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Effect of Video-Guided Tutorials in a Standard Curriculum and in a Flipped Classroom for a 3D-CAD Course

Dr. Luz Adriana Amaya-Bower, Central Connecticut State University

Dr. Luz Amaya-Bower joined CCSU's Department of Engineering as an Assistant Professor in August 2012. Before joining CCSU, she was an Assistant Professor of Mechanical Engineering Technology at New York City College of Technology. Her PhD was granted by the Graduate Center, CUNY for her work on dynamic behavior of multiphase flows in microchannels. Dr. Amaya-Bower earned her undergraduate and master's degrees from City College, CUNY. Her teaching and research interests include multiphase flow systems, computational fluid dynamics, and numerical methods.

Dr. Steven Joseph Kirstukas, Central Connecticut State University

Steve Kirstukas is an Associate Professor at CCSU, where he teaches courses in solid modeling, MATLAB programming, and engineering mechanics. He is exploring the use of computer-aided assessment of CAD files to give consistent, accurate, and quick feedback to students. He has degrees in civil and mechanical engineering, with a Ph.D. from the University of Minnesota. Steve has worked in industry as a civil engineer, software developer, biomechanics researcher, and mechanical design engineer.

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Dr. Luz Amaya-Bower and Dr. Steven Kirstukas
l.amaya.bower@ccsu.edu / kirstukas@ccsu.edu
Engineering Department
Central State Connecticut University

Abstract

Computer Aided Design is a 200-level engineering class tailored to introduce students to the fundamental techniques of a CAD software. The original structure of this class included a standard lecture format and assignments consisting of tutorials and exercises. The authors have recognized two main drawbacks of the standard class structure: Firstly, class time is insufficient to cover all the material and for the students to complete assignments with the assistance of the instructor. Secondly, the tutorials are written in a format which may be confusing and difficult to follow. In addition, these tutorials provide an emphasis on the tools to construct the CAD models, while dismissing the model planning stage, which is critical for an engineering design. The authors have attempted to address these drawbacks. Tutorial videos were created to clearly show the model construction process from start to finish. One instructor taught the course in the usual manner but made the tutorial videos available to the students. The second instructor converted the class to a "flipped" or inverted format and also used the tutorial videos. In both cases, access to the tutorial videos has significantly improved the experience of the students in the class. Regarding student performance, the students in the flipped classroom had much greater changes in performance relative to those in the standard classroom.

1 Introduction

Today there are hundreds of different CAD software programs used across multiple disciplines. The possibilities for design, manufacturing, and analysis are limitless. Engineering students are generally exposed to at least one CAD software as part of their core curriculum. At this institution, Mechanical Engineering and Engineering Technology students are introduced to 3D CAD in a 200-level class. The historical format of this class is based on a lecture-lab approach. However, there never seems to be enough time for individualized student-instructor interaction. As educators we are continually seeking to improve students' learning experience, which ultimately enhances their professional practice.[1] In recent years, there has been a shift from the lecture-based approach to the learner-centered approach for subjects such as math, engineering and science.[2,3,4] The success of a learner-centered method includes development and implementation of learning activities which meet the specific subject matter, while motivating and improving students learning experience.

The authors have focused their efforts to create a learner-centered environment by exploring two different approaches: (1) augmenting a more traditional lecture-lab course with tutorial videos, and (2) implementing a flipped classroom which also uses the tutorial videos. In recent years there have been many studies which have explored the implementation of flipped pedagogy and video classrooms to enhance the learning experience of the students. The flipped or inverted pedagogy is a concept in which lectures are provided usually in form of videos to be completed before coming to class. The videos cover the fundamental concepts of the class, provide examples, and quick assessment activities. Once videos are completed, students attend class and implement and reinforce the concepts learned in the videos, by completing a different series of practice exercises.[5,6] Flipped classroom has been successfully implemented in different subject such as Economics,[6] Software Engineering,[7] Industrial Engineering,[8] Architecture,[9] Computer Programming,[10,11] Mechanics of Materials,[12] Thermodynamics,[15] and CAD.[16] In addition, the use of videos to create a self-taught environment has been explored to teach solid modeling courses.[13,14]

2 Description

This section presents a description of the Computer Aided Design class and the changes that have been implemented to provide a better learning experience for the students, while shifting from a lecture-based to a learner-based approach.

2.1 Historical Class Description

Computer Aided Design is a 4-hour lecture-lab Engineering class which aims to introduce students to the fundamental concepts of solid modeling, highlighting the operations of design, drawing, and assembly, in preparation for the manufacturing process. The principal emphasis is on efficient use of computer software for designing simple, modifiable models of products.

The original format of the class followed a classical pedagogy in which the instructor taught a lesson, and presented some examples. In the remaining class time, students worked on assignments consisting of tutorials and exercises under the guidance of the instructor. In both tutorials and exercises, isometric views and orthographic layout views were provided from which the student constructed a three-dimensional CAD model. However, the purpose of the tutorials is to learn new modeling techniques as well as proficient modeling practices. As such, the textbook provides detailed written step-by-step instructions as to how to construct a particular model. In contrast, exercises are similar in presentation but require the student to develop the modeling approach for a particular model. It is in the exercises where we can evaluate whether a student has learned to properly construct a simple robust model that fully incorporates the design intent of the original layout drawing.

The authors have recognized two main drawbacks of the historical course structure: Firstly, class time is not sufficient to cover all the material and to allow students to complete assignments while an instructor is available to help with conceptual and software issues. Because of the time consumed by the lecture presentation and example demonstrations, there is limited one-on-one interaction between each student and the instructor. As such, many students need time outside of class to complete their tutorials and exercises.

Secondly, students sometimes have trouble completing the tutorials from a written list of instructions. If a student misses a single step in the sequence, or inverts steps, then the resulting model may be much different than the intended model. Occasionally, the instructions are hard to follow or missing intermediate steps. Finally, emphasis of the written tutorial instructions is primarily on the construction of CAD models and little time is spent on the model planning stage.

2.2 Class Changes

The authors have developed two significant alternatives to apply in the classroom in order to address both drawbacks while providing a better learning experience for the students. The first alternative was to create tutorial videos which illustrate step-by-step process of how the computer models are created. In addition to showing the construction of a tutorial model from start to finish, the videos discuss the planning stage, demonstrate new modeling features, and show alternative methods for accomplishing tasks. The videos were developed with the aid of Camtasia software. The computer display was recorded as one of the authors constructed the tutorials models. Post-processing of the videos allowed the removal of pauses, verbal tics, etc., and adding images of the original layout drawing and callouts such as circles and overlay text to show where certain model dimensions originate. In general, the videos were created in such a way to maintain the student's attention while providing helpful information that was missing from the written instructions. A total of 21 tutorial videos were constructed; one for each of the tutorial models that students must complete. The videos range in length from approximately 5 minutes to 18 minutes, with an average length just under 11 minutes. All videos were disseminated to the students through Blackboard learn.

The second alternative was to switch the teaching pedagogy from a traditional to a flipped or

inverted classroom. In essence, this format provides video lectures in advance, so that the students can use the class time to complete their assignments, ask questions, and obtain immediate feedback. A series of 11 lecture videos were created to cover all the material from the class. Nine videos corresponded directly to chapters from the textbook. Two more videos were created to provide additional information about core sketching and dimensioning tools. The length of the videos range from 6 to 27 minutes, with an average of length of approximately 16 minutes. Each video has embedded quizzes which test the students about the content of the lectures. The number of quizzes change depending on the length of the video; on average there is a quiz every 5 to 6 minutes of video time. The spacing of the quizzes was selected to ensure that students maintain a high level of attention. In addition to the video lectures, the flipped classroom students also had access to the same video tutorials that were available in the first alternative.

3 Results

This section presents a description of the results used to evaluate the effectiveness of the alternatives implemented in the CAD class. The results are divided into two sections: First, a comparison of the impact of the changes in the performance of students. Second, a set of surveys distributed to the students.

3.1 Student Performance

The assessment criteria used to evaluate the effectiveness of the changes varies slightly between the two instructors. However, both instructors require assignments which include a combination of about 30 different tutorials and exercises. Also, there are three different exams which cover the main components of the class: creating fully and properly constrained sketches using geometrical and dimensional constraints, employing 3D features such as extrusions, revolves, sweeps, patterns, threads, holes, grooves, and shells, creating assemblies from a collection of parts, and producing technical drawings.

Table 1: Effect on Assessment Grades for Video-Only Cohort

Assessment	**Standard Cohort 1**		**Video-only Cohort**		**% Difference**
	Section 02	**Section 03**	**Section 02**	**Section 03**	
Assignments	81	82	79	83	- 1 %
Exam 1	79	79	73	72	- 8 %
Exam 2	82	82	76	78	- 6 %
Exam 3	85	82	82	82	- 2 %

To maintain consistency and uniformity, the comparison is done between the sections of each author independently. Table 1 shows the effect on assessment grades in the section in which only the tutorial videos were introduced. One author evaluated the implementation of the tutorial videos, referred as the Video-Only Cohort, compared to previous offerings of the class taught by same author, referred as Standard Cohort 1. As it is shown in the table, student performance was

slightly down when video tutorials are used. A possible explanation could be due to the videos making the modeling seem so easy and students could mimic the actions in the videos without fully engaging their brains. In the Standard Cohort 1, students tended to occasionally struggle with tutorials for large amounts of time. At times, students had exclaimed that they spent hours on a tutorial that should take 15 minutes. The extra pain and time that students invested was not good from the standpoint of their other classes and outside work and life; but possibly did make them better prepared for modeling. This is an item that has to be studied further.

Table 2: Effect on Assessments Grades for Flipped Cohort

Assessment	**Standard Cohort 2**	**Flipped Cohort**	% **Difference**
Assignments	92	97	5 %
Exam 1	85	92	8 %
Exam 2	83	95	13 %
Exam 3	83	87	5 %

Table 2 shows the effect on assessment grades in the section in which both changes were implemented. One author assessed the implementation of both the tutorial videos and the flipped method, referred as Flipped Cohort, compared a previous offering of the class taught by that author, referred as Standard Cohort 2. As it can be seen from the table, there was a significant improvement in all the assessment tools used. The lowest difference can be seen in the assignments and the third exam 5% increase. On the other hand, the second exam had a significant increase of 13%. This trend is very positive and encouraging for the use of both the flipped method and the tutorial videos combined. Comparing the results from tables 1 and 2, it can be seen that there is a significant difference between the grades obtained by students in the different assessments due to different instructors.

3.2 Surveys

Two different sets of surveys were administered to the students. The first aims to obtain feedback about the tutorial videos. The second, to obtain the students perspective about the flipped methodology.

3.2.1 Tutorial Videos

In the last week of class, students were asked to complete a web-based survey. In the two video-only sections, 26 of the 32 students still active in the last week of class completed the survey, yielding a response rate of 81%. An additional 12 of 17 students from the flipped and video section completed the survey, representing a response rate of 70%. The survey for the tutorial videos consisted of one or more radio-button questions followed by an open-ended question.

The first question determined their level of video usage: *"Did you use the videos to help you complete the tutorials? (always/sometimes/never)"* If the student selected "never", the follow-up

open-ended request was to "Please explain why you chose to not use the tutorial videos". And for that student the survey was complete. In total, 4 students did not use the videos, (one from the video-only cohort and three from the flipped cohort) and they provided explanations such as:

- "I prefer to read."
- "I wanted to test my ability to make a part without a step by step instruction."
- "I often did not have ear buds to listen to the videos in class."
- "I think that the book had written instructions that were easier to follow than spoken instructions."

For the students who watched the tutorial videos, the second question was: *"Tell us about your video usage..."* For consistency, the results for this question is presented separately for the Video-Only and the Flipped Cohorts.

Table 3: Opinion of Student Use of Tutorial Videos for Video-Only Cohort

Activity	No	Yes
Did you find the tutorial videos more useful than the book's written tutorial instructions?	0	25
Did you tend to watch the tutorial videos more than once?	6	19
Did you watch the tutorial videos before exams to review material in preparation for the exams?	10	15
Did access to the tutorial videos make you feel that class attendance was not so important?	22	3

From table 3, the 25 students that did use the videos all found the tutorial videos more useful than the book's written tutorial instructions (100%). Many of these students (19 of the 25) tended to watch the tutorial videos more than once (76%). Fewer of these students (15 of the 25) tended watch the videos as a study aid for the exams (60%). Only 3 of the 25 students (12%) said that the tutorial videos make class attendance not so important.

Table 4: Opinion of Student Use of Tutorial Videos for Flipped Cohort

Activity	No	Yes
Did you find the tutorial videos more useful than the book's written tutorial instructions?	3	6
Did you tend to watch the tutorial videos more than once?	4	5
Did you watch the tutorial videos before exams to review material in preparation for the exams?	4	5
Did access to the tutorial videos make you feel that class attendance was not so important?	8	1

From table 4, it can be seen that about 67% of the students found the tutorial videos more useful than the book's written tutorial instructions. In addition, about 55% tended to watch the tutorial videos more than once. The same percent of students tended watch the videos as a study aid for the exams. Lastly, only one student said that the tutorial videos make class attendance not so important.

In response to the last question, *"What would you change or add to the tutorial videos to make them more useful?"* The most common response was not to change the videos (appearing in 9 of 25 answers for the video-only cohort and 5 of 12 for the flipped cohort). A typical answer was "I wouldn't change anything, they were well done." A few students (3 for both cohorts) felt that the pace of the videos was too fast. On the other hand, one student remarked that, "The pace of tutorials is slow and sometimes really boring." The final type of repeated response (3 for both cohorts) involved the desire to better understand WHY something was done.

Samples of other responses included:

- "Perhaps, you should tend to go through your process slightly slower when your putting in dimensions, so that people who are obviously slower could put them in themselves."
- "Maybe edit it them in a way that gives students a chance to work out a step."
- "Add a list of steps."
- "Add subtitles."
- "Use a mouse tracker."
- "Make videos interactive."

3.2.2 Flipped Pedagogy

This survey consisted of a series of open-ended and multiple choice questions which aim to gain a better insight about students' perspective about the flipped methodology. The survey was administered to 12 students.

The first question was: *"How did the flipped classroom help you in learning the material for the class?"* In general, the student responses were very positive. Here are sample responses:

- "I think the most important part about the flipped classroom was being able to do the homework in class. I was able to concentrate on the material more so than if I were to do it outside of class. Also having instant feedback was a great tool in completing the work."
- "It allowed me to ask questions in class while working on assignments instead of doing the assignments outside of the classroom and getting stuck and having no one to assist me in solving any issues I was having."
- "The professor was always there when I ran into obstacles while working on assignment, so i never got stuck too long"

The second question was: *"What was your favorite experience about the class?"* The responses are very encouraging. Here are some sample responses:

- "My favorite experience about the flipped component of the class is that the videos allow one to re-watch a lecture as many times as I wanted. This was quite useful when I was working and ran into a problem. Oftentimes, I was able to look at the corresponding lecture video and solve my issue."
- "I enjoyed doing the homework in class. I was able to concentrate more because of the classroom environment. I was also able to get hands on help with the homework while in class time."
- "Once the material was reviewed, we had time to do the assigned work. It also allowed for more one-on-one time with the instructor for questions, tips, etc."

The third question was: *"What was your least favorite experience in the class?"* The responses were limited to the flipped component, not to the level of difficulty or class assignments. In general, students did not provide a dislike about the flipped method. However, an important comment indicated that sometimes doing the examples in the lecture videos was difficult due to the unavailability of the software at their personal computer.

The fourth question was: *"How confident did you feel about the material after watching the videos but before coming to class to do the exercises?"* The responses showed that 33% of the students are extremely confident while the remaining are somewhat confident. None of the students responded "not confident." This result indicates that the material does cover the material properly, however a review before starting exercises is always recommended to ensure all students are at an even knowledge level.

The fifth question was: *"When you watched the videos did you - Scale your responses from 1 to 5. 1 to be the most frequent"*. The responses are represented in table 5. The five activities presented in the table are the some of the most important advantages of using the flipped method. Recall that this questioned was answer by 12 students. As can be seen from table 5, the three most frequent activities are the re-watched sections, to stop when needed and to pay 100% attention. These results indicate that the students are maximizing the positive aspects of the flipped methodology.

Table 5: Activities Performed by Students While Watching Lecture Videos

Activity	**1**	**2**	**3**	**4**	**5**
Take Notes	2	1	2	5	2
Stopped when needed	1	**6**	1	4	0
Marked when you had questions in the notes	1	2	1	1	7
Re-watched sections when you did not understand a concept	**6**	1	3	1	1
Paid 100% attention to the video with no distractions	2	2	**5**	1	2

4 Discussion

Two different alternatives were implemented and evaluated in a 200-level CAD class. One involved the introduction of tutorial videos and the other involved a flipped classroom with tutorial videos.

The change in the classroom atmosphere was immediate as soon as the tutorial videos were available. Suddenly, students had the ability to watch a video of an instructor constructing a CAD model on the exact same software that they were using. Using video player features such as speed control, pause and replay, they could watch the videos at their desired pace and learn much more than just by following a set of written instructions. The instructor no longer had to help so many students with very basic issues caused by incomplete or erroneous tutorial instruction wording. Instead, that time can be used to help students with assignments and any other difficulty they may had.

Comparing the assessment grades between the the video-only cohort to the standard cohort 1, it appears that the video-only cohort scored 1 to 6 percentage points less on exercises and exams. The drop in performance was not uniform: top students continued to do very well but low performing students sometimes did much worse. This result was not expected and could be due to the videos making the modeling seem so easy, or could be because students used the videos in unexpected ways, such as with the sound off. Students could mimic the actions in the videos and produce decent solid models without fully engaging their brains. In the standard cohort 1, students tended to occasionally struggle with tutorials for large amounts of time. At times, those students had exclaimed that they spent hours on a tutorial that should take 15 minutes. The extra pain and time that students invested was not good from the standpoint of their other classes and outside work and life, but possibly did make them better prepared for modeling.

It was observed that some students watch the tutorial videos without sound or use auto-generated closed captioning. However, the closed captioning translation ranges from decent to dreadful. Students who do not listen to the instructor's verbal commentary usually can construct acceptable models but they totally miss out on why certain things are done, such as why we are constructing one feature before another feature, or why we attaching a sketch to the coordinate frame at this point rather than at that point. They will get a good CAD model merely by copying the actions of the instructor, but they remain oblivious to the instructor's thought process if they cannot hear the instructor.

In the video-only cohort, attendance was not explicitly required and there was a fear that the videos would make the modeling appear too easy, and attendance and performance on assignments and exams would suffer. The survey results showed that very few students felt that the tutorial videos made class attendance not so important. Of those three students who admitted that their attendance may have suffered, they still scored an average of 90.

Comparing the assessment grades between the the flipped cohort to the standard cohort 2, it shows that the implementation of both the tutorial videos and the flipped methodology increased the student performance by at least 5%. The most significant reason is that now the students have at least 40% more time during class to work on assignments with the assistance of the instructor. To gain proficiency in CAD, students must understand how to use the different tools of the

modeling software and have ample time to practice those tools. By taking much of the instruction out of the classroom, more time in the classroom was available to practice and to have interaction with the instructor.

In addition, the survey results demonstrated that practically all students in the flipped class utilized and appreciated the lecture and tutorial videos. The embedded quizzes in the lecture videos insured that the students completed the lecture before coming to class and were prepared to start class assignments after a brief review of the topics.

The goal of this study was evaluate the alternatives created to address two main drawbacks observed in the original format of the class. In general, the two alternatives paired together proved to be successful in providing quality materials to the students, therefore improving their learning experience. Which at the end, is the ultimate goal as an educator.

5 Future Work

The video-only approach will continue to be used in some sections of the CAD class and compared with the full flipped classroom. The authors will review the videos with fresh eyes and enhance them as appropriate. The goal is to retain the ease of tutorial creation without affecting exercise and exam performance.

The authors will create more uniform grading criteria between instructors to evaluate and compare the results from the video-only cohort and the flipped cohort.

References

[1] Litzinger T. A., Lattuca L. R., Hadgraft R. G. Newstetter W. C. Engineering Education and the Development of Expertise. Journal of Engineering Education January 2011; 100: 123-150.

[2] Albanese M. A., Mitchell S. Problem-Based learning: A Review of Literature on its Outcomes and Implementation Issues. Academic Medicine 1993 68 52-81.

[3] Yadav, A., Subedi, D., Lundeberg, M., Bunting, C. F. Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course. Journal of Engineering Education 2011;100: 253-280.

[4] Prince M.J., Felder R.M. Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. Journal of Engineering Education 2006; 95: 123-138.

[5] Bishop J.L., Verleger M. A. The Flipped Classroom: A Survey of the Research Proceedings, American Society for Engineering Education. Atlanta. June 2013.

[6] Lage M.J. , Platt G.J. , Treglia M. Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. Journal of Economic Education 2000; 31: 30-43.

[7] Gannod, C., Burge, J., Helmick, M. Using the Inverted Classroom to Teach Software Engineering. Proceedings, 30th International Conference on Software Engineering. Leipzip, Germany. May 2008.

[8] Toto R., Nguyen H. Flipping the Work Design in an Industrial Engineering Course. Proceedings, 39th ASEE/IEEE Frontiers in Education Conference. San Antonio. October 2009.

[9] Zappe, S., Leicht, R., Messner, J., Litzinger, T., Lee, H.W. "Flipping" The Classroom to Explore Active Learning in a Large Undergraduate Course. Proceedings, American Society for Engineering Education. Austin. June 2009.

[10] Talbert, R. Learning Matlab in the Inverted Classroom. Proceedings, American Society for Engineering Education. San Antonio. June 2012.

[11] Amaya-Bower L. Changing the Approach of How to Teach Computational Methods for Engineering Proceedings, American Society for Engineering Education. Seattle June 2015.

[12] Thomas, J. An Inverted Teaching Model for A Mechanics of Material Course. Proceedings, American Society for Engineering Education. San Antonio. June 2012.

[13] Baxter, D. H. Examining the Benefits of a Self-Taught Solid Modeling Course. Proceedings, American Society for Engineering Education. Albuquerque. June 2001.

[14] Baxter, D. H. Evaluating Student Performance in a Freshman Graphics Course to Provide Early Intervention for Students with Visualization and/or Design Intent Difficulties. Proceedings, American Society for Engineering Education. Montreal. June 2002.

[15] Lemley, E. C., Jassemnejad, B., Judd, E., Ring, B. P., Henderson, A. W., Amstrong, G. M. Implementing a Flipped Classroom in Thermodynamics. Proceedings, American Society for Engineering Education. San Antonio. June 2012.

[16] Ling N.G. Flipping a CAD Classroom Proceedings, Advances in Technology Education. Singapore. September 2014.

[17] Yip-Hoi D. M. Enhancing a Blended Learning Approach to CAD Instruction using Lean Manufacturing Principles Proceedings, American Society for Engineering Education. Seattle June 2015.