2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34754

Student Feedback on Best Practices for Flipped Classroom Courses in a First-year CAD Course

Dr. Angela Boronyak, University of Cincinnati

Dr. Angela Boronyak joined the University of Cincinnati in 2016 and is an Assistant Professor-Educator in Biomedical Engineering and the Undergraduate Program Director in Biomedical Engineering. Before joining the University of Cincinnati, she was an Assistant Professor in Chemical and Biomedical Engineering at Syracuse University for two years. She teaches a variety of biomedical engineering courses from the first year to the fifth year in the curriculum, including CAD, electric circuits, and sensing and measurement. Her educational research interests include the use of teaching technologies and student engagement in learning. Her Ph.D. and Masters in Biomedical Engineering were granted from Vanderbilt University where she completed a certificate in college teaching. She earned her undergraduate degree in Biological Engineering from the University of Georgia.

Student Feedback on Best Practices for Flipped Classroom Courses in a First Year CAD Course

Abstract

This study investigates student perceptions of a flipped classroom computer-aided design (CAD) course. While flipped classroom models are gaining popularity in higher education, student's attitudes towards these courses are often mixed. Over three years, a first-year engineering CAD course was "flipped" by the instructor recording short video demos of SOLIDWORKS techniques for students to watch outside of class in addition to step-by-step text instructions. While in class, the instructor gave a brief overview of new techniques, and then the rest of class time was used to complete homework assignments and group projects. At the end of the course, student perceptions of the course were assessed by an anonymous survey. More than 75% of the students responded that they preferred this CAD course be taught in the flipped classroom format over a traditional lecture format (without video demos); however, when asked about other courses, only 33% of students preferred their other courses to be taught in a flipped classroom format. Student comments to explain their preferences show that engineering graphics design and software-based courses may be best suited to the flipped classroom model over other course topics. To improve student attitudes towards flipped classroom courses, the videos should be recorded by the instructor and available for replay as many times as needed. The instructor should also allow some class time to work on homework or traditionally "outside of class" assignments to make up for the out of class time required by students to watch the videos.

Introduction and Literature Review

In a flipped classroom course, the learning of new content is structured to occur outside of class time (most commonly by watching videos, but sometimes through readings or interactive tutorials), while in class time is spent practicing and reinforcing content through assignments, group work, quizzes, or practice problems. This style of course is slowly becoming more common in engineering courses, with studies showing the results of flipped classrooms in a wide variety of engineering fields, including statics [1], computer engineering [2], computer programming [3], heat and mass transfer [4], environmental engineering [5], aerospace engineering [6], biomedical engineering [7], CAD [8], and engineering design [9]. While some studies show improvements in student learning in flipped classroom courses compared to traditional lecture courses [1],[2], student learning is often difficult to assess due to student-to-student variability, instructor variability, methods of flipped classroom implementation, and changes in the number of assignments or content covered between traditional lecture courses and flipped courses. Other studies do not show a statistically significant improvement in student learning in flipped classroom courses compared to traditional lecture courses [9], [5]. Flipped classrooms are also of interest to study for their effect on student attitudes towards learning, even if they may not statistically improve student learning outcomes. Student preferences between flipped classroom courses and traditional lecture courses are often varied [1]. Some students

enjoy the in class time for more active learning exercises, while others lament the feeling that they are now required to learn on their own instead of being taught by a professor during class time [10].

This study involved flipping a computer-aided design (CAD) course by creating video demonstrations for students to watch outside of class, while practicing the material with assignments and group work during class. Many instructors hesitate to flip their classes due to fear of negative student attitudes to the new learning format. However, the instructor for this study was inspired by other research which reported an improvement in instructor satisfaction by flipping CAD courses so that less time is spent repeating material and lecturing both to bored students and students who cannot keep up with the material as it is presented [11]. Flipping the classroom allows more time to be spent in class helping students as they are actively working.

The instructor of this study wanted the course to be an enjoyable experience for both herself and her students. Students in flipped courses commonly cite concerns over the time required of them outside of class [7], [5] so following best practices for flipped classrooms reported in other studies [5],[12], [13, [14], videos were kept short, content was briefly (<10 minutes) reviewed at the beginning of class, and the rest of class time was used for working on homework and group projects which would have traditionally been required for students to complete outside of class. In this study, student attitudes and utilization of flipped classroom resources were assessed to further identify best practices for flipped classroom courses.

Methods

This two-credit hour CAD course is a mandatory first-year course for students majoring in biomedical engineering taught every year in the spring semester. Results from anonymous online student surveys given at both the beginning of the course and the end of the course were averaged over two years of the course. In the first evaluation year, 93 students completed the surveys, and in the second evaluation year 56 students completing the surveys, for a total of 149 students. Video lectures (a total of 14 video lectures, averaging 15 minutes in length) were recorded in Echo360- a video and active learning management online program provided for free by the university. Videos included audio of the instructor explaining topics with text instructions in PowerPoint slides, as well as live screen and audio recordings while the instructor demonstrated techniques in the SOLIDWORKS software. Videos were not edited and therefore included similar pauses and blunders that would occur during a traditional in class lecture. High quality edited videos are time intensive [9], so skipping editing allowed videos to be made quickly and remade each year as needed as software versions are updated and course content was modified. In addition to the video lectures, PowerPoint slides with text instructions and descriptions for each topic or SOLIDWORKS technique were also provided to the students through Blackboard course management.

The course consisted of two days of full lecture in class during the first week of class, before moving to the flipped classroom model for the rest of the semester, where students watched a video lecture outside of class and then worked on homework or group projects during class. This flipped format allowed class time for the students to ask the instructor or TAs for help as they worked. Students were not given additional in class problems to work, only homework and group

projects that typically would be completed outside of class time in a traditional lecture course. Attendance was encouraged although not required, except during group project work days. Homework assignments consisted of creating 2D drawings, 3D parts, and assemblies in SOLIDWORKS. Homework assignments were similar to video demos, but not identical.

During the course, two open-ended group projects were completed allowing students to be creative in designing a medical device- an orthotic shoe insert for their own foot and shoe measurements- based on real world constraints and combine their knowledge of CAD techniques from the entire semester. The group projects also required students to incorporate FEA modeling, motion studies, tolerancing, and manufacturing processing, which had not previously been covered in homework assignments, but were introduced in video demos and text instructions. These topics were introduced in a limited application setting to get students exposed to these processes, but were not developed in depth due to the time limited nature of the class and student's lack of background knowledge at this point in their curriculum, particularly in physics. The designs students created as part of their group projects were then 3D printed using Ultimaker 3D printers through university provided resources. 3D printing the students' designs allowed students to see their manufactured device in person and identify improvements that could be made to their design in the next iteration. Improvements included making the designs better fit their personal body measurements, smoothing rough transitions between features, or adding features to improve ergonomics and comfort.

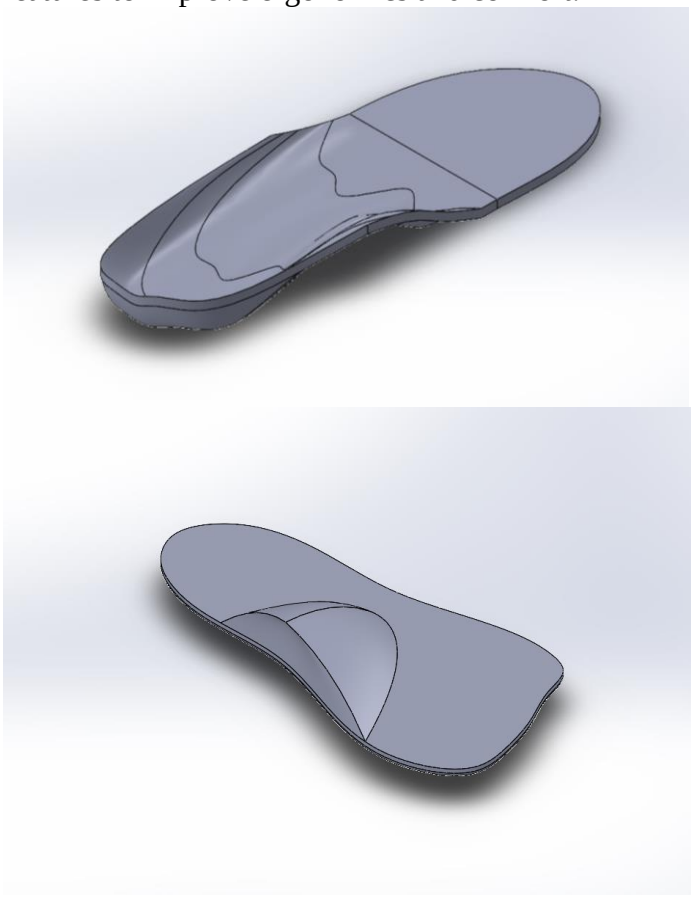


Fig. 1. Sample student designs of orthotic shoe inserts.

Three timed tests were also given in the course that students completed online. These tests consisted of two types of problems: multiple-choice problems about the design process and CAD techniques, as well as problems requiring students to create their own SOLIDWORKS part, drawing, or assembly files to demonstrate their ability to use SOLIDWORKS and follow design protocols. Tests were not proctored due to the difficulty of proctoring online tests with a large number of students in the class (>100 students), but at least four versions of each question were randomly assigned using test banks, student's names had to be incorporated in their designs, and the tests were timed to limit cheating.

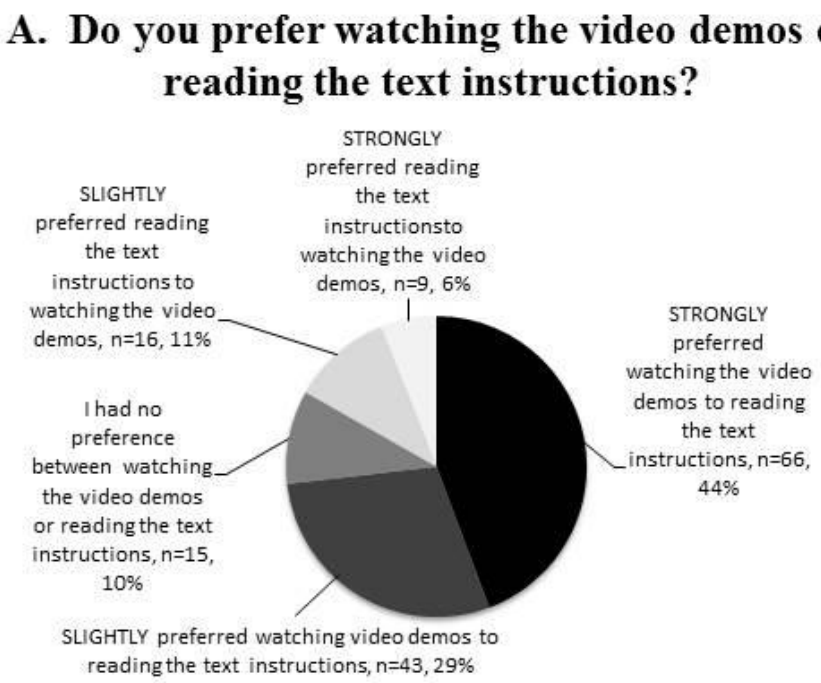
Results

As indicated in the beginning of course survey, many students already had opinions about flipped classroom courses, as 82% of students had previously taken a flipped course. The most common course that students had already taken in a flipped format was a first year engineering design course; however students also responded that they had taken a flipped calculus, physics, biology, or high school course. In the anonymous end of course survey, students indicated they preferred to watch the videos over reading text instructions (Fig. 2A: total number who either strongly or slightly preferred watching the videos over reading the text instructions was 109 students, 73% percent). Research by Yip-Hoi and Welch [11] similarly found that text-based instructions are difficult for CAD students to understand compared to video demonstrations. Almost all of the students responded that they watched each video lecture at least once (139 students, 93%), with 70% of students reporting that they watched the videos an average of at least two times (Fig. 2B).

Seventy-seven of the students preferred (either slightly or strongly) the flipped classroom format for this CAD course compared to a traditional lecture course (which would not have videos to watch outside of class, but would have live demonstrations during class) (Fig. 3A). When asked in the survey to explain their preference for a flipped classroom or a traditional lecture format for this course, student comments included:

- "The flipped classroom provides only upsides in my opinion. If you watch the lecture and have no questions, then you're good to go. And if you do have questions, now you have a full class period to ask. In a traditional class, sometimes there isn't enough time to ask long questions, or you don't even realize you have a question until you start the homework and it may be too late to ask."

- "I liked the class being a flipped classroom format. The video demos and text instructions were extremely helpful to complete assignments. In a traditional lecture class, I probably would have forgotten where tools [are located] and small things like that whereas with the videos and text instructions it was easy to reference them and find what you needed and not be stuck searching through the program for hours…Having the class time to ask questions about assignments and any problems that arose while completing assignments was very helpful to me…"



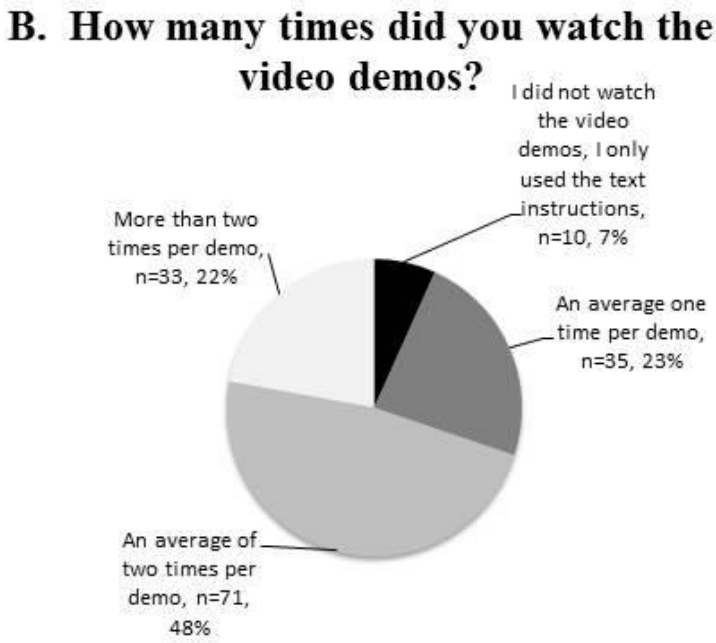
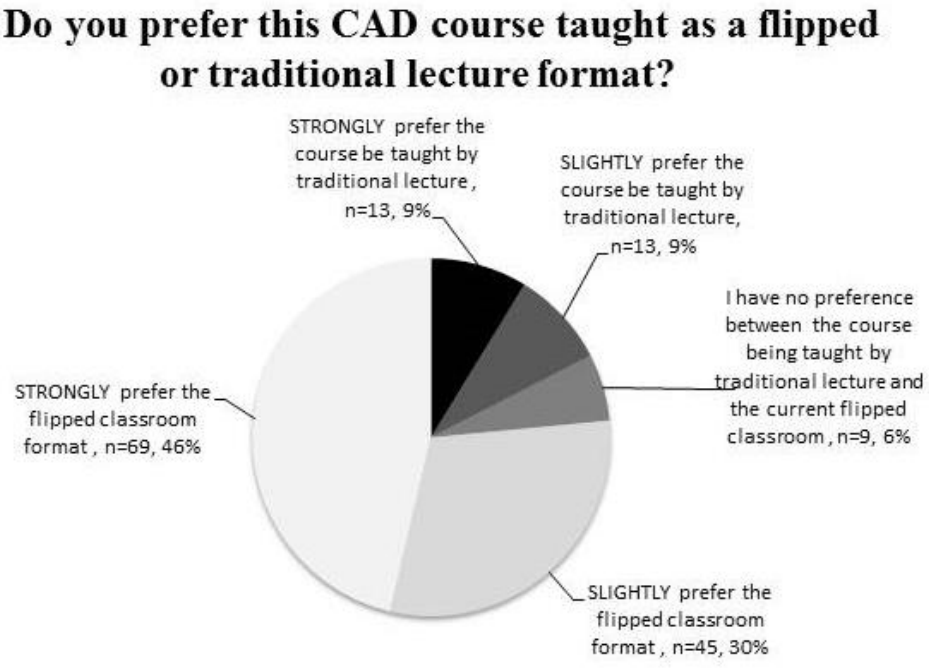


Fig. 2. Use of flipped classroom resources: watching video demos or reading text instructions. In the end of course anonymous online survey, students (n=149) were asked A) whether they preferred to watch the video demos or read the text instructions, and B) how many times they watched the video demos.



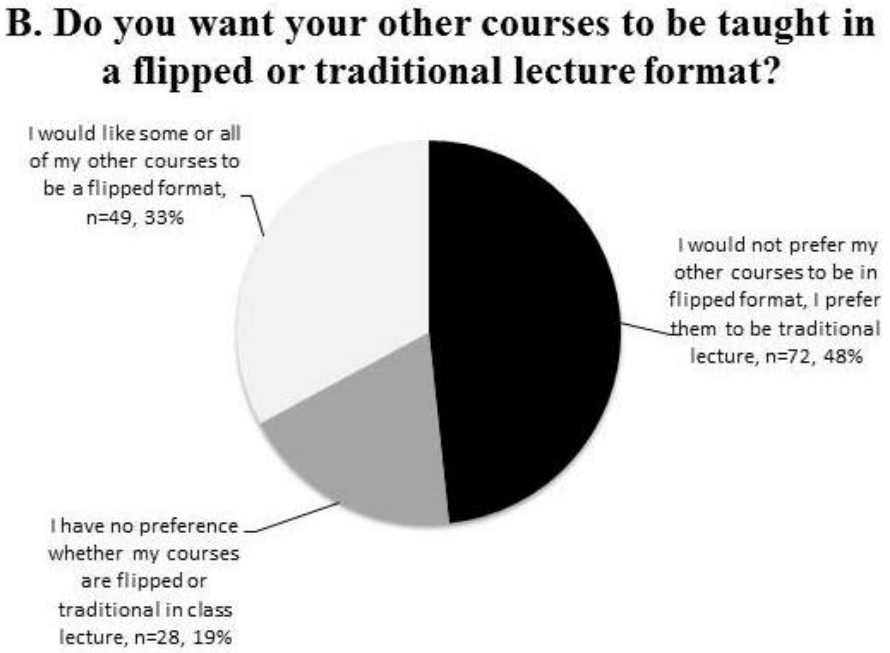


Fig. 3. Preference for flipped classroom or traditional lecture format courses. In the end of course anonymous online survey, students (n=149) were asked A) whether they preferred this CAD course to be taught as a flipped classroom or traditional lecture format (without the video demos), and B) whether they preferred their other courses to be taught in a flipped classroom or traditional lecture format.

- "I really liked the flipped-classroom format of this class because CAD requires a lot of kinesthetic and visual learning since we are learning how to utilize SOLIDWORKS and apply the software's tool[s] to reach a desired product…Since the class was flipped and attendance was mostly up to each student's needs, I had the opportunity to manage my workload according to both CAD and my other classes which is something invaluable both as a focused student and commuter."

- "I really enjoyed how this class was set up. I was originally nervous for the flipped classroom style, but with this it worked out very nicely. I liked having the videos and slides to refer back to. I've even referred back to videos and slides from weeks before…"

If a student misses a step while following a demonstration in SOLIDWORKS, they cannot easily catch up with the remaining steps. Therefore, videos allow students to stop, rewind, and replay steps that would not possible if the instructor only demonstrates the technique during class. Many students appreciated this aspect of flipped classroom courses. However, when asked if students preferred their other courses to be taught in a flipped classroom format, most students preferred their other courses to be taught in a traditional lecture format, not a flipped format (Fig. 3B). When asked to explain why they either did or did not prefer other courses to be taught in a flipped classroom format, some students commented about the quality of videos in other flipped classroom courses:

- "…I also liked that these were in person videos of [the professor] and not an AWFUL robot voice (like in [some other flipped classroom courses]).

- "…the videos and slides that we are provided are actually very helpful whereas other courses provide videos that are subpar to the actual instruction."

Many student explanations mentioned the amount of work required of students in flipped classroom courses, such as:

- "I don't want other courses to because of the fact that a lot of other courses require more work."

- "…On another note, when all of your classes are flipped classroom with an hour or so of pre class assignments to complete before each class it becomes very, very difficult to find the time to complete all of the pre classes, go to class, complete all homework assignments, and study… enough as well. I found this to be a large problem this semester as the vast majority of my large course load used the flipped classroom method, and I think it is an aspect of the flipped classroom method that isn't thought about enough."

Students often resent being given more work than they think is necessary. When students are required to take time outside of class to learn the material (by watching video lectures, reading, working through exercises, or completing pre-class quizzes) in addition to being assigned homework or projects to be completed entirely outside of class, students may view this as an unfair workload compared to traditional lecture courses where students are only required to complete homework or projects outside of class. The instructor for this CAD course wanted to

ensure that if out of class time is required to watch videos, then in class time should be given for homework assignments and projects to hopefully increase student satisfaction and compliance with completing all the required work.

Students also commented that the content of the CAD course suited itself to the flipped classroom format more than other courses:

- "Other classes are good as a traditional classroom format because they are much more conceptual and it is more important to fully understand the content rather than get a lot of practice doing problems."

- "I do not like the flipped classroom method for classes that are…more math based, because for subjects like math I am able to learn more effectively when I can get any questions answered as they arise in the lesson. In other math based flipped classroom classes I have taken, the problems often jump substantially in difficulty between explaining the concept in video lectures beforehand to in class problems, and the professor often doesn't explain how to do the more difficult problems because they assume you already understand how to do them from simpler videos."

- "I think that since CAD is more hands on this works but regular classes such as a math or science where you would learn better by physically taking your own notes, this may not work as you wouldn't take in parts of the material."

CAD is a highly visual process- requiring the ability to comprehend orthographic views as a representation of a 3D object, breaking down a complex part into simple 3D shapes and modifications, and arranging parts together into assemblies. Therefore, videos showing CAD techniques may be more useful than videos of math equations or text-based computer programming due to the visual, rather than textual, or mathematical, nature of the material. Other software-based graphics courses or courses that rely on visual processing skills may similarly be well suited to the flipped classroom format.

Admittedly, the instructor observed that student attendance in classes was low except on required group project work days. In the future, in class quizzes or other incentives could be used to improve attendance. However, prior research of flipped classrooms has found that students may not attend class for flipped courses because they are able to learn the material and complete problems with the resources provided without attending class [5].

Anecdotally, the instructor greatly enjoyed teaching this course in a flipped classroom format. While the instructor had not previously taught an entire semester CAD course in a traditional lecture format, she had taught a CAD segment of a course in a traditional lecture format. When using the traditional format of in class lecture and out of class homework/group project assignments to teach CAD, many students asked the instructor simple procedural software questions, such as "How do I change the units?" or "How do I specify a fillet radius?" These questions took up a large amount of time for the instructor as class sizes grew, leading to a frustration and a lack of time and energy to spend on more substantial student questions, such as "How do I decompose a complex design into individual features?" or "How do I determine an

appropriate type of mate when assembling two parts?" In the flipped classroom format, while basic procedural questions are still asked occasionally, many students can find the answers to such questions quickly in the video or text resources provided.

Study Limitations

This study has several limitations. First, this study relied on anonymous survey data of student perceptions. Student responses may not be accurate when recalling how many times they watched videos, or may be biased due to the desire to seem like a "good student", even when they are anonymous. Second, student attitudes and perceptions are often poorly matched to how students learn. Student performance in this flipped format course was not compared to student performance in a traditional in class lecture course, as the course was only offered in a flipped format. The instructor believed this flipped format would be the most beneficial to students for this course, and therefore did not want to potentially hinder any students learning by subjecting them to a traditional lecture class without the video lectures solely for the sake of research comparison. Another study investigated traditional lecture versus flipped classroom courses where students in both versions of the course were given access to video tutorials so that no students were deprived of access to the potentially helpful learning tool of videos [8]. Not surprisingly, the investigators in that study did not find a statistically significant difference in student performance between these course versions since students had access to identical resources [8]. Despite these limitations, this study provides insight of students' preferences for flipped classroom courses and what they find to be most beneficial to their learning with this new educational technique.

Conclusions

Most students appreciated that this CAD course was taught in a flipped classroom format. The flipped format consisted of watching short video lectures outside of class, which allowed in class time for students to work on homework and group work and get help from the instructor and TA. However, student's positive association with this flipped classroom CAD course did not extend to their desire to have other courses taught in a flipped classroom format. One explanation for this discrepancy in students' preferences for the format of different courses was concern over workload. Students in flipped classroom courses are sometimes burdened with videos to watch in addition to homework or group projects to complete outside of class; while in class time is spent working on additional in class activities or problems. To attenuate student resentment towards flipped classroom courses, instructors may want to provide class time for students to work on homework or group projects that otherwise would be completed outside of class. Also, instructors should evaluate their courses when transitioning from an in class lecture format to a flipped classroom format to ensure that they are not overburdening students with out-of-class work. If videos are used, they should be short in length and recorded by the instructor. Student preference for the format in which courses are taught may also be explained by the course subject. Visual topics, such as CAD, naturally lend themselves well to video demonstrations. More numerical or text-based courses, such as math or physics, may not benefit as greatly from out of class video demonstrations. Therefore, this research will hopefully encourage other CAD instructors to flip their courses.

Future Work

As a further extension of the flipped classroom format for this CAD course, the instructor plans to explore transitioning this course to a fully online offering. In the Spring of 2021, this course will be taught in a fully online format. Online office hours will be offered to ensure students still have access to help if they need it. Logistics of group work in an online class will need to be carefully considered using video conferencing software.

References

[1] M. Holdhusen. "A "flipped" statics classroom," presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA, June 14-17, 2015. Paper ID #12162.

[2] M. Radu. "Applying the Flipped Classroom Pedagogy in a Digital Design Course," presented at the 126th ASEE Annual Conference and Exposition, Tampa, FL, June 15-19, 2019. Paper ID #25080.

[3] H. Ozyurt and O. Ozyurt. "Analyzing the effects of adapted flipped classroom approach on computer programming success, attitude toward programming, and programming self-efficacy." *Comput Appl Eng Educ* 26: pp. 2036-2046, Apr. 2018:.

[4] R. Castedo, L. Lopex, M. Chiquito, J. Navarro, J. Cabrera, and M. Ortega. "Flipped classroom-comparative case study in engineering higher education." *Comput Appl Eng Educ*. 27: 206-216, Oct. 2018.

[5] S. Butler Velegol, S. Zappe, and E. Mahoney. "The Evolution of a Flipped Classroom: Evidence-Based Recommendations." *Advances in Engineering Education.* vol. 4. Winter 2015. pp. 1-37 Jan 2015.

[6] C. Aji and M. Khan. "Flipped Classroom and its Impact on Student Engagement," presented at the 126th ASEE Annual Conference and Exposition, Tampa, FL, June 15-19, 2019. Paper ID #27370.

[7] C. Ankeny and S. Krause. "Longitudinal Assessment of Student Persistance, Achievement, and Attitude in a Flipped Biomedical Engineering Classroom using Pencases and Muddiest Point Web-enabled Tools," presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA, June 14-17, 2015. Paper ID #12097.

[8] L. Amaya-Bower and S. Kirstukas. "Effect of Video-Guided Tutorials in a Standard Curriculum and in a Flipped Classroom for a 3D-CAD Course," presented at the 123rd ASEE Annual Conference and Exposition, New Orleans, LA, June 26-29, 2016. Paper ID #15680.

[9] A. Saterbak, T. Volz, and M. Wettergreen. "Implementing and Assessing a Flipped Classroom Model for First-Year Engineering Design." *Advances in Engineering Education.* vol. 5: Fall 2016, Jan. 2016.

[10] J. Biship and M. Verleger. "The Flipped Classroom: A Survey of the Research," presented at the 120th ASEE Annual Conference and Exposition, Atlanta, GA, June 23-26, 2013. Paper ID #6219.

[11] D. Yip-Hoi, and J. Welch. "Enhancing a Blended Learning Approach to CAD Instruction Using Lean Manufacturing Principles," presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA, June 14-17, 2015. Paper ID #11432.

[12] S. Brenna, C. Ankeny, and M. Caplan. "Investigation of Student Achievement and Attitude about a Flipped Classroom Using Linked Lecture Videos in Biomedical

Engineering (Work in Progress),” presented at the 124th ASEE Annual Conference and Exposition, Columbus, OH, June 25-28, 2017. Paper ID # 19399.

[13] R. Leicht, S. Zappe, J. Messner, and T. Litzinger. “Employing the classroom flip to move “lecture” out of the classroom.” Journal of Applications and Practices in Engineering Education. 3.1, pp. 18–31. Jan. 2012.

[14] S. Zappe, R. Leicht, J. Messner, and T. Litzinger. “Flipping” the Classroom to Explore Active Learning in a Large Undergraduate Course,” paper presented at the 116th Annual Conference of the American Society for Engineering Education, Austin, TX, June, 14-17, 2009.