A CAD Course Revision: Active Learning In and Out of the Classroom

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Larger classes in a growing program have prompted instructors to seek alternative classroom management techniques while maintaining student-instructor interaction. A revision of a Computer Aided Design (CAD) course was necessary due to annual software updates and an initiative to promote classroom discussion. Early offerings of the CAD course focused on learning how to use SolidWorks in a combined lecture and lab time. The instructor passed on his/her knowledge to the students by lecturing and demonstrating. The instructor could easily move around the classroom and help students as needed in classes with small enrollments. With small class sizes in a new, growing program, instructors did not assign a textbook, but used notes and handouts. A later offering of the course used a textbook, and the instructor used the same approach in the classroom. With growing enrollment requiring full computer labs, the pedagogical approach has shifted the instruction of the software out of the classroom in order to maximize individual student interaction. Without the need to revise notes and handouts for a newer edition of the software, the instructor assigned a series of short instructional video lessons to be watched before coming to class for the day's topic. During class the instructor did a short overview, led discussion, and then allowed students to work on the daily assignment or lab. Previously, a significant portion of the lab and class time was devoted to lecturing on software use. This change in instruction has allowed more time for in-class discussion, student collaboration, and in-class design exercises. The complexity of parts and models created over previous offerings shows that the change in presentation style has resulted in more rapid understanding of SolidWorks. The use of the external tutorials has also assisted the instructor with keeping class content up-to-date for each new version of the software. This paper summarizes the results of revising a traditionally taught course, with notes and handouts, to one that utilized a textbook, and finally into a hybrid flipped classroom model.

Introduction

One of the challenges in the teaching profession is to motivate and inspire students to learn. There are numerous examples to motivate students as expressed by Barbara Davis. These range from incorporating different teaching methods to various ways to organize the course[1]. Chickering and Gamson argue that time on task and active learning leads to better understanding[2]. Vogt emphasized and elaborated for "time expending the necessary mental effort." She also continued in her study to show that student self-efficacy had "very strong effects on effort and critical thinking where academic confidence had insignificant effect"[3]. Another challenge is moving students from passive to active participants in the learning process. Engaging students in the learning process leads to a deeper level of thinking and cultivates students that are more creative and motivated[4].

As a teaching focused school, The Citadel's School of Engineering has had a proud record of significant contributions since its inception in 1842. The Civil and Environmental Engineering Department was established in 1912, and the program became accredited in 1936. The Electrical and Computer Engineering Department was established in 1941, and the program was accredited in 1976. The Mechanical Engineering Program was added in 2014 with the first mechanical engineering courses offered in the fall of that year. The School of Engineering applied for

accreditation of the new Mechanical Engineering program as soon as the first mechanical engineering students graduated in May 2016.

The initial name of one course, Computer Applications, was chosen to include topics such as Computer Aided Design (CAD) or numerical methods that would be beneficial for the curriculum. For Mechanical Engineering, the evolution of this junior-level CAD course, MECH 325 Computer Applications, was motivated by three dynamics: increasing enrollments, keeping current on an evolving software program environment, and fostering classroom discussion. With projected student enrollments for larger class sizes, faculty within the Mechanical Engineering department were investigating alternative approaches to instruct. They had the goals to increase student-instructor interaction, promote critical thinking, and improve the overall student learning experience. The department had already chosen SolidWorks as the CAD software for the course and obtained an extended (multi-year) license.

Initially, student enrollment in the course was small (fewer than 10), but has since grown into full computer labs of 24 students. The instructors in the early offerings of the course lectured on using the software and spent half of the classroom time directing students to work in class. Students received all instruction in the lab and from information posted on Blackboard. The three initial offerings of the course did not require a textbook. However, during the fourth offering, the instructor required a textbook and assigned work to prepare students for the class and lab. Instructors up to this point had relatively small sections and could interact with all students. With the growth of the program and student enrollments, the fifth offering of this course posed a challenge to continue with either of the two previous styles. While the SolidWorks software is important for preparing students for work or graduate school, it required significant classroom time and resources to lecture, which competed with class time for hands-on work.

The faculty investigated and chose to teach the course using a hybrid approach. Adopting a hybrid or flipped classroom has become a solution for some instructors wishing to spend less time lecturing and devoting more time to hands-on or interactive problem-solving activities. This course style is intended for the students to study the lecture material outside of the class and subsequently allow time inside of the class for hands-on activities and collaborative problem solving, discussion, and most importantly for the instructor to work example problems, answer questions, and/or introduce real world applications. The instructors, however, did not have the time or resources to create and continually update instructional content on using SolidWorks. The need to update content is important for this course as the college updates to the newest version of SolidWorks every year. Instead, the instructor assigned an “e-text” (SolidProfessor) for the course. This research explores using commercially-produced content to teach the software program portion of a computer-aided design course.

Research Questions

One goal of the new mechanical engineering program is to identify best practices through assessment of the courses and program. Another goal of the faculty is to ensure the students have a positive experience in each course. After every semester, student evaluations are assessed for trends and opportunities to improve the course. Most recently for this course, the instructors

wanted to gage the students' opinions regarding the hybrid classroom approach and evaluate how it impacted their learning. Results of an institutional level survey reveal student perceptions of the course and the instructor. A department level end of the course survey shows the evaluation of the course objectives. Overall, student evaluations of the instructors were very positive. Three questions the instructor wanted to answer include:

1) Can student interest be influenced by a different delivery style in this mechanical engineering course?
2) How will junior mechanical engineering students receive the new hybrid style Computer Applications course?
3) How well and will the students still meet course objectives with the hybrid format?

The flipped classroom model moves instruction to a learner-centered model in which class time explores topics in greater depth and creates learning opportunities, while educational technologies such as online videos are used to deliver content outside of the classroom. In the traditional model of classroom instruction, the teacher is the focus of a lesson and the primary base of information during the class period. Professors have used the flipped classroom model for years. Humanities instructors expect students to read on their own and rarely dedicate any class time to covering the basic storyline or narrative. Instead, class time is committed to discussing themes. Some professors use the Socratic Method in their courses, requiring students to study the material before class or face a volley of questions. On the other hand, STEM disciplines are traditionally taught by disseminating information and content, making them particularly fit for lecture[5].

Course Overview

A first semester junior course, MECH 325 Computer Applications, was taught for five terms, including summer, beginning in the fall of 2014. Four different instructors have taught the course with two having taught twice or in multiple sections. Approximately 70 students have taken the course as a requirement in the mechanical engineering curriculum. Few of the mechanical engineering students had experience with SolidWorks (exceptions are from transfer students coming in from technical colleges). With very little prior student knowledge, it was important to provide a well-structured way for them to learn and use the software. Frequent homework assignments were used to reinforce material from each chapter. The different instructors had different assignments, but the assignments covered the same topics and were approximately the same level of difficulty.

The first three offerings of the course had low student enrollments as they were part of developing a new engineering program. It was offered during two fall and one summer term with fewer than 10 students each term. The SolidWorks vendor provided an instruction manual which the instructors used as a guide for classroom instruction and sample models to build. Although the instructors made available sample files and other instructional documents, students had no reference or method to teach themselves if they missed a class or needed additional practice. 'Need a textbook' was a common End of Course comment. Some students found online videos of some SolidWorks instruction. Unfortunately, many were in different languages and students had no audio explanation of this form of instruction.

A textbook was adopted for one semester which allowed students to make up some instruction when they missed classes. There were many more examples and variations of models to create. Additionally, the text offered instructions and tips creating the models. Students overall found the text helpful and felt the course was more traditional with an assigned textbook. In both the no text and required text delivery of the course, instructors spent about half of the class time instructing and directing students to mimic what the instructor was doing on the screen. The instructor would then have students create new models and would work with students if they needed additional instruction or assistance. Instructors teaching during these first four offerings experienced the challenges from the quick coverage of this course where hands-on reinforcement is necessary and not well-exercised.

The latest iteration of teaching the CAD course was conducted as a flipped hybrid classroom. The SolidWorks team was contacted to inquire as to what kind of tutorial programs they offered to supplement learning their CAD environment. They had developed an interface called SolidProfessor which is a repository of a few hundred video walkthroughs demonstrating various elements of the SolidWorks tools. It also complemented each of these videos with pre- and post-tests to track how the student's understanding of a topic improved after watching the walkthrough. The instructor can assign problems or labs that are similar to what was demonstrated but requires the students to perform different tasks. The SolidProfessor interface was very flexible and a course was developed to target and mirror the learning objectives in the classroom. As such, students were assigned groups of videos and tests to complete before coming to class. The SolidProfessor software management system allows the instructor to know if, when, and how much of the assigned video each student has played/watched. On the day of the class, a brief overview of the topics covered was conducted and the rest of the time was devoted to working with the SolidWorks software.

The model is termed hybrid due to the students also using a textbook to supplement their learning, to refresh topic details, to work problems, and to be used as a reference. While the students were working on assigned problems, if they wanted to quickly refresh the steps for a given program functionality, they could easily find it using the text. The use of the textbook enabled a three-pronged approach to learning the course objectives wherein they would be exposed to and gained familiarity with a topic through the SolidProfessor videos, receive recapping of the material and direct help from the instructor, and have quick-reference access to the textbook for troubleshooting and progression.

The use of SolidProfessor and utilizing the flipped classroom enabled the students to acquire more hands on experience with the program in a setting where they could directly ask for assistance from the instructor or a classmate. This approach allowed for the instructor to immediately step in to offer assistance to the students as they began connecting their understanding, from the out-of-class preparation, to the hands-on environment. During class time as opportunities presented themselves, the instructor made a concerted effort to extend the class content by posing questions and initiating class discussions that explored design applications/alternatives or having students defend their modeling approach.

In all, the flipped classroom culminated in the students working 58 in-class models and simulations in conjunction to 12 more challenging assignments for homework. Additionally, the flexibility gained in this setting allowed for more dynamic exercises to be completed so as to reinforce the student's understanding of the course objectives. The mechanical engineering department possesses a 3D printer and many SolidWorks-based models that utilized current methods learned in the course were printed and given to the students. They then had to measure all of the relevant dimensions of the part using rulers and calipers and recreate the forms in SolidWorks. Models ranged from very simple shapes to complex cube puzzles that had to both be solved with the printed parts and inside of the software using appropriate mates and interference detection. This methodology was conducted four times throughout the semester and provided a way to connect real-world functionality to the use of the CAD software.

Survey and Findings

The assessment method included student end of the course survey data that was collected during the last days of class and focused on measuring student's interest in the material and effectiveness of the instructor. The data from approximately 60 students who responded to the surveys was included in this study. A standard five-level Likert Scale was used to assess the level of agreement or disagreement for the questions (Table 1).

Table 1: Assessment Scale

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

The rating scale is a normal set of responses used at The Citadel for student surveys. Students and faculty alike are familiar with the same standard set of responses and their interpretation.

The first hypothesis examined by this paper is if student interest can be influenced by a different delivery style in mechanical engineering courses. Figure 1 shows a partial result of the course survey that asks course related questions. Additional survey questions addressed the course syllabus and grading system and are not included here. Overall, responses were very favorable ranging from 4.40 to 4.65 on the Likert Scale. The lowest score was in the area of "using many methods to involve the students in learning." This is particularly noteworthy in the times when there was no textbook or tutorials from SolidProfessor. Students simply learned what was presented in class and modelled the assignments in the remaining class time and out of class. Once the students had a textbook or access to SolidProfessor tutorials, this area was also the biggest change. Students now had additional resources to learn or reinforce the material.

Another big difference was on the second question in Figure 1, "I learned a lot in this course." Students felt they learned more as they were engaged in more active learning and time on task, especially in the classroom. The changes from no text, to a text, and finally an e-text that required students to study the lecture material outside of the class resulted in improvements in this area each time. Rather than having the instructor teach everything this allowed time inside of the class for hands-on activities, collaborative problem solving, engaging in discussion, and

most importantly allowed the instructor to work example problems, answer questions, and/or introduce real world applications.

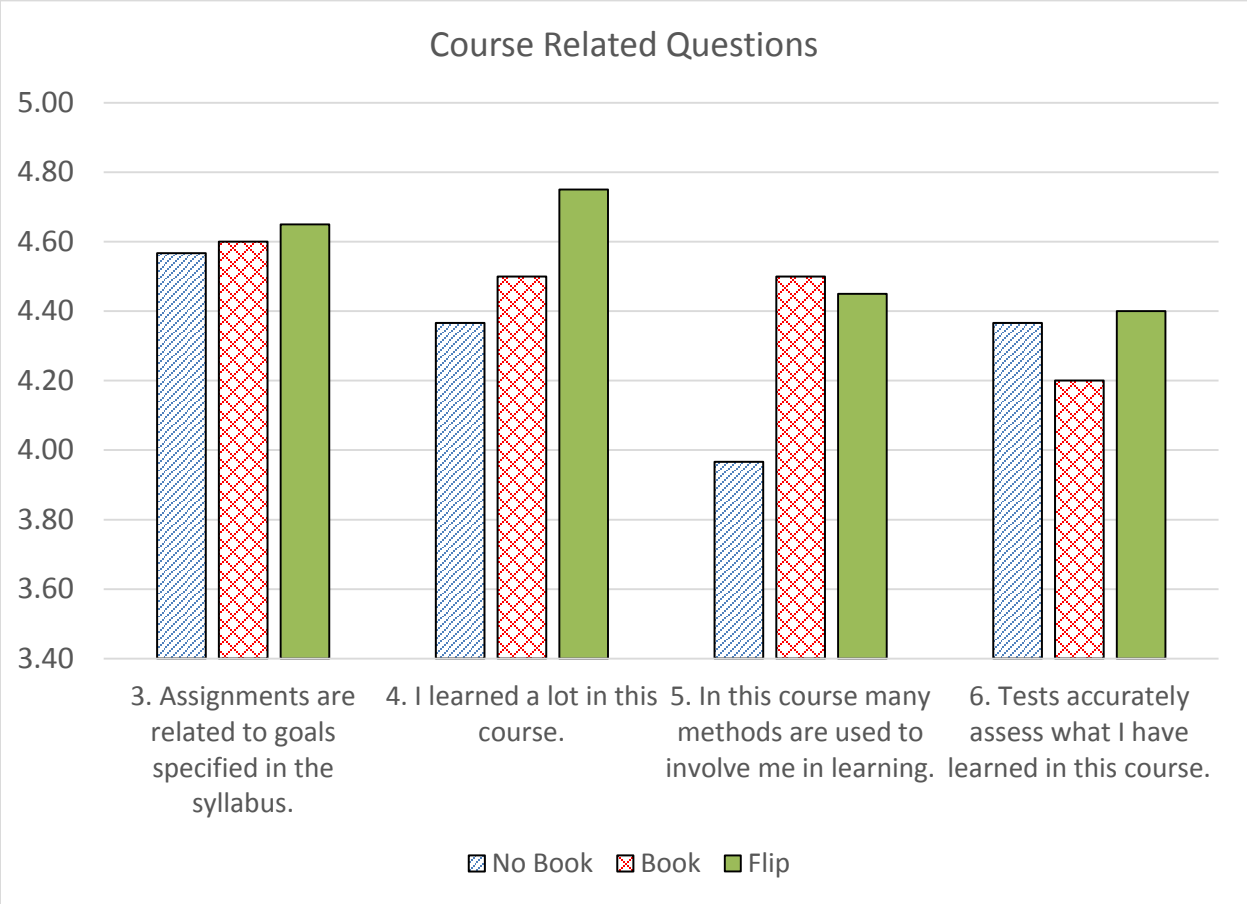

Figure 1: Course Related Questions

The second research question was to determine how students received the new hybrid style Computer Applications course. Figure 2 shows a partial result of the course survey that asks instructor related questions. Additional survey questions addressed the instructor's enthusiasm, class dynamics, and student's willingness to take another course from the instructor. Again, the student evaluations on the instructor were high, ranging from 4.45 to 4.60 on the Likert Scale. Questions 1, 2, 5, and 6 clearly show the students' impression of the instructor using a flipped classroom approach was better than the no textbook instructors and on par or better than the textbook instructor.

It is noteworthy in these surveys to reveal that the flipped classroom instructor was a new, first semester assistant professor using this technique. The textbook instructor was a seasoned associate professor who had also taught the course without a text previously. The no textbook instructors included two seasoned associate professors as well as a new, first semester assistant professor. The flipped classroom instructor had better results (evaluations) in this course than previous instructors. In the new instructor's other traditionally taught courses, he performed

about the same as other instructors. The only difference was using the flipped classroom approach in this course.

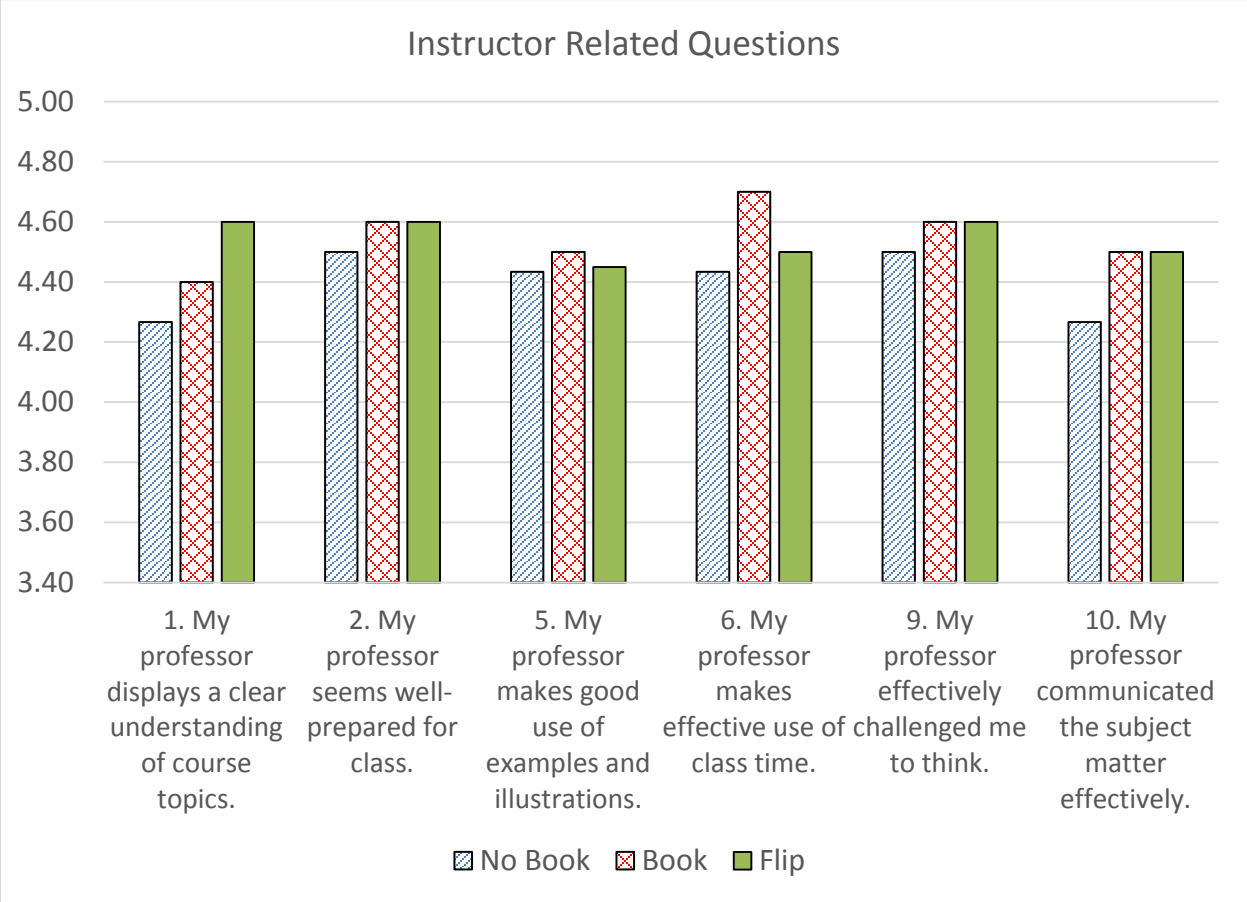

Figure 2: Instructor Related Questions

The third research question concerns student performance in meeting the course objectives. This question was answered with an assessment of the course objectives through embedded indicators. First, student performance in the form of graded events (or embedded indicators) is combined with a subjective faculty rating to produce an assessment of each objective in a course. The course director or instructor enters embedded indicator data after the graded event or at the end of the semester. The statistical data for each graded event is available from the instructors' gradebook. At the end of the term, all the entered data allows the overall average and standard deviation to be computed for each course objective and level of support by each embedded indicator. An analysis of data of student performance from many graded events can produce a detailed assessment of the course and areas for course improvement. Figure 3 easily shows that students successfully met course objectives with a range of objective scores from 4.02 to 4.44 out of 5.0 on the Likert Scale. Even though the flipped classroom instructor was new and used the e-text, many of the exam questions were very similar to what was used in the previous semesters. Students were clearly performing at a similar level or better that students who had taken the course previously.

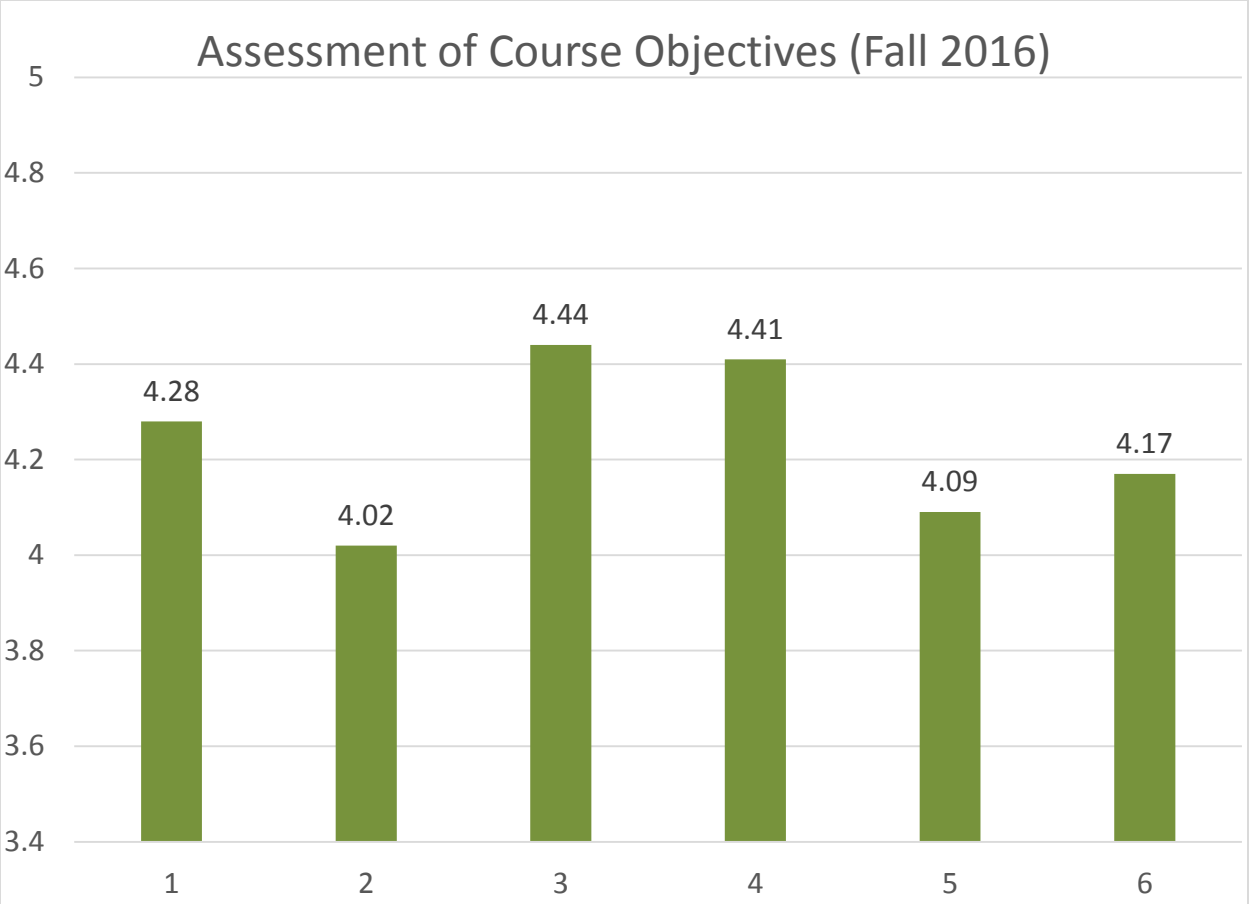

Figure 3: Assessment of Course Objectives

Conclusion and Future Work

Using a flipped or hybrid classroom approach is not always easy, nor is it the right answer for every course. It is hard to be perfect in the first implementation. Continuous monitoring, improvements, and modifications are needed to make the most of using this approach for student learning[6].

For the authors, this was the first step towards incorporating third party technology to augment the classroom using flipped learning. A hybrid flipped model was chosen to investigate how students responded to the experience versus the traditional classroom lecture approach. The survey data collected revealed positive student impressions about the flipped learning method. The instructor was able to spend more time with each student answering questions. Previously, a significant portion of the class and lab was devoted to instructor lectures on how to use the software. This change in instruction where much of the 'how to' part is the student's responsibility has allowed more time in-class for discussion and hand-on exercises. The use of SolidProfessor has also assisted the instructor with keeping class content up-to-date with changing versions of the software.

The first area for future research is to corroborate the results with future Computer Applications classes. The sample population in this study was 60 students, and was a mix of traditional day students and some evening transfer students who have taken many CAD classes at technical colleges. Further research is needed to show if the same results are true with different or more mature learners, and if the results are different with different instructors. Other research could focus on hybrid or flipped instruction in other mechanical engineering courses and to determine the best techniques.

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