Online Computer-aided Design Class

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Abstract

A section of a sophomore-level Computer Aided Design (CAD) class, which is offered in a 100% online format at The University of Texas at Dallas, is described in this Work in Progress (WIP) paper. While the traditional sections of the course are well established, appreciated by the students, and meet their educational objectives, the online section was developed during the Summer of 2018 for a first time offering in the Fall of 2018. The overall experience of teaching this course online and the student's feedback are described.

The online section is considered successful because the work completed by students (homework assignments, exams, and design project) in the first offering of the online course is comparable to work performed in previous traditional sections with the same professor. Challenges with a design project, which is included in this class, are intensified in the online section and improvements are described. Specifically during the second offering of the online section in the Spring of 2019, the number of teammates in each team are reduced and additional project milestones are imposed to balance the teamwork over the duration of one semester.

1. Introduction

Classes are taught within an engineering program in numerous formats. In general, these include learning in a classroom, learning online, or a hybrid blend of the two. Regardless of the format, students taking a class are expected to meet the course's educational outcomes. At the completion of a CAD class, which is the subject of this paper, students are expected to be able to create engineering designs and communicate the designs effectively using engineering drawings.

There are numerous resources to learn CAD including textbooks [1-5] and online resources [6-12]. Toogood [1] offers tutorials to create three dimensional (3D) models and engineering drawings in CREO Parametric. Zeid [2] offers more advanced content in addition to high-level tutorials that are designed using SolidWorks but are intended to be software independent. These tutorials can be used in SolidWorks, CREO, Unigraphics, and CATIA 3D CAD software.

Additionally, online content is available. According to Cozzens [6], in the year 2001 there was virtually no web-based CAD training but by the year 2005, there was an abundance of web-based CAD training companies. Today, numerous web-based platforms are used for distributing online educational content free of charge or with subscription [7-12]. Some of this online content is searchable and task-oriented while other content is offered in a structured format that includes assessment that can result in certification.

CAD is taught, in our mechanical engineering program to meet four Course Learning Outcomes (CLOs). Specifically, upon completion of the course, the students are expected to: (1) be able to create 3D geometric models, assemblies, and engineering drawings that are suitable for

manufacturing; (2) be able to determine degrees-of-freedom of sketches and assemblies; (3) be able to generate fabrication packages to represent mechanical assemblies ready for traditional and emerging manufacturing processes; and (4) be able to function effectively in teams to generate concepts and prototypes for the design of mechanical assemblies. To meet these outcomes, a typical timeline of a 16-week semester is shown in Table 1. The number of weeks can vary between different sections and one additional week, not included in Table 1, is a holiday week.

Table 1, Typical Course Timeline

Subject	Number of Weeks
3D Part Creation	2.5
Assembly	1.5
Engineering Drawings	2
Degrees of Freedom	1.5
Fabrication Packages	2
Special Sweeps	1.5
Parametric Curves	1.5
Surfaces	1
Finite Element Modeling	1.5

Traditionally, the class is offered in a classroom where a computer, equipped with CAD software, is provided for every student. The professor gives lectures and hands-on tutorials in this class in a face-to-face format. Students learn from the professor, one another, reference books, and online resources throughout the semester. Over the past years, our students have performed very well in the class and enjoyed it as well.

When offering a section of this well-established class in a 100% online format, our intent is to retain the same high performance from the students while maintaining a sense of community where students continue to learn from the professor, one another, reference books, and online resources in an enjoyable manner. The students are offered a choice to select the online section or the face-to-face section when they register for the course based on their preference. This choice is not intended to affect their tuition or their learning outcome. However, we are aware of pros and cons of online classes as described in a report by Washington University [13]. Among the pros from a student's perspective are access convenience, schedule flexibility, ability to re-watch online lectures. Pros, from the institution's perspective, include less pressure on classroom space, ability to track more information on student's progress. On the other hand, among the cons students may struggle to stay organized and on-task without physical interaction with a community. Among the cons, from the institution's perspective, include higher instructor's workload because the instructors often seek to compensate for the lack of in-person interaction by maintaining a high degree of communication with students, which can be very time-consuming according to this report.

The motivation for offering an online section of the CAD class is twofold. Firstly, we observe practicing mechanical engineers who are involved with design projects. They often work with team members spread around distant geographical locations. According to Jensen et al. [3], groups involved in engineering design or manufacturing may be working in different departments, plants, countries, or even continents. CAD software permits the rapid exchange of design and manufacturing information regardless of where the team members may be located according to these authors. Successful teams master and use communication tools effectively to work with their teammates. Sophomore students are already capable of using smart phones, computers, and other technology for communication. However, their use is often for personal needs, entertainment, or social interaction. Using technology to communicate in engineering is not simple. Brewer [14] writes on the difficulty of working virtually in a global environment using a variety of technological communication tools because it takes longer to build trust without social communication. We intend for the online section of the CAD class to prepare students to communicate, work, and interact without the direct face-to-face contact.

A second motivation for offering the online section is to eliminate a physical cap on the number of students who can take the class at one time. Our mechanical engineering department has a new lab (established in 2018) for teaching CAD. While the new lab is well designed for effectiveness and is conducive for learning, it is strictly limited to 40 students. The online section is also intended for 40 students but offers room for expansion should there be a need. The expansion was utilized right away when there was a waiting list and the class size was increased to 50 in the fall semester of 2018.

Teaching online is not trivial and not easily accepted. The online sections as a percent of all sections offered at The University of Texas at Dallas range between 5.8 and 6.6% in 2013-2018. The university offers comprehensive training for faculty to achieve online teaching certification. This training comes with numerous resources including software for recording videos, studio for recording lectures, infrastructure for streaming videos, and technical support. Overall, the university supports the development of online classes, even though some faculty and staff are not in favor of online teaching. A report by Allen and Seaman [15] indicate that institutions with online offerings in 2014 to 2015 are just as positive about it as ever, but those who have no offerings are no longer saying that it will be part of their plans for the future. Moreover, academic leaders at institutions with online offerings have consistently held a more favorable opinion of the learning outcomes for online education than those at institutions with no offerings. Even after a decade of substantial growth in the number of schools with distance offerings and the number of students taking these courses, the level of skepticism among faculty has remained very high according to the authors.

This work in progress (WIP) paper includes the course format in the Learning Management System (LMS), student assessment, project, course assessment and improvements, and student feedback.

2. Course Format in the LMS

The online class is offered through the eLearning Black Board LMS. The course homepage includes a link to the syllabus, a link to the schedule, the CLOs (even though they are already listed in the syllabus), and locations on campus where computers are available. Since this homepage is visited repeatedly by all the students, having this information here is a continuous reminder of these important items.

A link is provided from the homepage to a discussion board, which includes three threads. Questions or remarks posed in the discussion board are visible and beneficial to all the class. The first is "ask the professor," where students can post questions. The initial intent behind using this thread was to answer questions during the office hours. However, when students did not receive an immediate response to their questions using this thread, they used email, which was not as effective. Specifically, email communication gives clarification to only one person when, in most cases, all the class needed the offered clarification. For that reason, this thread was visited numerous times each day and a notification was set to trigger an email to the professor when a new question was added. The second thread is "student lounge" which is intended for students to share information. Students can post information in this thread to help others or to request help from others in the class. The third thread is a "self-introduction" where students can introduce themselves to the class. It was very nice to see self-introductions at the start of the class and catch a glimpse of some personalities. This initialized a sense of community. Ray and Tabas [16] deployed a survey in their online class. Their survey indicates that 8% and 54% of the students strongly agree or agree that the discussion boards provided the biggest impact on community. However, in our class, following the self-introductions, most students communicated by email, which is consistent with the findings of Brewer [14] whose research indicates that email is the preferred and most used mean of communication among engineering professionals.

A folder including all the lectures is included next in the homepage. The lecture contents are introduced in modules (series of recordings and written instruction) according to timeline shown Table 1. Each complete module includes numerous individually titled video recordings and guiding text for easy reference and access. The format is asynchronous so the students can view the recordings within each module at any convenient time as long as they complete the module within the imposed course timeline. The introduced modules remain available for the duration of the semester for reference. The video recordings are in a voice over PowerPoint slides format spanning 2 to 10 minutes per recording. Only a few recordings with demonstrations of the software extend up to 15 minutes.

Folders including the homework assignments, exams, and project information are also directly visible from the homepage. These are described below. Two additional folders include support materials regarding eLearning and opportunities on campus.

A thank you note is added at the bottom of the homepage. It includes a portrait picture of the professor and a simple but well-meant statement of thanks to the students for taking the class and for all their hard work. It includes the email of the professor and an encouraging statement.

3. Student Assessment (Homework, Exams, Quizzes)

Homework assignments and exams are used to assess student learning. All the homework assignments are revealed to the students on the first day of the semester in the homework folder, with a clearly stated deadline for each assignment to match the course's timeline. The homework is worth 35% of the grade for the course. Additional video recordings, materials, and/or links to publicly available content are included with most assignments to support the students as they work on the homework. The recordings here include tutorials and assignment-specific help similar to help offered in a traditional class. The assignments and their scaffolding recordings remain available throughout the semester (beyond the submission deadline) for reference. The homework assignments submitted by the students taking the online class in the fall semester of 2018 are well done and comparable in quality to work performed by students in previous traditional offering of the course.

Two exams are offered in the testing center on campus and are worth 23% of the total grade for the course. This center has a capability for administering exams onsite or remotely. Each exam includes 30 multiple-choice questions that cover the design and drafting CAD concepts in addition to mechanics of running the CAD software. Results of the exams by the students of the online class in the fall semester of 2018 are well aligned with previous results by students in previous traditional offering of the course.

Quizzes are required at the end of each of the first seven subjects (Table 1) allowing two attempts with the highest grade entered in the gradebook. Each quiz includes 10 multiple-choice questions and is worth one percent of the grade for the class. Offering a quiz incentivizes the students to follow the course's timeline and to watch the recordings attentively. The quizzes in the online class are intended to be comparable to taking attendance and asking questions in the traditional class. Students can take these quizzes on their own time anywhere using any device with Internet capability. In general, the students did well on the quizzes, which indicates that most have kept the pace according to the imposed schedule.

The remaining 35% of the grade for the course is allocated to the project, which is subject of the next section below.

4. Project

The project used in the course is open-ended and implemented in a manner, which maps to the course learning outcomes. It challenges the students to use their creativity in designing a mechanical system, modeling it using CAD software, creating a complete fabrication package, and fabricating the assembly or a representative part of the assembly as they work in

collaboration within their team. The project is also instrumental in creating a sense of community because it requires collaboration among students. We know from the survey deployed by Ray and Tabas [16] that 23% and 77% of their surveyed students strongly agree or agree, respectively, that collaboration among students helps create a sense of community. We expect that our students will feel the same way.

Throughout the course, students are asked to self-enroll in teams of four to six members and create a mechanical assembly of interest to them. They are asked to create hand sketches of their mechanical assembly, create CAD 3D models of their components and assemblies, and generate a complete fabrication package. They are also asked to fabricate a scaled down prototype of the complete assembly or a notable part of the assembly.

Imposed project milestones are: (1) team formation document including portrait pictures of all teammates, (2) hand sketches of the assembly, subassemblies, and parts, (3) complete fabrication package, and (4) presentation to describe the product and a fabricated prototype.

Empty teams that can accommodate six members are created in the LMS. The students are allowed to self-enroll into any team. Each team is offered a space in the LMS for file exchange, blog, discussion board, group journal, tasks list, and group email link. Since this was a first offering of the online class, the use of these tools is optional and other communication tools are allowed.

Getting the project teams to form happened quickly and efficiently in the online section using the self-enroll functionality within the LMS. Students self-enrolled and joined the teams, assigned a leader, and started to work together, which was encouraging during the first few weeks of the semester. It is noted that none of the teams used the file exchange utility in the LMS. Instead, they found more convenient free file storage and sharing sites, which was allowed.

The start of the project was encouraging. However, some teams experienced conflict regarding the selection process of a subject for their project. Some students took a passive aggressive route and simply stopped communicating. Since communication is outside the LMS and away from the professor’s control, the project halts before this can be detected and an intervention can be developed to persuade the team to compromise, come back together, and start working again.

5. Course Assessment and Improvement

Since students did well in this class in previous semesters (face-to-face instruction), the quality of online class is checked against previous semesters. Specifically, assessing the online class is based on the performance of students taking the online class relative to others who took the course in the traditional format in previous semesters with the same professor.

There is no detectable difference between the student’s performance on homework assignments and exams. The student’s work is comparable regardless of the format of the class. This is very

encouraging since this is the first experience with a 100% online class with plenty of room for future improvement. Specifically, the average score on the exams typically ranges between 80% and 84% in the class with the same professor in previous semesters. This average is 81% for the online course during the fall of 2018.

The majority of students studied the online lectures and materials according to the schedule (Table 1), as revealed by the results of the quizzes. Even though the lectures in the course were asynchronous, the quizzes forced students to march through the class according to the schedule and complete one module before the next module was made available. It was encouraging to see that learning was spread evenly throughout the semester.

As for the project, the final fabrication packages, prototypes, and recorded presentations provided by the online students are also comparable to those from previous semesters. However, the journey to get there was quite difficult due to two factors that are addressed during the second offering of the online course in the spring of 2019 as follows.

Firstly, the schedules of students are very busy and it was hard for some teams of six students to communicate effectively. This is compounded with communication issues where students stopped to respond when some disagreements occurred with their teammates. Continuous and active online intervention from the professor was needed to help the teams to continue moving their project forward. For that reason, an improvement is incorporated for the next semester. The teams are asked during the third week of the semester to specify a primary and secondary hour every week where they can have synchronous team communication. The size of the teams are also reduced from up to six students to smaller teams of three or four students in each team. This should reduce the lines of communication within the team and improve productivity. While smaller teams mean more teams to manage in the course, the smaller teams should have better communication and fewer disagreements among the students in each team.

Secondly, some teams found problems with subassemblies that did not fit properly into the top-level assembly. Parts and subassemblies were redesigned in a last minute rush to get the drawings completed and submitted. While problems with subassemblies can be expected in engineering design, students in previous semesters were able to work together after class and correct the models. However, the lack of synchronous communication in the online class required urgent online intervention from the professor to help the teams resolve such issues and continue to communicate in order to complete their project. An improvement is incorporated for the next semester. A new milestone is added into the schedule where a screen print of the complete assembly is required between the hand sketch milestone and the fab pack submittal. This additional milestone is expected to help the teams to create the full assembly well in advance of creating their detailed part drawings and fab packs.

6. Student Feedback

The class evaluations completed by the students are positive. The online section included 48 students during the fall semester of 2018. Seventeen (17) students (35%) answered the course evaluation at the end of the semester. Each student responded to given statements on a 5 level Likert scale including Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly Agree (SA). The complete results of this course evaluation are publicly available on https://coursebook.utdallas.edu/ues-report/mech3305.0w1.18f. Among the statements given, some notable ones and the corresponding responses by the students are shown in Table 2 and discussed below.

Table 2, Student Course Evaluation

Item	Statement	SD	D	N	A	SA
1	The course objectives were clearly defined.	0%	0%	0%	18%	82%
2	The course was well organized.	0%	0%	0%	24%	76%
3	Overall, the course was excellent.	0%	0%	0%	24%	76%
4	The instructor provided timely feedback.	0%	0%	0%	12%	88%
5	The instructor was accessible outside of class.	0%	0%	0%	12%	88%
6	I was free to ask questions and express my opinions and ideas.	0%	0%	0%	24%	76%
7	I discussed ideas from this course with others outside the classroom.	0%	0%	0%	13%	88%
8	This course has been (or will be) of value to me.	0%	0%	0%	12%	88%
9	This course inspired me to learn more.	0%	0%	0%	24%	76%

Items 1 to 3 in this table indicate that the students agreed or strongly agreed that the course objectives were clearly defined, the course was well organized, and overall, the course was excellent. The use of a separate module to cover each of the subjects shown in Table 1, above, is very helpful to achieve this evaluation. Specifically, the students were made aware of the schedule on the first day of class and the modules followed that schedule. The quiz at the end of each module helped wrap-up the module and prompt the students to move to the next module.

The statements numbered as items 4 to 6 indicate that the students agreed or strongly agreed that the instructor provided timely feedback, the instructor was accessible outside of class, and they were free to ask questions and express opinions and ideas. It is worthy to note here that there were a total of four face-to-face meetings and one phone communication between the instructor and the students throughout the entire semester. The communication in this class was done by email or using the "Ask the Professor" forum in the learning management system. Achieving 100% as the total of agree or strongly agree from the students in that area required long hours of answering questions in writing promptly to achieve and maintain a high level of trust between the professor and the class of 48 students. All the students who answered the survey felt comfortable asking questions using their mobile devices or computers and were able to receive clarifications to their satisfaction.

Statement number 7 relate to the student's discussion of the course materials with others outside classroom. In this context, even though there was no physical classroom, there was an online classroom community and students discussed ideas from the class with others outside the classroom community. These discussions can help the students learn from others in addition to learning from the professor and the teaching assistant.

The final two statements (8 and 9) in Table 2 indicate that the students feel the course has been or will be of value to them and inspired them to do more. Again, there were no neutral or disagreements with these statements.

The course evaluation also includes three questions asking the students what aspects of this course should remain the same, what aspects should change, and offers a place to add additional comments. Answers to what should remain the same are quite flattering. One student wrote, "I think virtually everything should remain the same."

As for what needs improvements, one student felt the "homework toward the end and was a little disconnected from the topics we were studying." Looking back at the course materials and its homework assignments toward the end of the semester, there are lecture materials about geometric tolerances while the homework asks to create an assembly. In the next semester, more guidance and support materials will be provided to make sure the tolerances are used in the assembly to make sure holes on different parts are aligned and the surface flatness is specified.

Two students wrote about audio issues in the video recordings. One explained, "I think you might want to redo some of the sections of your videos (if possible), because some of them had audio issues. During your explanations the audio would be interrupted or choppy." Following these comments, we went through the entire set of videos and could not find any issues. We anticipate that this may be due to the student's Internet connection. Some students taking the online class in the spring of 2019 are also asked to give feedback if they find any issues so we can rerecord any video and repost it.

The additional free comments were also flattering in general. One student wrote, "Overall, this was a very well organized and competently run course." These comments from the students are well appreciated and make worthwhile all the course preparation and teaching efforts.

7. Summary

One section of a computer aided design class is offered in a 100% online format during the fall semester of 2018 and is described in this work in progress paper. Significant effort was needed to learn how to teach online, develop the modules, keep the students engaged, and establish a community in the online class. This was especially needed as the students worked in teams on their projects throughout the semester.

The online section is considered successful, as the results of the homework assignments, the exams, and the project provided by the students are acceptable and show comparable results to previous offering in a traditional face-to-face format by the same professor. The student's feedback, provided in their course evaluation, indicates appreciation for the class and justifies all that effort. After the successful completion of a first semester of online teaching, some modifications are implemented and offering the online section of the CAD class is approved for at least one more semester. Further evaluations will be performed on the effectiveness of the course as more data is collected in the future.

References

[1] R. Toogood, Creo Parametric 5.0 Tutorial, SDC Publications ISBN-10: 1630572071, ISBN-13: 978-1630572075, 2018.

[2] I. Zeid, Mastering CAD/CAM, McGraw Hill, ISBN-0070634343, 9780070634343..

[3] Jensen, Helsel, and Short, Engineering Drawing and Design, 7th Edition, ISBN-978-0-07-352151-0.

[4] A. Saxena and B. Sahay, Computer Aided Engineering Design, ISBN-13: 978-1402025556.

[5] "SolidWorks Books".

[6] R. Cozzens, "Youtube: An Effective CAD Training Resource," in *ASEE Annual Conference and Exposition*, San Antonio, Texas, 2012.

[7] "Autodesk," [Online]. Available: https://www.autodesk.com/autodesk-university.

[8] "PTC University," [Online]. Available: https://precisionlms.ptc.com.

[9] "SIEMENS Solid Edge Training & Certification for Students," [Online]. Available: www.udemy.com/solidedgecertification1 and www.siemens.com/plm/solidedgecertification.

[10] "Solid Edge Gear Up University," [Online]. Available: www.gearupu.com and www.gearupu.com/topology-optimization.html.

[11] "SolidWorks Certification Center," [Online]. Available: https://solidworks.virtualtester.com.

[12] "Youtube," [Online]. Available: www.youtube.com.

[13] "Leading change in public higher education," University of Washington, 2013.

[14] P. E. Brewer, International Virtual Teams – Engineering Global Success, IEEE PCS Professional Engineering Communication Series, Wiley, ISBN 978-1-118-33900-8, 2015.

[15] I. E. Allen and J. Seaman, "Online Report Card Tracking Online Education in the United States," Babson Survey Research Group and Quahog Research Group, LLC., 2016.

[16] V. M. Ray and J. Tabas, "Developing Improved Methodology for Online Delivery of Coursework Providing a Framework for Quality Online Education," in *Proceedings of the ASEE Annual Conference and Exposition*, Salt Lake City, Utah, 2018.