Transitioning between a flipped transportation engineering classroom and fully online learning

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Abstract

Flipped teaching is a rising pedagogy, but limited information is available about how it can prepare students for a transition to fully online teaching. The COVID-19 pandemic caused Universities to shift instruction to online modes in Spring 2020. The purpose of this study was to examine how flipped teaching prepared civil engineering students to transition to full online instruction and vice-versa. Data included student survey and test scores from an Introductory Transportation Engineering course each spring from 2019 to 2022. Preliminary results suggest that students taking flipped courses during or before the pandemic felt more prepared for success when courses shifted to online formats. Results also support previous research that flipped teaching of road design concepts improved student's ability to meet the stated learning objectives. Last, this study also provides new knowledge about the application of flipped teaching for traffic signals and public transit.

Introduction

Flipped learning, also known as the inverted classroom, has been gaining momentum for more than a last decade. The number of studies focusing on flipped teaching has dramatically increased since 2010 and ASEE is one of the most frequent venues for these publications [1].

Flipped learning is generally considered to include four key parts [2]. First, the learning environment should be reorganized so that time in-class is flexible to the learning needs of students. Second, learner-centered activities should be adopted to match the students served. Next, the difficulty of material should be monitored and active learning strategies leveraged to improve student understanding of key concepts. Last, the faculty should track student performance and provide timely feedback [3].

Overall, the design of flipped learning shifts more responsibility to students for their own learning [4]. Although this pedagogy provides student the opportunity to become more engaged, deep learning will only occur for students who put in the work. This teaching mode simply motivates students, through various incentives, to dedicate adequate time to learn and master the material [5]. Others agree that the success of flipped teaching is closely related to students embracing the completion of pre-class work [6].

Previous Work

Studies of flipped teaching are numerous. The following section summarizes the findings from previous studies as they relate to student performance, the perception of flipped teaching from students and faculty, flexibility, and student professional skills. Although some evaluated flipped teaching throughout the curriculum [7], the majority of studies focused on one class.

When studying student performance, previous studies found that flipped teaching helped students achieve greater overall learning [8]. Evidence included improved performance on exams [9, 10], 5-6% better overall success passing an engineering mechanics/statics class [6, 11, 12], and increased comprehension of the material [13].

Several studies examined how student learning changed between traditional lecture and flipped methods. The latter enabled students to better-achieve higher-order learning objectives [14, 15, 16, 10, 17] but not lower-order objectives. Some found better student performance on all questions at or above Bloom's level three [10] and other found improved performance, "specifically for the middle two quartiles of students (25-75% percentile)" [18]. Based on these findings, some researchers recommend that classroom time in flipped classes be focused towards solving, particularly problems targeting higher-order learning objectives [16] and courses focusing on Bloom's application-level skills [18].

Blooms taxonomy is a method of categorizing understanding into different levels of complexity. The Vanderbilt University Center for Teaching created the following summary of these levels (Figure 1).

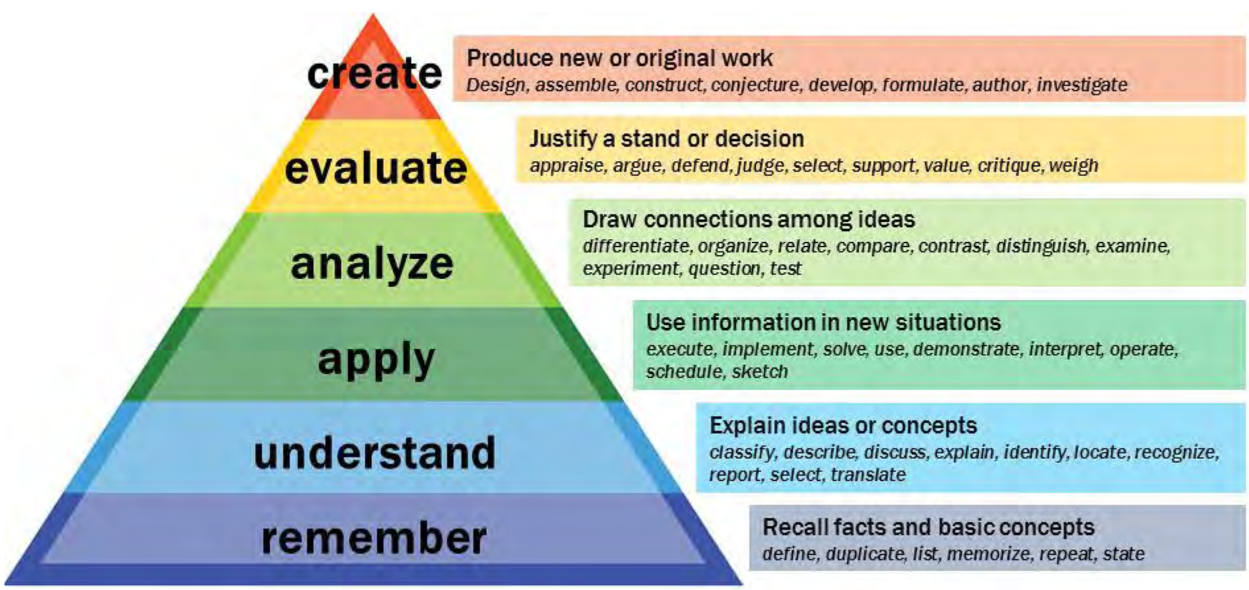

Figure 1. Blooms Taxonomy (Adapted from **[19]**)

Previous research has also examined the perceptions of students and faculty, with respect to flipped teaching. The majority of students (69%) agreed that flipped teaching was a good use of their time [11], and (55%) would recommend flipped teaching to a friend, instead of traditional face-to-face lecture [11, 20]. Several studies have found that students enjoyed work sessions during class time, where they worked with peers on problem solving [21, 22, 23, 24, 25, 26] and found that time well-spent [6]. One study found that the vast majority of students (79%) also agreed that the problem solving sessions helped them master the material [5] or improve their conceptual understanding and critical thinking abilities [18]. This study also reported that half of students (50%) agreed that answering classmates' questions helped them learn the material [5]; and more than half (56%) agreed that their classmates' guidance helped them understand the material [5]. The majority of students (58%) agreed "they learned best in small groups and/or with the instructor" after experiencing flipped teaching; whereas only 14% of students in a traditional class agreed [16]. Several studies of student perspectives about flipped teaching have concluded that the students appreciated having more direct interactions in class with the faculty [27, 21].

Regarding activities before class, the vast majority of students reported that the pre-class work was helpful in learning the material (slightly 56%, very 23%) [5]. Overall, students felt more supported in a flipped class environment [28].

Not all students agree that flipped teaching is better than traditional lecture. Evidence suggests that students who preferred traditional lecture over a flipped class did so for time management reasons [16]. Other studies concluded that students perceive flipped teaching to place greater demands on them, but acknowledge benefits such as deeper learning [26] and that students with higher GPAs were more likely to prefer flipped teaching [29].

Student opinions were also found to change during a semester. For example, as course materials became more difficult towards the end of the semester, students in one study expressed that flipped teaching made it more difficult to learn on their own [30]. Another study found that students' perceptions of learning in a flipped classroom is not always accurate, especially in the beginning part of a flipped class [31].

Previous studies on flipped teaching have also considered the perceptions of faculty. Overall, faculty perceived better student engagement with flipped teaching [32, 28], better student questions at office hours and discussions during class [6], and increased class attendance [33].

In addition to evidence of student performance, student perceptions, and faculty perceptions, studies have found that flexibility and professional skills are also benefits of flipped teaching. Students appreciated the flexibility to watch pre-class videos again [1], to solve problems multiple ways [18], and feel they are "treated more individually" [28]. Faculty have noted that flipped teaching allows weaker students to learn at a slower pace [34] and an analysis of the video analytics suggested that students were watching videos just-before class, to review for tests, and watch at multiple locations [35].

Several studies have noted that flipped teaching can help students build their professional skills. Most commonly, studies have found that students can improve their autonomy or ability for self-learning [36, 37, 38, 29, 39] and lifelong learning [40, 29]. Individual studies have noted that students can improve their critical thinking [41] and interpersonal skills [42]. Autonomy, lifelong learning, critical thinking, and interpersonal skills are all important to the careers of engineers.

Other studies of flipped teaching found no evidence of changes. Several studies measuring student test performance between flipped and traditional, found no significant difference [43, 22, 32, 38, 23, 24, 25]. Another study between flipped and blended courses across multiple Universities found no significant change [26].

Flipped teaching has been studied in lower-level Civil Engineering courses such as Statics [44, 45], Mechanics of materials [46, 22, 8, 47], and Dynamics [29]; as-well-as upper-level courses such as Geotechnical Engineering [16], Structural Design [18], and Transportation Engineering [20, 48]. Specific findings included that most students preferred flipped over traditional [47] and that students learned better in flipped class than an online class [48].

The objective of this study was to evaluate changes in student perceptions and performance in a partially-flipped transportation engineering course. These results were compared to a face-to-face lecture format, a virtual synchronous partially-flipped format, and the Spring 2020 semester that began as face-to-face partially-flipped then abruptly transitioned to virtual asynchronous because of the COVID-19 pandemic.

Methods

This study evaluated student perceptions and performance in a junior-level introductory transportation engineering course in two methods 1) Final Exam performance and 2) Student surveys. The class was offered in three 50-minute sessions each week for 16 weeks. The number of lectures on each topic remained the same for all years of the study. This study included two surveys. One survey containing a list of questions about the student experience with flipped teaching compared to lecture-based traditional teaching and was collected every semester. The second survey was a questionnaire on student experiences with flipped teaching after COVID-19 and was specific to Spring 2020.

During Spring 2018, the course was taught in a traditional face-to-face format, with a moderate inclusion of active learning. Most lectures included a group problem for 5-10 minutes. The course did not include a specific lab component, but students participated in a group project to analyze and assess the performance of a transportation facility.

During Spring 2019, the course was taught in a partially-flipped format. The flipped topics first included a 5-class sequence on geometric road design (stationing, elevations, vertical and horizontal curve lengths and considerations, and superelevation transition), similar to Hayes 2015 [48]. The next flipped topic included a 3-class sequence on intersection performance analysis and traffic signals (terms and formulas in video, activities in our traffic signal lab during class meetings). Last, the class included a 2-class sequence on public transportation (definitions in video, in-class group discussions and problems to solve during class meetings). This offering included a group project, similar to 2018. The flipped modules included a short video before each week. Based on the recommendations of previous research that the videos are best kept short [7, 16], the videos were approximately 20 minutes or less. The videos introduced the terminology and formulas for each model. Students were given strong encouragement to watch and take notes on the pre-class videos. Based on the recommendations of other studies [18], the students were informed that there would be a quiz to confirm their video completion. At start of the next class, faculty allowed for a 5-minute question/answer session, then administered a short quiz. These assessments usually had 2-3 questions, were closed book, but open notes. This offering also included a group project, similar to the previous year.

During Spring 2020, the COVID-19 pandemic caused an unexpected change in the course format. The initial plans were identical to Spring 2019. Instead, the course was a partial flip for first half, then online asynchronous the second half of the semester. This included a 5-class flipped sequence on geometric design of roads and a 3-class flipped sequence on intersection performance analysis and traffic signals. Students were not required to complete a group project, instead the value of homework was doubled. Student feedback was solicited about this change and no students expressed dissent.

In Spring 2021, the course was taught in an online synchronous format. The flipped topics were implemented using break out rooms in Zoom. The lecture topics were the same as previous semester, but the group project did not require all members to visit the study site.

Last, in Spring 2022 the course was taught face-to-face using a partially-flipped format. This offering was the same format as Spring 2019, except that the students were primarily taking online-courses the previous two years. Table 1 compares the instructional formats included in this study, where a dash (-) indicates traditional face-to-face instruction.

Table 1. Summary of Instructional Methods

<table>
<tr><th>Topic/Module</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th></tr>
<tr><td>Introduction and Vehicle Characteristics</td><td>-</td><td>-</td><td>-</td><td>Virtual Synchronous</td><td>-</td></tr>
<tr><td>Geometric design</td><td>-</td><td>Flipped</td><td>Flipped</td><td>Flipped Virtual</td><td>Flipped</td></tr>
<tr><td>Pavement design</td><td>-</td><td>-</td><td>-</td><td rowspan="2">Virtual Synchronous</td><td>-</td></tr>
<tr><td>Traffic flow</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Intersections and signals</td><td>-</td><td>Flipped</td><td>Flipped</td><td>Flipped Virtual</td><td>Flipped</td></tr>
<tr><td>Transportation planning</td><td>-</td><td>-</td><td rowspan="6">Virtual Asynchronous</td><td rowspan="2">Virtual Synchronous</td><td>-</td></tr>
<tr><td>Traffic safety</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Public transit</td><td>-</td><td>Flipped</td><td>Flipped Virtual</td><td>Flipped</td></tr>
<tr><td>Airport design</td><td>-</td><td>-</td><td rowspan="3">Virtual Synchronous</td><td>-</td></tr>
<tr><td>Freight and curb management</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Sustainable and intelligent transportation</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Student survey feedback and their performance on the course final exams were utilized to compare a variety of course offerings. The test performance was separated by topic and classified using Bloom's levels of cognition. The following learning objectives were assessed for each topic, with the associated Bloom's levels in parentheses.

- Geometric Design or Roads
  - Calculate the required length of crest curves (Apply)
  - Recommend solutions for providing adequate horizontal curve sight distance (Analyze)
- Traffic Signals
  - Apply common signal terms (Understand/Apply)
- Public Transit
  - Classify types of public transit (Understand)

When possible, statistics were applied to measure differences between offerings. The survey instruments, student disclosures, and research practices were reviewed and approved by the University's Institutional Research Board. These findings are described in the next section.

Analysis

This section will first describe the findings from student surveys each semester. These surveys asked students for their perceptions of flipped teaching and their learning in both flipped and traditional classrooms.

Student perceptions

The survey asked students if they would, "take another flipped course" and, "recommend a flipped course to another student." The results indicate student's opinions of flipped teaching are increasing over time. In addition, the students were less satisfied during the Spring 2020 course when the instructional mode was shifted from flipped to online (Figure 2).

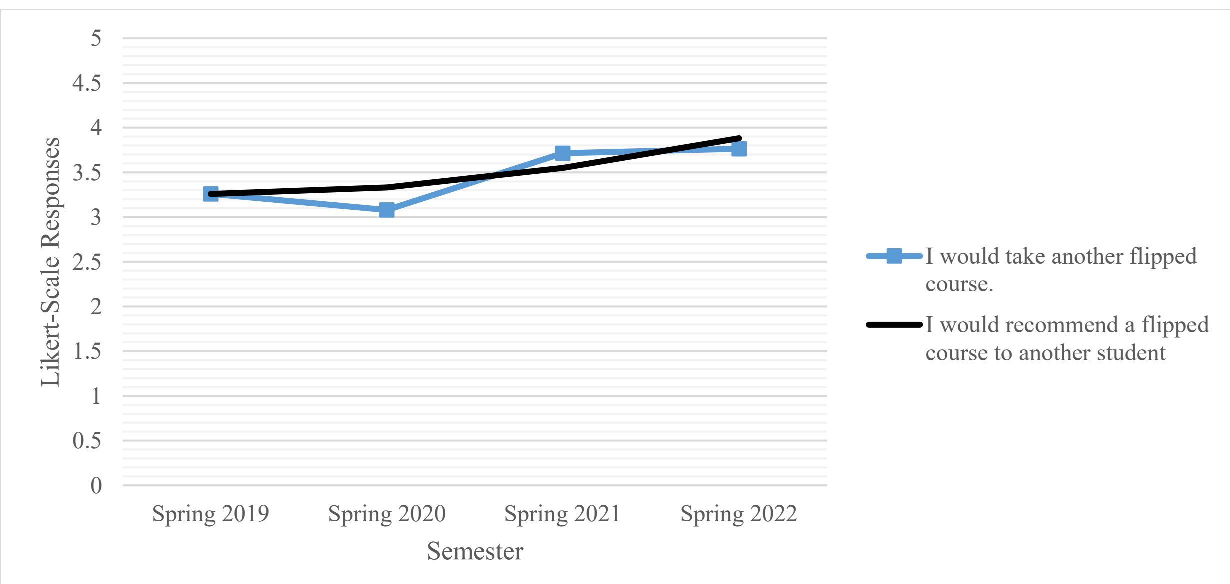

Figure 2. Student Overall Opinion of Flipped Classes

Next, students were asked about their engagement, time spent, and attendance in flipped classes. Students reported more engagement over time, suggesting that continuous improvement in the activities and the shifts to synchronous (Spring 2021) and face-to-face (Spring 2022) course formats are important to student engagement. Students reported the highest out-of-class time during the Spring 2020 semester, compared to other offerings. Last, students reported better class attendance when a virtual option was available. Figure 3 shows the results and trends.

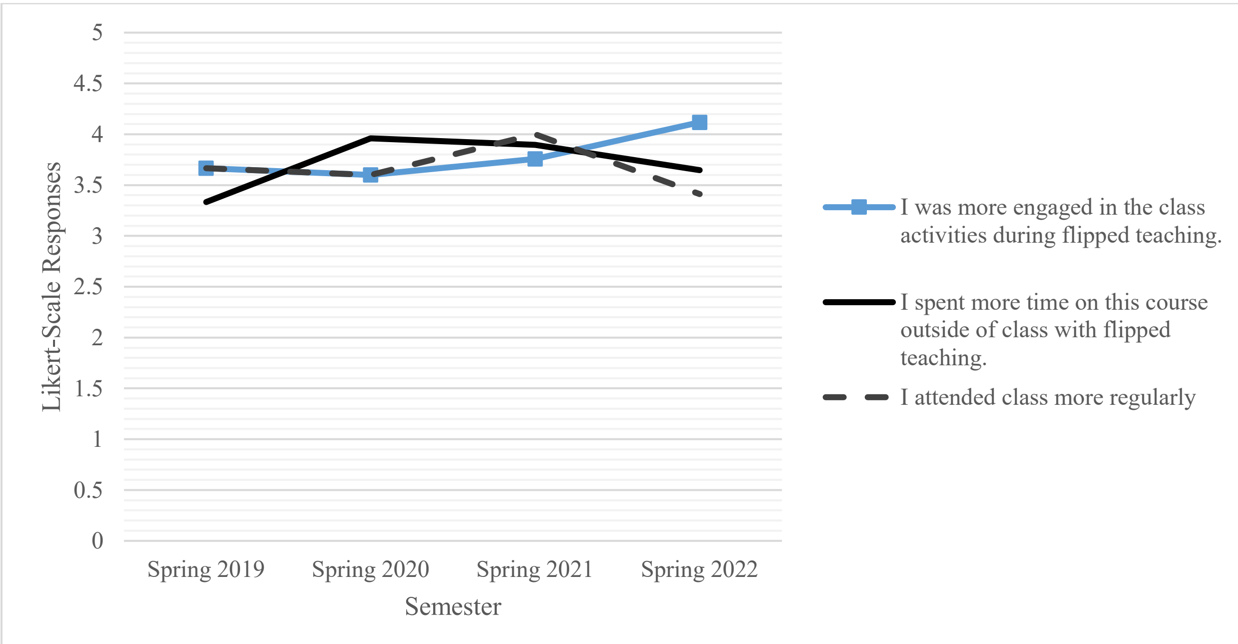

Figure 3. Student Engagement, Time Spent, and Attendance

Students were asked several questions about their learning in each class. Students were slightly positive that they learned more from flipped teaching and were more confident with the course material. Answers to these questions were nearly identical and showed an increase over time, with the low point in 2020. Also, the survey asked students about their ability to connect course content to the real world. Responses to this last question were the most positive and also showed increase over time.

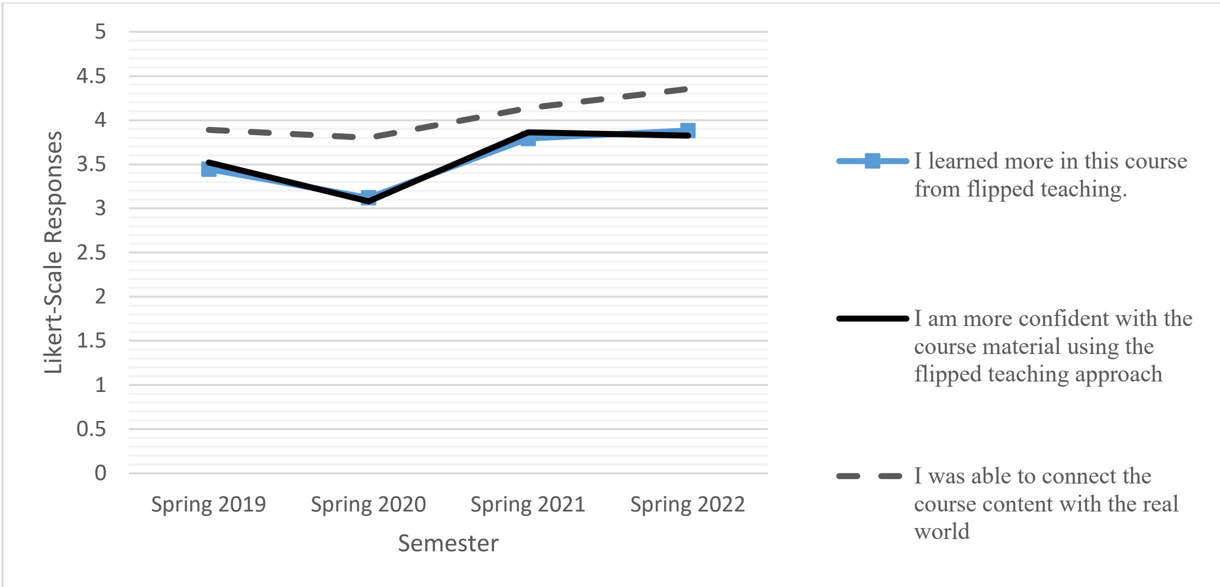

Figure 4. Student Perceptions of Learning

The surveys also gathered feedback about student's perception about their learning in a flipped classroom. The responses indicate improvement over time for the activities and class atmosphere. For pre-class activities, the responses were mixed. It is noteworthy that pre-class activities were not present in the second half of Spring 2020 because of the asynchronous format of the course (Figure 5).

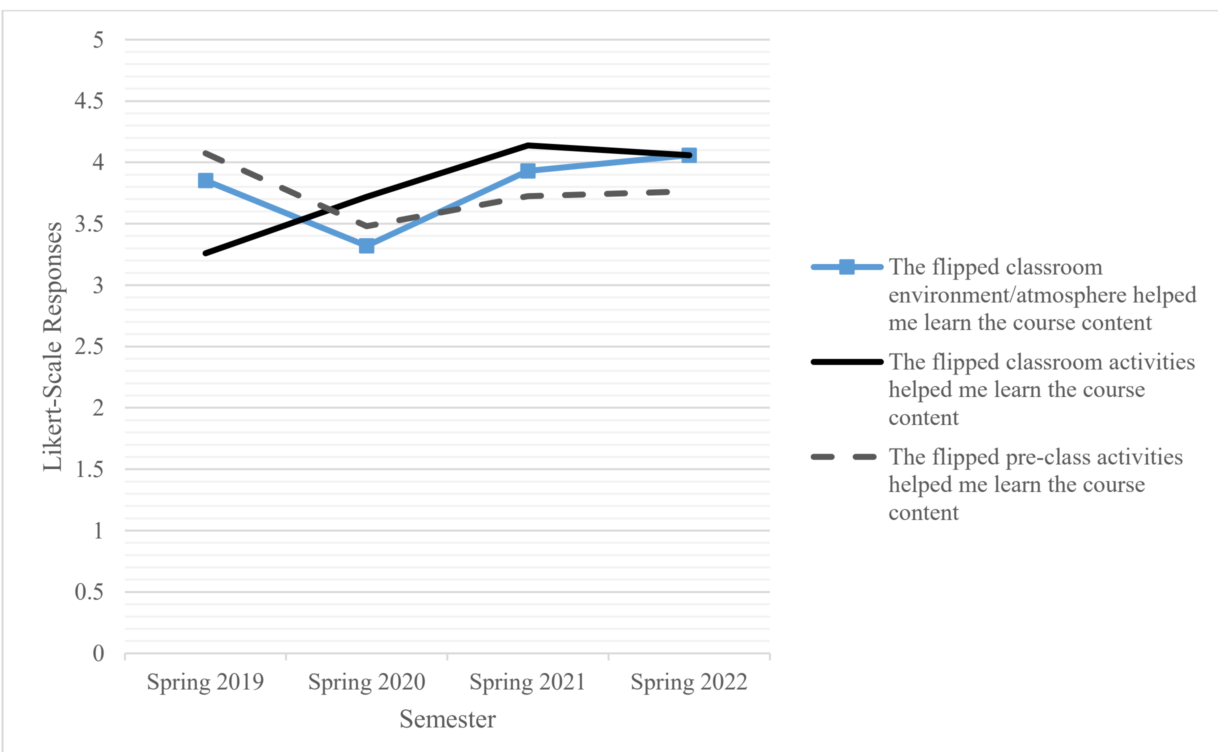

Figure 5. Student Perceptions of Flipped Teaching

Student performance

The authors next compared student performance on the final exam. The cumulative performance is shown in Figure 6 and indicates similarities among semesters with virtual classes and more consistent student performance over time. During 2020 and 2021 when the course was at least 50% online, the final exam performance was very similar, which may be a result of using virtual tests. The results also suggest that students performed the worst during the first implementation of flipped teaching in Spring 2019. The performance could be caused by student resistance to complete pre-class work or the design of the activities. The overall trend indicates that flipped teaching methods can improve final exam performance when implemented in-person or online synchronous.

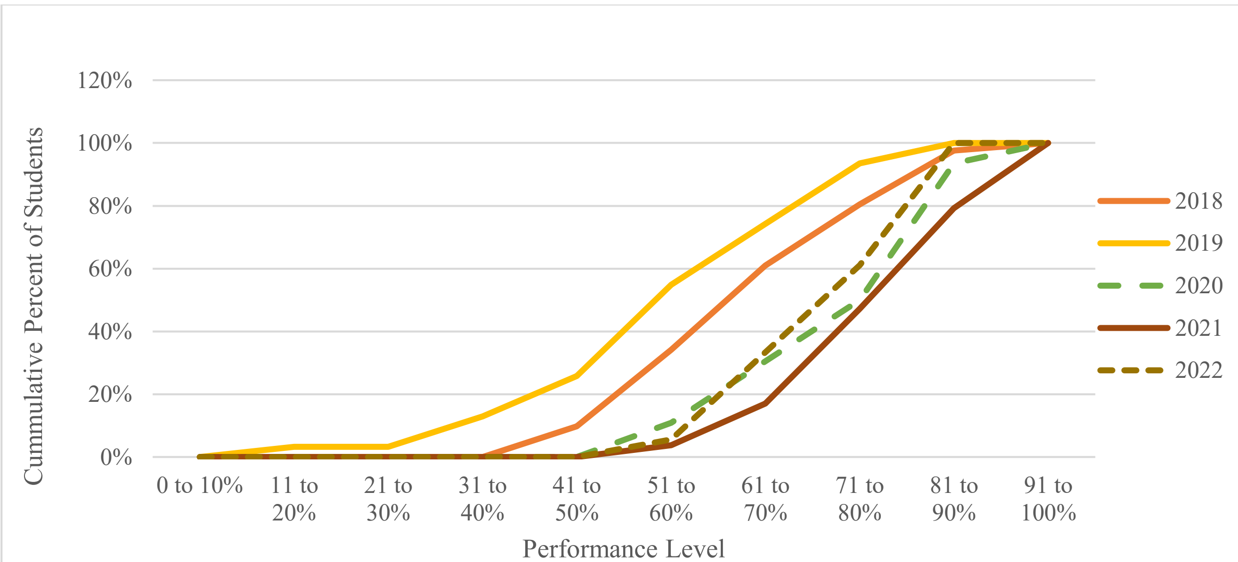

Figure 6. Student Final Exam Performance

Student Performance on Flipped Topics

To learn more about student performance on specific topics that were taught using a flipped method, final exam performance was analyzed for problems on these topics. This course included flipped modules on geometric design or roads, public transit, and traffic signals. The authors compiled student performance on final exam problems focusing on each topic. When multiple problems existed, a weighted average was calculated, considering the point value of each problem. The results indicate that performance did not improve for all topics. The topic of geometric design showed improvement after implementing flipped teaching activities, which supports the findings of others [48]. The trends were unclear for the other topics, but could be related to the learning objectives assessed. Other studies found improvements only for higher-order learning objectives [10, 14, 15, 16, 17], such as Bloom's level three (apply) or higher [10]. These results require further investigation to identify nuances that could have caused these trends the last two offerings of the course.

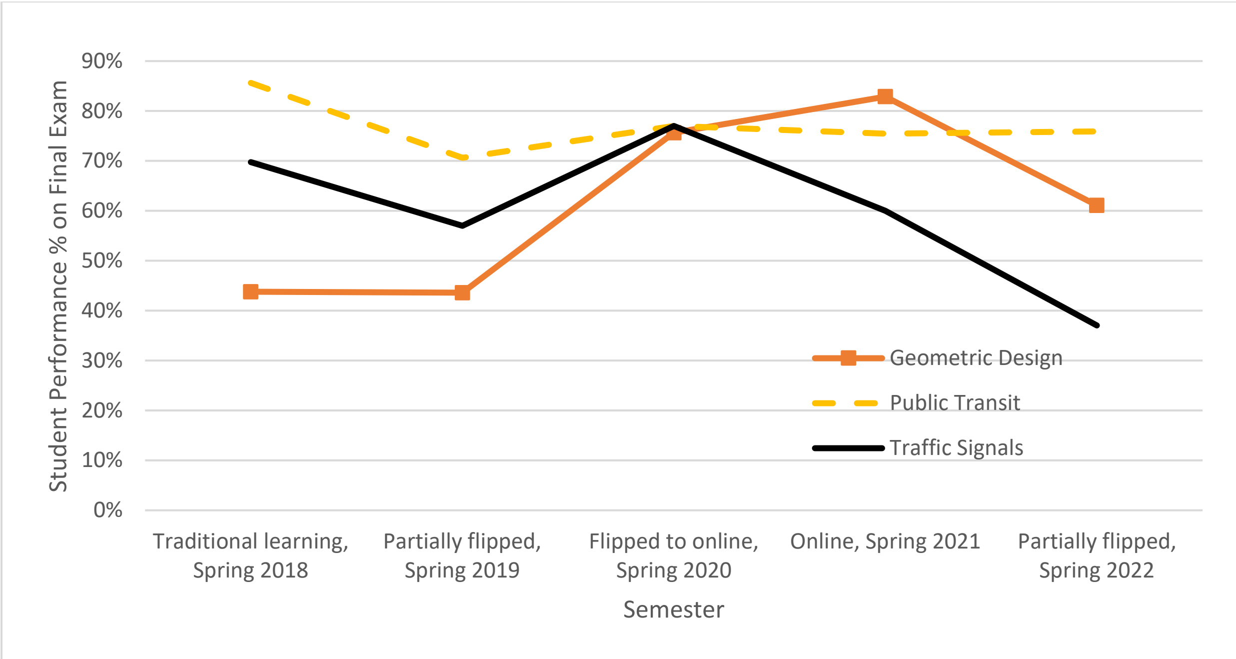

Figure 7. Student Performance on Flipped Teaching Topics

Flipped Teaching Transition to Online

To learn more about using flipped teaching could have prepared students for the shift to online learning researchers reviewed how student perspectives shifted between the flipped format (Spring 2019) and the flipped-to-online format (Spring 2020). The comparison revealed a decrease in several key factors, from 2019 to 2020. First, students were less confident in the content (Figure 4). Students also reported that the classroom environment was less conducive to learning in 2020 (Figure 5). Most notably, the students were also less confident that the in-class activities helped them learn in 2020. This change in responses was significant at the 95% level (Figure 8).

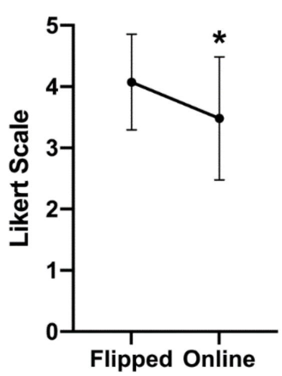

Figure 8. Student Responses to, "The in-class activities helped me learn."

To learn more about how students were adapting to the changes during the spring 2020 semester, an additional survey was conducted. Although the response rate to this additional survey was low (9 responses from 48 enrolled), the feedback provides some valuable insight into their ability to adapt. Overall, few students found the transition from flipped to online difficult. Specifically, 45% rated the transition easy, 45% rated it medium, and 10% rated it difficult. In addition, 75% of students reported being confident (30%) or very confident (45%) in their ability to complete the course in an online format. Most students (78%) had some experience with online teaching before COVID-19, but many (67%) were still adjusting to the shift to online.

Conclusions

This study demonstrated how flipped teaching effected the transition of students to online teaching during the COVID-19 pandemic of 2020 and also provided examples of student perceptions of flipped teaching across semester. Flipped teaching improved student's ability to transition to an online format in Spring 2020.

The overall study results suggest that student perceptions of flipped teaching are improving over time and their ability to connect content to the real world was one of the highest rated benefits.

Results for specific topics showed unclear trends. Students tended to improve their performance on the geometric design of roads, but not on public transit or traffic signals. These findings support the assertion that flipped teaching is a better investment for topics that are higher-order in Bloom's taxonomy.

Future work could examine if flipped teaching provides better gains for higher-level learning objectives. For traffic signals these could include, "calculate green times for a two-phase intersection" and "construct and interpret time-space diagrams." For public transit, learning objectives could include, "Describe how transit design and planning can address the seven elements of good service."

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