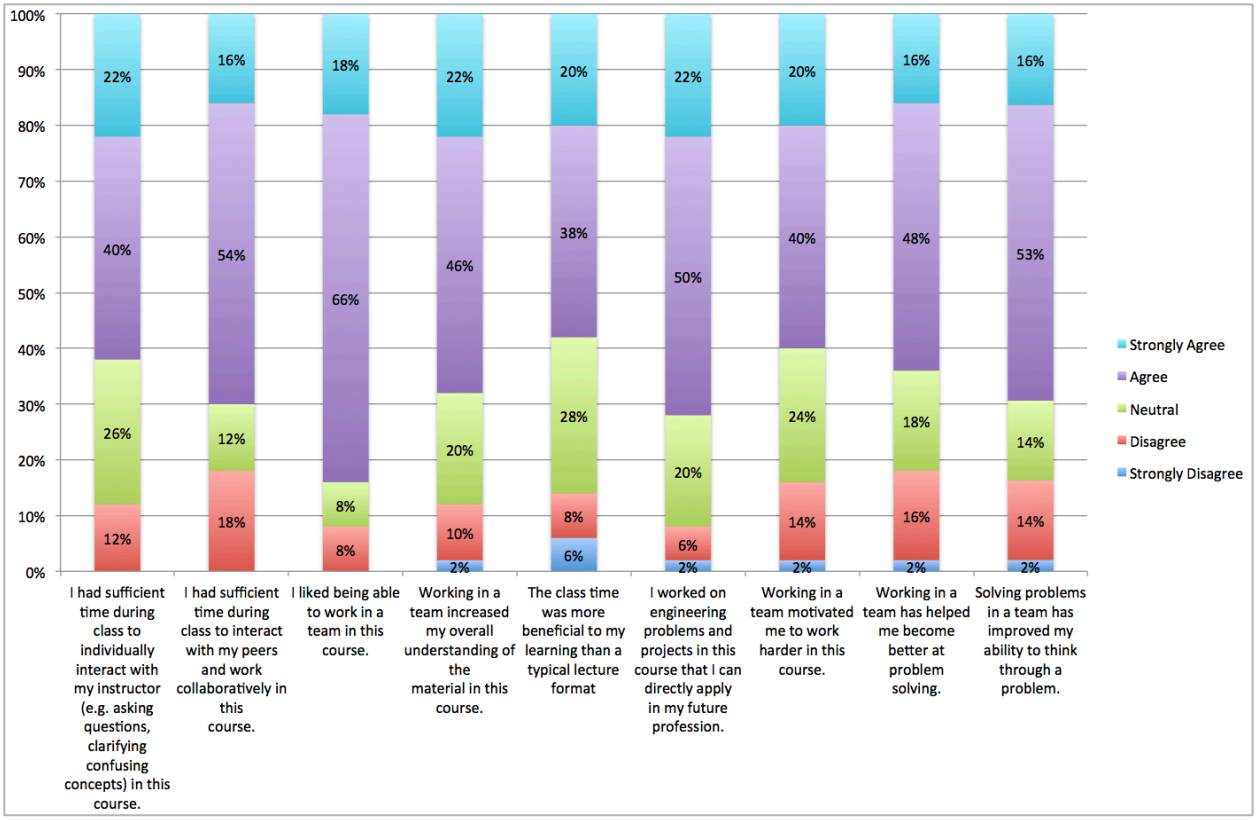

Figure 4. Student perspectives on the face-to-face component of the course

Problem solving. Being able to identify, formulate, and solve engineering problems is included in the ABET accreditation requirements. To achieve this outcome, students need the opportunity to solve complex problems that may or may not have single solution and learning through the experience of problem solving enables students not only learn the content but also thinking strategies[30]. The in-class assignments in this class aimed to improve such problem solving skills. The majority of participants (72%) agreed they worked on engineering problems and projects that they could apply in their future professions (See Figure 4). It was hoped that using class time for such problem-solving would be more beneficial to student learning than a typical lecture format. Although 58% of the participants agreed with this statement, 38% remained neutral, and 14% rated negatively. The focus group interviews revealed some concerns about how in-class assignments were completed. Many students pointed out that time left for the in-class assignments was not sufficient to work through the problems, and they turned out to be homework assignments for many groups.

> I thought that obviously the class assignments were very very lengthy and usually they did turn out to be homework. My group worked really fast through them because were always trying to get them done during class. We felt like we never had enough time so I kind of like got left behind, I was like, "Wow, what's going on?" (Student 7, Focus Group 5, p. 4-5).

Students made some recommendations that would improve their experience during in-class problem solving. Reducing the time on reviewing the lecture material would be one way to ensure students have sufficient time to effectively work on their in-class assignments. Another recommendation was to make the in-class assignment available prior to class so that students know what to expect and make necessary preparations as opposed to seeing the problem in the class for the first time.

Overall course satisfaction. Overall course satisfaction was measured through three items, which were rated relatively positively. Students felt they would be able to retain what they learned in this course (56%), wanted to see more flipped classrooms in their other courses (52%), and would recommend taking flipped courses to their friends (52%) (See Figure 5). The following student comment illuminated the success of this flipped course.

> It seems like every time I've ever taken an experimental class or any kind of class where they try and switch things up, it just seems like it sucks two weeks in and then they switch back to the traditional style. This one actually stayed the course, I guess it was done well. I think I liked flipped class more than a traditional lecture. (Student 8, Focus Group 1, p. 7)

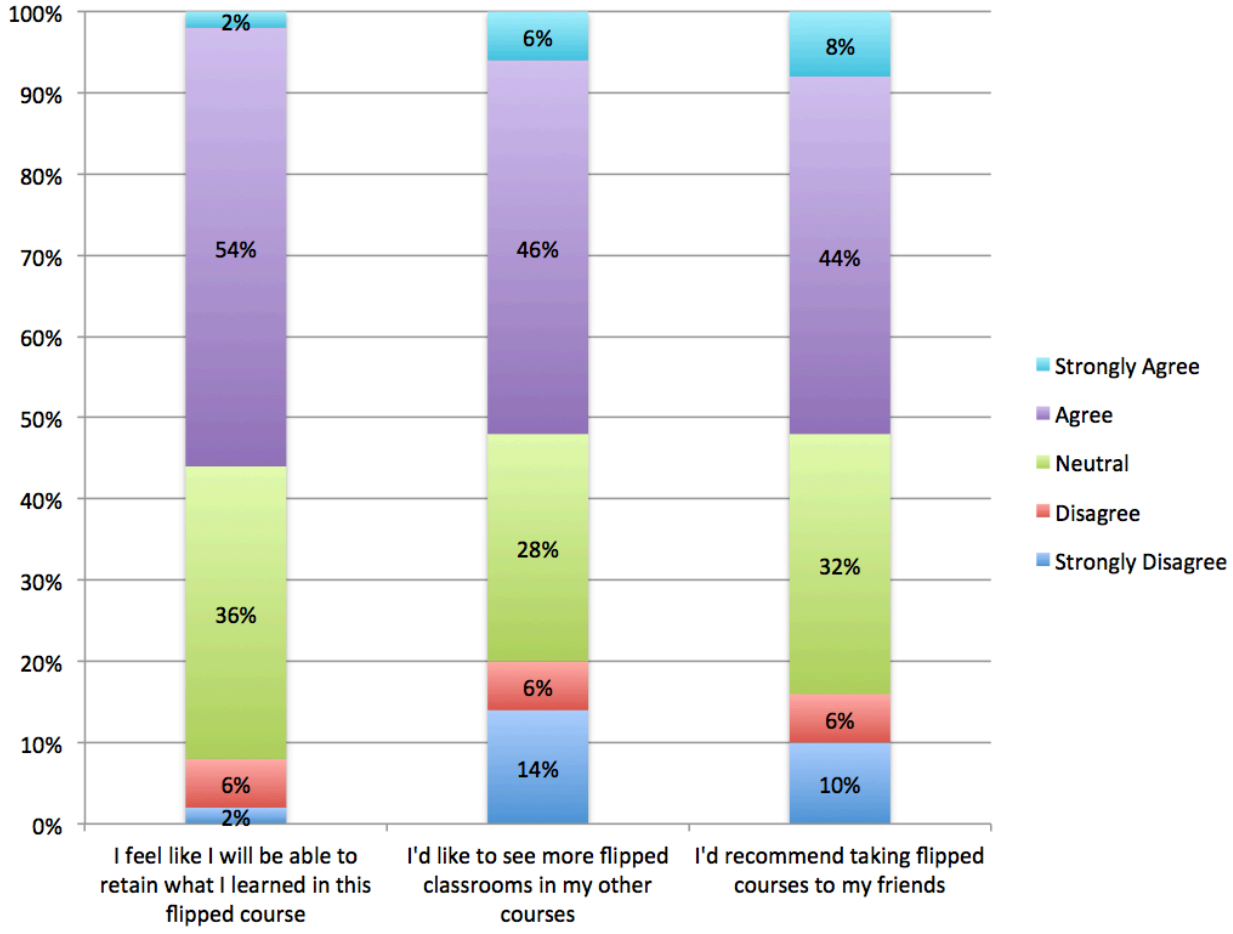

Figure 5. Student perspectives on overall course satisfaction

Conclusions and Recommendations for Improvement

Overall, students seemed to have enjoyed their experience in this flipped course. Having the opportunity for students to work at their own pace, to interact with their instructors at an individual level, and to work collaboratively with their peers are all contributing factors to student success in a flipped learning environment. However, revisions to improve course structure and enhance the learning experience would be desirable. The following practical recommendations can be given not only for the improvement of this course, but also for others who are interested in converting their courses into a flipped format.

Remove the time limit on quizzes. Generally, the purpose of including quizzes in flipped classrooms is to hold students accountable for completing the online tasks rather than strictly assessing student learning. As students recommended in this course, going back and forth between the lecture video and the quiz question might actually improve learning.

Set aside sufficient time for in-class assignments. Complex problems that are appropriate for in-class assignments usually take longer to solve than more structured problems. Even though the instructors would like to use some of the class time to review material and clarify any confusing points, they need to make sure enough time is left for students to effectively work on the in-class assignments as a team.

Include specific due dates for online tasks. Students were encouraged to complete the online tasks before the in-class sessions, but there were no specific deadlines established during this initial offering. The focus group interviews indicated that some students waited until after the in-class time to take the quiz, which weakened one of the primary objectives of the quizzes. Having specific deadline would encourage better preparation for the in-class activities. The subsequent course offering has established firm deadlines prior to the first in-class session each week.

Limitations and Directions for Further Research

As with any research, this research has some limitations to take into consideration while interpreting the findings. First, the interpretations were based on self-report data (i.e. survey and interview) which might sometimes entail bias. The authors tried to address this concern about self-report data by triangulating different data sources and creating a safe environment during data collection. Second, no data were included to measure any learning gain via flipped classroom. The instructor taught this course for the first time at this institution, and there was only one section. Therefore, it was not plausible to design an experimental or quasi-experimental study to compare student learning in a flipped environment to a traditional lecture environment. However, it was noted that the grade distribution was quite similar to that previous semesters which were taught in a traditional format by various instructors. Finally, student interactions during in-class assignment sessions were not included in this study because of time and space considerations. How students work with each other, how they use the information they gained from online tasks during in-class sessions can be further investigated to inform researchers and practitioners interested in flipped learning.

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