Work in Progress: Teaching Design Theory and Mastercam in a Hybrid Flipped Classroom Environment

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The revision of the junior-level Computer Aided Design and Manufacturing course MFGE3316 was driven by three forces: ABET, keeping current on an ever-changing software program, and fostering classroom discussion. At an ABET outcomes annual review, the consensus opinion was that the students could effectively design but they needed more practice to better recognize the concepts of engineering design theory. This weakness led to a push for students to practice more with designing and design theory before their senior design courses. Traditionally, MFGE3316 lectured on design theory, fundamentals of CAD/CAM systems, and CNC code generation by CAD/CAM software using a combined class/lab time. The Mastercam software is important for preparing students for industry, but was taking significant classroom time and resources. The revised course pedagogy is a hybrid flipped classroom environment to shift instruction of software use out of the classroom, but the instructor did not have the time or resources to create and continually update video content on how to use Mastercam. Instead, the instructor assigned an “e-text” (SolidProfessor account) for the course. The videos from the e-text are assigned to be watched before coming to class for that topic. During class the instructor does a short overview, leads discussion, and then the students work on the lab. Previously, a significant portion of the lab and class time was devoted to lecturing on software use. This change in pedagogy has allowed more time for in-class discussion and in-class design exercises. As well, the change in presentation style has resulted in more rapid understanding of Mastercam, as evidenced by the semester week in which the class completes the labs. The use of the e-text has also assisted the instructor with keeping class content up-to-date for each new version of the software without having to personally create new videos. The effectiveness of the additional time spent on design theory was assessed with the beginning of semester and end of semester engineering design self-efficacy survey instrument. This instrument was administered to determine if the course and time spent on design had an effect on the students’ engineering design self-efficacy.

Index Terms - CAM, Design, Flipped, Hybrid, Mastercam.

Introduction

A new trend of hybrid or flipped classrooms has become a solution for some instructors wishing to spend less class time lecturing and more class time on 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, collaborative problem-solving, engage in discussion, and most importantly allow the instructor to work example problems, answer questions, and/or introduce real world applications. A class can be fully flipped, with all lecture-type content delivered outside of class, or a hybrid flipped, with part of the lecture content delivered outside of class and part within class time [1]-[6].
The revision of the junior-level Computer Aided Design and Manufacturing MFGE3316 was driven by three forces: ABET accreditation, keeping current on an ever-changing software program, and fostering classroom discussion. The impetus for researching a revision of the pedagogy for teaching this class was driven by an ABET outcomes annual review meeting, at which the consensus opinion was that the students could effectively design, but they needed to better recognize the concepts of engineering design theory. This weakness led to discussion on how could students do more exercises and practice with designing and design theory before their senior design course. MFGE3316 traditionally had lectures on design theory, fundamentals of CAD/CAM systems, and CNC code generation by CAD/CAM software using a combined class/lab time. As it already contained engineering design theory, it was a natural place to try to increase the design experience for students. While the Mastercam software is important for preparing students for industry, it was taking significant classroom time and resources, which was a roadblock to increasing class time on engineering design theory using a traditional lecture delivery. In order to free more class time for design content, the revised pedagogy of a hybrid flipped classroom environment was selected for this course. The instructor, however, did not have the time or resources to create and continually update video content on how to use Mastercam. The need to update the content was especially relevant for this course as the university stays current on its version of Mastercam and, as such, the lead author has had a new version of the program each time he has taught the course. Instead, the instructor assigned an “e-text” (SolidProfessor account) for the course. This research explores using industry-produced content to teach the software program portion of a computer-aided design and manufacturing course.

Background

The flipped classroom movement frequently relies on video content to be a primary mode for the presentation of lecture material outside of the physical classroom [7]. For very common course topics, such as Mechanics or Statics, high quality video content is often developed by textbook manufacturers for faculty adopting a certain textbook or for a fee [4] & [8]. Instructors of less common courses must develop their own video course content for their classes, although some textbook manufacturers do offer access to instructional design professionals for a fee to assist with the process [9]. The video styles reported in the literature encompass many styles including recordings of lectures taken during a class, instructors lecturing to a camera, and power point style presentations with a voice recorded over pictures and texts [10] & [11]. Most of the videos reported in the literature were produced by the course instructor [12], [13], & [7], with a few mentions of student-produced content [13], [14], & [11]. The task of generating video-based lecture content for a course can be a huge project that can exceed the time that the instructor has available [15] while also meeting research and service expectations.

Students watching a video may be reviewing pre-existing knowledge or they could be introduced to a new topic. Either way, these students are engaged in remembering previous knowledge and then applying new knowledge, whereby their pre-existing knowledge is reiterated and retained. When using the lens of Bloom’s Revised Taxonomy to these students watching videos, their
lower-order thinking skills, such as remembering, were used [16]. It is also expected that high exposure to video content, whether through social media outlets such as YouTube, television, or even Khan Academy videos, have given students preconceived ideas about how they might learn from digital video. Furthermore, when the content being viewed had an actor or person the student can relate to, the content becomes more engaging [17]. Videos are actually a means of flexibility in different fields of study [18] & [19], such as distance learning where students can attend lectures virtually so some students may have experience with other courses including video content and be less resistant to this form of instruction.

To get insight into the effects of the courses focus on learning and applying design theory, an instrument was used to measure participant engineering design self-efficacy. The instrument was designed and validated by Carberry et al [20]. The tool measures individual’s self-efficacy towards engineering design tasks. Self-efficacy is an individual’s belief in their ability to complete a specific task [21]. This instrument examines four aspects of an individual’s self-efficacy: 1) Confidence, 2) Motivation, 3) Expectation of Success and 4) Anxiety towards completing engineering design [20]. The instrument was administered at the beginning and end of the Hybrid2 semester, which is the last semester for which data has been collected.

**Computer Aided Design and Manufacturing Course**

The SolidProfessor system allows the instructor to assign exercises/labs that are set of videos. This system has content for a variety of software packages such as AutoCAD, Solidworks, Onshape, and more [22]. This research focuses on using the SolidProfessor system as an “e-text” to instruct students how to use Mastercam. The e-text contains videos explaining the topic and then demonstrating how to use the software along with step by step written instruction on how to do the exercise in Mastercam. The instructor can then assign a lab that is similar to what was demonstrated but requires the students to perform different tasks. The videos are assigned to be watched before coming to class for that topic. The SolidProfessor software management system allows the instructor to know if, when, and how much of the assigned video each student has played/watched. When students come to class the day a video is due, the instructor does a short overview and discussion of the software concept, and then the students work on the lab.

**Experiment**

The instructor has taught the course four times. The teaching of the Mastercam software portion of the class, has changed with each time the course has been taught. The first time the instructor did not use an e-text but lectured and walked the students through learning each software topic in class from his understanding of the software. The second time the instructor taught the course (Lecture), the e-text was assigned as a support reference for the students to use, but the instructor still lectured and walked the student through learning each software topic in class. For that second iteration of the course, the instructor used 2-D labs #1-5 and one 3-D lab from the e-text and then assigned in-class learning labs. In the third iteration of the course (Hybrid1), the instructor used the e-text to implement the hybrid flipped course pedagogy. The students are therefore assigned the “homework” of watching the content video before class, with the instructor spending less than five minutes reviewing the topic before the students are directed to
work in class on the software labs. As the students work, the instructor walks through the classroom engaging in one-on-one discussion with the students to answer questions. In all semesters of this course, time is spent on lecture and discussion of computer integrated design and manufacturing theory in addition to learning the Mastercam software. The fourth iteration of the course (Hybrid2) was presented in the same manner as hybrid1 but with the addition of students completing an engineering design self-efficacy survey assessment tool at the beginning and end of the semester.

Feedback from end of course surveys in the first two semesters indicated that student felt it took too much time to learn how to use the software and they did not get enough time to use the CNC software to make projects. This work in progress paper presents the comparison of the second, third, and fourth semesters that the instructor has taught the class; referenced in the subsequent discussion as the lecture, hybrid one and hybrid two courses, respectively.

**Preliminary Results**

Data was collected on how much class time in the first six weeks of the course was devoted to design theory. The order of the course content is the same; only the change to a hybrid flipped classroom pedagogy for the instruction of Mastercam is different. In the first six weeks of the semester, there was a significant difference in how many class hours were able to be devoted to design theory lecture, discussion and hands on exercises shown in Table I.

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>3</td>
</tr>
<tr>
<td>Hybrid1</td>
<td>9</td>
</tr>
<tr>
<td>Hybrid2</td>
<td>9</td>
</tr>
</tbody>
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Table I show that three times more in-class time has been available for design theory content under the hybrid flipped course pedagogy than using the traditional lecture approach. The in-class time for design theory focused on the same design principals. The additional time was focused on having the students do multiple hands-on experiences with implementing the design theory at each stage of the design process in addition to more in-depth discussion and exploration of the design principals. For example, as part of the curriculum the instructor has a lecture discussing mission statement, design constraints, and criteria for design evaluation. In all semesters the instruction discussed the topic and provided examples of each with in-class discussion. In the hybrid semesters additional in-class time was available for the students to break into groups and spend time attempting to write their own mission statement, list of constraints and evaluation criteria. This in-class time for attempting to define their own statements for a design resulting in much lengthier and engaging in-class discussion of this topic. These in-class exercises and hands-on attempts were done for each step of the design process. In addition, the same five 2-D Mastercam labs (#1-5) were used in all three semesters. Data was
plotted in Figure 1 to show how many weeks into the course semester was the respective lab completed in the course based upon course type.

Figure 1: Weeks When Labs Were Completed in the Two Styles of Course Offering

Figure 1 shows how labs #1-#5 were able to be covered in class one to three weeks earlier in the course than in the traditional lecture-based class. The students demonstrated the same understanding of the material by completing the same labs in both semesters. Figure 1 thus illustrates the students in this hybrid flipped courses are learning the software faster than their counterparts in the traditional lecture section.

The students’ written end-of-course comments were also evaluated. At the end of the lecture section of the course a student expressed “Drawing the basic geometry took up a lot of the class time, maybe a little too much”. Similar comments were not seen in Hybrid course semesters. A student wrote, “The method of training videos for homework was very helpful when learning how to use a new software” and “Labs are challenging and fun.” No students expressed written comments that were neutral or negative about the e-text/videos. Thus the emerging themes from these end-of-course evaluations was that the traditional lecture format was frustrating for the students who were eager to engage in engineering and that students in the hybrid sections of the course expressed positive comments about using the e-text. Further ethnographic evaluation will be undertaken to explore the students videos on the differences in design theory instruction and practice.
Embedded assessments of student outcomes and student self-assessment results for the course are being recorded during this experimental semester. Therefore, comparison of changes in these two metrics and end-of-course surveys will be further used to gauge the effects on student learning and perceptions of the course once this hybrid course semester is completed.

The engineering design self-efficacy instrument was administered at the beginning and end of hybrid2, the last semester for which data has been collected. At this time, the researchers are looking to collect more data with the engineering design self-efficacy instrument to get a larger sample size.

Lesson Learned and Conclusions

The instructor is able to spend more one-on-one time with the students answering questions when using this hybrid flipped class pedagogy. Previously, a significant portion of the lab and class time were devoted to an instructor lecturing on how to use the software. This change in pedagogy has allowed more time for more in-class discussion and in-class design exercises. The change in how the software is presented has also allowed for more rapid understanding of how to use this software as evidenced by the semester week in which the same labs were completed. This change has enabled more opportunities to practice design theory from initial program statement to production of the final design on a CNC mill using Mastercam software during the course. The use of the e-text has also assisted the instructor with keeping class content up-to-date for each new version of the software without having to personally create new videos. The first attempt at collection of engineering design self-efficacy instrument resulted in an under sampling of the class population. In subsequent semester more effort has been devoted to get a larger percentage of students to compete the instrument. This research is continuing with future semesters of the course focusing collection data to determine he effects on student learning and engineering design self-efficacy.

References


[14] Young, J. R., “Across more classes, videos make the grade: In some science and writing courses, final papers are giving way to multimedia”, Chronicle of Higher Education, 57(36), 2011, A18.


