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Developing a Comprehensive Online Transfer Engineering Curriculum: Assessing the Effectiveness of an Online Engineering Graphics Course

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Eva Schiorring has almost two decades of experience in research and evaluation and special knowledge about STEM education in community colleges and four-year institutions. Ms. Schiorring presently serves as the external evaluator for three NSF-funded projects that range in scope and focus from leadership development to service learning and experimentation with alternative delivery, including online lab courses. Ms. Schiorring is also evaluating a project that is part of the California State University system's new initiative to increase first year persistence in STEM. In 2014, Ms. Schiorring was one of the first participants in the NSF's Innovation-CORPS (I-CORPS), a two-month intensive training that uses an entrepreneurship model to teach participants to achieve scalable sustainability in NSF-funded projects. Past projects include evaluation of an NSF-funded project to improve advising for engineering students at a major state university in California. Ms. Schiorring is the author and co-author of numerous papers and served as project lead on a major study of transfer in engineering. Ms. Schiorring holds a Master's Degree in Public Policy from Harvard University.

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Tracy Huang is an educational researcher in STEM at Cañada College. Her research interests include understanding how students become involved, stayed involved, and complete their major in engineering and STEM majors in general, particularly for students in underrepresented populations.

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Abstract

Community colleges play an important role in educating future scientists and engineers, especially among students from groups that are traditionally underrepresented in science, technology, engineering, and mathematics. Community college transfer programs offer lower-division courses that students can take in preparation for transfer to a four-year program. For many small community colleges, however, developing a comprehensive transfer engineering program that prepares students to be competitive for transfer can be challenging due to a lack of facilities, resources, and local expertise. As a result, engineering education becomes inaccessible to many community college students. Through a grant from the National Science Foundation Improving Undergraduate STEM Education program (NSF IUSE), three community colleges from Northern California collaborated to develop resources and teaching strategies to enable small-to-medium community college engineering programs to support a comprehensive set of lower-division engineering courses that are delivered either completely online, or with limited face-to-face interactions. This paper focuses on the development and testing of the teaching and learning resources for Engineering Graphics, which is a four-unit course (three units of lecture and one unit of lab) covering the principles of engineering drawings, computer-aided design (using both AutoCAD and SolidWorks), and the engineering design process. The paper also presents the results of the pilot implementation of the curriculum, as well as a comparison of the outcomes of the online course with those from a regular, face-to-face course. Student performance on labs and tests in the two parallel sections of the course are compared. Additionally student surveys and interviews, conducted in both the online and face-to-face course are used to document and compare students' perceptions of their learning experience, the effectiveness of the course resources, their use of these resources, and their overall satisfaction with the course.

1. Introduction

The 2012 President's Council of Advisors on Science and Technology (PCAST) report, "Engage to Excel" indicates that the United States needs to produce one million additional STEM professionals in the next decade in order to retain its historical preeminence in science and technology. To meet this need, the number of undergraduate STEM degrees will have to increase by about 34 percent annually over the current rates. The PCAST report proposes that addressing the retention problem in the first two years of college is the most promising and cost-effective strategy to address this need[1]. The California Community College System, with its 112 community colleges and 71-off campus centers enrolling approximately 2.6 million students—representing nearly 25 percent of the nation's community college student population—is in a prime position to grow the future STEM workforce[2]. However, with shrinking resources and the increasing cost of education, an effective approach is to "more fully exploit the advanced information technology capabilities that science and engineering have produced, which have proven to be valuable in reducing costs and improving productivity in manufacturing and private sector businesses"[3].

Over the past decade there has been an increased interest in online education due to wider acceptance of its potential benefits including increased access and broadening participation of nontraditional students[4], diversity, potential for individualized and student-centered learning, collaboration, reduced cost, and its potential to be more effective than traditional methods[5-8]. The US Department of Education has recently started compiling data on online enrollment in higher education. In Fall 2012 about 5.5 million students were enrolled in at least one online course, representing about 25.8% of all students[9].

In California, the State Chancellor's Office of the California Community Colleges funds the Online Education Initiative (OEI), a collaborative effort among California Community Colleges to ensure that significantly more students are able to complete their educational goals by increasing both access to and success in high-quality online courses[10]. The initial focus of OEI is on high demand courses, to allow students who are unable to take these courses at their home institutions to take the courses online through other institutions that are part of the consortium. With a focus on high-demand courses, none of the courses offered in the OEI consortium are in engineering. For the case of engineering courses, the divergence and increasing variability of transfer courses required by different majors and different universities has made it difficult for small community college engineering programs to offer all the required transfer courses because of low enrollment[11]. To increase the viability of supporting these courses with low enrollments, the Joint Engineering Program (JEP) was established to allow sharing of engineering students from different community colleges. Developed initially through a grant from the National Science Foundation, and subsequently supported by a US Department of Education grant, JEP currently has 27 partner community colleges from all over California. As a result of JEP and the engineering courses that are offered online, the number of community college students who are able to take these courses and be prepared for upper-division courses upon transfer has increased. A JEP enrollment survey shows an increase of 61.3% in engineering courses over the last five years even though overall enrollment at the JEP partner institutions decreased slightly. However, courses requiring laboratory components are currently not offered online in any of these colleges. As a result many students are not able to complete the required lab courses. For instance at Cañada College, although enrollments in lecture courses have increased 118% due to a dramatic increase in online enrollment (508% over the first four years of JEP), enrollments in lab courses have only increased 23%[12].

Inspired by the success of the Joint Engineering Program, Cañada College collaborated with College of Marin and Monterey Peninsula College to develop the Creating Alternative Learning Strategies for Transfer Engineering Programs (CALSTEP). One of the main objectives of CALSTEP is to develop laboratory courses that are delivered either completely online, or with limited face-to-face interaction. The online laboratory courses developed include Introduction to Engineering, Engineering Graphics, Materials Science, Circuits, and MATLAB Programming. Each of the three partner institutions is responsible for developing curriculum for a specific set of courses, and the curriculum materials developed are shared, piloted and tested at the three sites. Together with the online lecture courses already developed through the JEP, these lab courses will provide community college engineering students with access to the full range of lower-division engineering courses needed for transfer to a four-year institution. Without the ability to increase enrollment by offering the lab courses online, many of these courses will be canceled due low enrollment.

The CALSTEP online laboratory courses are developed to best achieve the thirteen objectives for engineering educational laboratories defined by the ABET/Sloan Foundation effort[13,14]. Echoing the recommendations of the PCAST report[1], CALSTEP employs evidence-based approaches that maximize persistence and learning in a distance environment, including the use of inquiry and design-oriented activities that engage students in authentic engineering experiences. Content is delivered using a variety of formats similar to those used in many existing online and hybrid engineering courses[5,15-20]. A general strategy in developing the course content and activities is to provide students with more substantial guidance during the early foundational lab exercises, but as the exercises progress, to offer diminishing support and require more concept formation, experimentation and debugging.

Although the CALSTEP project aims to develop a comprehensive lower-division curriculum that is delivered completely online, the focus of this paper is the development of the course materials for the online Graphics course and its pilot implementation at Cañada College in Fall 2015.

2. Developing an Online Engineering Graphics Course

When switching to an online teaching environment, faculty have identified issues and concerns in both areas of course design and implementation[21]. These issues include time commitment[21], use of technology tools[23], implementing effective pedagogical strategies[24,25], and the switch in faculty role to facilitator of learning[26]. In a qualitative study of faculty switching from face-to-face to online instruction, Chiasson et al. found that faculty used their prior face-to-face course as the conceptual framework, and that asynchronous delivery required different instructional tools while synchronous delivery did not[27]. One critical aspect of online learning is the lack of interaction in an online environment, especially in asynchronous delivery, compared to the traditional face-to-face setting. This lack of interaction has been attributed to result in higher dropout rates in online courses[28-32]. The Engineering Graphics course that is the focus of this paper is completely online and asynchronous. While it was developed by an engineering instructor who has previously developed and taught the face-to-face version of the course, this was the first time he taught an online course in an asynchronous environment.

Online resources for a Graphics course have previously been developed and successfully implemented in a blended or hybrid environment. At North Carolina State University, in a large course redesign to switch the introductory graphics course to hybrid instruction, online resources consisting of voiced-over content presentations, software demonstrations (SolidWorks), and sketching videos were developed and delivered asynchronously. These resources are complemented by weekly face-to-face meetings. The performance of students in the multiple hybrid sections was compared with those in the face-to-face sections, and the comparison showed no statistically significant difference in the performance in midterm, final exam, and final course grade between students in the face-to-face and hybrid sections. The study concluded that that students in the hybrid sections understood the material just as well as students in the face-to-face sections[33].

The study presented in this paper is different from the North Carolina State University study in four respects: (1) the pilot online graphics course described in this paper is completely online and asynchronous, i.e., unlike the NC State's redesigned graphics course, there are no regular face-to-face meetings held to supplement asynchronous course activities; (2) the course in the current study is developed and implemented in a small community college that has an open-enrollment policy, and hence a more diverse student population; (3) the course uses a combination of AutoCAD and SolidWorks to introduce students to engineering graphics and design; and (4) the sample sizes in the current study are significantly smaller than those used in the NC State study.

The Engineering Graphics class at Cañada College

Cañada College, located in the San Francisco Bay Area, CA is a member of the California Community College System and is a federally-designated Hispanic-Serving Institutions. During the 2014-15 academic year, the college enrolled 10,285 unique students, with Hispanic students as the largest single group at 46.3%, followed by white students at 27.4%, and Asians at 14.8%. Like all California Community Colleges, Cañada College is an open-enrollment institution, designed to welcome students of all backgrounds. Cañada College's Engineering program is a small transfer program that offers a comprehensive set of lower-division engineering courses needed to transfer to most four-year engineering program in most fields of engineering. About 25 to 30 engineering students transfer to a four-year engineering program every year, mostly to the public universities in California.

The Engineering Graphics course at Cañada College is a four-unit course (corresponding to 48-54 lecture hours plus 48-54 lab hours) designed to satisfy the introductory engineering graphics/graphics communication requirement for students intending to transfer to a four-year program in Civil Engineering, or Mechanical Engineering. Since Cañada College engineering students transfer to a variety of universities in a range of majors, and to ensure articulation of the course with these universities, the course covers both the use of AutoCAD and SolidWorks. A complete description of the course including course objectives, topics covered, and student learning objectives can be found at http://www.canadacollege.edu/nsf-iuse/. The course was designed for articulation with the state-wide approved course descriptor for Engineering Graphics as published in the course identification numbering system (c-id) website at https://c-id.net/view_final.html.

Online Course Materials Developed

Before commencing the development of online materials for the course, considerable effort was devoted to reviewing available resources and curricula on Engineering Graphics, AutoCAD and SolidWorks that could be adopted. Since AutoCAD and SolidWorks are the two CAD software systems most commonly used by four-year engineering programs, it is important that the community college online course being developed prepares students in using both systems. After reviewing a number of commercially available products, the instructor decided to develop new resources for the class because of the following considerations: (1) Most available teaching resources focus on developing proficiency in using the software applications, and considerable customization would be needed to blend these resources with simultaneous student exposure to engineering graphics concepts; (2) No commercially available products were found that have well developed resources for both AutoCAD and SolidWorks; (3) Costs to students would be prohibitive, especially if they have to pay for both AutoCAD and SolidWorks resources; (4) Autodesk products are now available free to students, and free copies of the student version of SolidWorks usually come with institutional licenses. As a result online students have access to these CAD programs without costs associated with using commercially available curricula; (5) There is evidence that instructor-generated video lectures and learning resources can be more effective in engaging students and improving student performance than those provided by textbook publishers[34].

The online Graphics class at Cañada College was developed by an engineering instructor who has been teaching the face-to-face version of the class for about 20 years, and has been teaching online lecture courses (Statics, Dynamics, Circuits lecture, Materials lecture) delivered synchronously for the past several years. The online Graphics class is the first asynchronous class to be developed by this instructor. Online course materials that have been developed include PowerPoint lectures, lecture videos, video tutorials, laboratory exercises, and homework assignments. Most lecture videos and video tutorials were created and edited using a tablet computer and screen capture software such as Camtasia Studio (for details, see https://www.techsmith.com/camtasia.html). A total of 22 lecture videos and 28 video tutorials were created. The videos were designed to be short because short videos have been found to be more engaging[35]. Most of the lecture videos were between 15 to 20 minutes long, with the shortest video at 12 minutes long, and the longest at 28 minutes. The video tutorials (which include topics on AutoCAD, SolidWorks, and free-hand sketching) were shorter, with most videos between 8 and 12 minutes long, with the shortest video less than 5 minutes and longest video around 19 minutes long. Additionally, PowerPoint files for lectures were available, as well as PDF files for 24 laboratory exercises and homework assignments. These course materials were made available to the students through the course Learning Management System (Moodle). A complete collection of these online resources are available at the project website.

3. Implementation of the Online Graphics Course

To assess the effectiveness of the online resources developed for the course, the online Graphics class was piloted in Fall 2015 at Cañada College. As part of the assessment of the online course, student outcomes are compared with those of the face-to-face section offered in the same semester. Table 1 shows a comparison of the online section and the face-to-face section of the Engineering Course in Fall 2015. The online section was taught by the engineering instructor (Professor A) who developed the online course. The face-to-face course was taught by an adjunct instructor (Professor B) who was teaching the graphics class for the first time. The two instructors used the same PowerPoint lectures to deliver content to students. For the online class, the PowerPoint slides were presented in pre-recorded lecture videos, while the PowerPoint slides were presented by the instructor during class time for the face-to-face section. The same laboratory exercises with the same laboratory handouts were given to students in both sections, with the FTF students completing the labs during class session with assistance from the instructor while online students completed the labs on their own time without live assistance from the instructor. The quizzes given were not the same, and the formats were also different. For the tests, the two instructors collaborated on having identical multiple-choice questions and two or three of the problems identical for each of the tests. Tests were administered on campus by the instructors, with the online students taking their tests in the evening and FTF students taking the tests during their class sessions (MW, 2-5 p.m.). For all of the tests given during the semester, the online students took their tests at least a day before the FTF students had theirs. Identical homework sets were also given to students in both sections. In addition to laboratory exercises, quizzes, homework, and tests, a final design group project was also given to the students. Since the projects given to the two sections were not the same, student outcomes for the projects are not included in the comparison. Throughout the semester, two drop-in tutors were available on campus to assist students in completing their labs and assignments outside of class.

Table 1. A comparison of class characteristics for the online and face-to-face sections of Engineering Graphics in Fall 2015.

Class Characteristics	Online Section	Face-to-Face Section
Number of students (as of census date)	12	19
Instructor	Professor A	Professor B
Lecture Delivery	Asynchronously through pre-recorded videos	In-person, twice a week for 1.5 hours per meeting
Laboratory Exercises	Asynchronously with students using their own computers and downloaded student versions of the software	In a computer lab with the instructor, twice a week for 1.5 hours per meeting
Homework	Submitted online via Moodle	Submitted online via Moodle
Quizzes	Online	In-person
Tests	In-person, proctored by the instructor	In-person, proctored by the instructor

To standardize the grading of the tests and the labs, rubrics were established. For the tests, each instructor graded the tests for their own class following the established rubrics. The labs for both sections were graded by the same student assistant. For the homework assignments, grading was not standardized.

In addition to comparing the student performance in the course, a survey was administered towards the end of the semester to assess student usage of and satisfaction with the various course resources, student opinions of their learning, and overall satisfaction with the course. The survey was developed by the CALSTEP External Evaluator, with input from the instructors and the institution’s Research Office. The survey covers six general areas: (1) student background, (2) online students’ preparation and experience, (3) course resources, (4) lab experience, (5) team work, and (6) overall assessment and ideas for improvements. A copy of the survey questionnaire is given in Appendix A.

4. Results of the Implementation

Comparison of Student Characteristics: Institutional Data

Table 2 shows a comparison of the academic characteristics (number of semester units completed at the end of Fall 2015 semester and cumulative GPAs) of students in the online and face-to-face sections of the Engineering Graphics course at Cañada College in Fall 2015, as obtained from institutional data. On the average the online students have completed about 12 more units than students in the face-to-face section, although this difference is not statistically significant due to the large standard deviations and the small sample sizes. The mean cumulative GPAs are exactly the same at 3.14 for both student groups, the face-to-face students having a higher median GPA of 3.20 and a higher standard deviation as well. These institutional data do not show any significant difference between the academic performance of the two groups of students.

Table 2. Comparison of the number of semester units completed at the end of Fall 2015and cumulative GPAs for students in the online and face-to-face sections of the Engineering Graphics course.

Characteristics	**Online** (N=12)			**Face-to-Face** (N=19)		
	Mean	**Median**	**St Dev**	**Mean**	**Median**	**St Dev**
Units Completed	71.5	75.5	46.1	59.7	57.5	34.7
GPA	3.14	3.09	0.38	3.14	3.20	0.58

Comparison of Student Performance in the Graphics Class

To directly compare the performance of students in the two sections of the graphics course, the two instructors collaborated to give a set of common questions and problems on the three tests that were given during the term. For each of the tests, an identical set of 10 multiple choice questions (each worth 2 points) was given to both sections. Additionally, for Test 2 and Test 4, the first two of the three problems were also identical for the two sections of the course. For Test 3, the first three of the four problems were identical for the online and face-to-face sections. Table 3 summarizes a comparison of the scores received by online and face-to-face students in the test problems that were identical for the two sections. In all but two of the test items (Problem 2 and Problem 3 of Test 2), the mean score for the online students is higher than the mean score for the face-to-face students. However, the difference between the scores of the online and face-to-face sections is not statistically significant except for one test item, Test 2-Problem 1. This test problem covers the topic of *Sectional Views*, which is one of the most difficult topics in the class.

Table 3. Comparison of the scores received by students in the online and face-to-face sections of the Engineering Graphics course.

Test Items	Online			FTF		
	Mean	Median	St Dev	Mean	Median	St Dev
Test 1-Mult Choice	12.36	14.00	4.80	12.13	12.00	5.15
Test 1-Problem 1	27.82	28.00	2.48	25.47	28.00	7.49
Test 1-Problem 2	17.00	18.00	1.41	14.67	17.00	5.88
Test 2-Mult Choice	14.44	14.00	3.71	11.45	12.00	4.30
Test 2-Problem 1*	16.78	17.00	1.72	14.73	14.00	1.62
Test 2-Problem 2	14.22	15.00	6.22	15.45	18.00	6.20
Test 2-Problem 3	18.56	20.00	1.94	18.73	18.00	1.01
Test 3-Mult Choice	16.22	16.00	2.11	14.00	16.00	3.22
Test 3-Problem 1	14.22	14.00	1.79	13.86	15.50	5.18
Test 3-Problem 2	22.67	21.00	2.24	21.27	20.00	1.66

*The difference between the scores of the online and FTF sections is statistically significant [$t(1,16) = 2.73$, $p<.015$].

Due to the small sample sizes, it is difficult to obtain statistically significant results. Although statistically significant difference is observed only for one of the test items, Table 3 suggests that the online students did at least as well (if not better) than the face-to-face students on the tests the were given to both sections.

Table 4 is a comparison of student retention and success for the online and face-to-face sections of Fall 2015 Engineering Graphics course. The second column represents the number of students enrolled in the course as of census day, 12 students for the online section, and 19 for the face-to-face section. Of the 12 students in the online section, 9 completed the class, and all 9 students received a passing grade, representing identical retention and success rates of 75%. For the face-to-face section, of the 19 students enrolled in the class, 11 completed the class, and 10 passed. This represents a retention rate of 57.9% and a success rate of 52.6%, lower than those for the online section and average retention rate (89%) and success rate (83%) for previous 5 terms of the Engineering Graphics course taught by Professor A.

Table 4. Comparison of student retention and success for the online and face-to-face sections of Fall 2015 Engineering Graphics course. Retention is defined as completing the class and receiving a letter grade, and success is defined as receiving a passing grade (C or higher) in the class.

Section	# of students	Retained	Passed	Retention Rate	Success Rate
Online	12	9	9	75.0%	75.0%
Regular	19	11	10	57.9%	52.6%

Table 5 shows a comparison of the grades received by the students who completed the class (9 for the online section and 11 for the face-to-face section). The median grades are identical at 3.00. For the face-to-face section, the mean grade is slightly lower and the standard deviation higher due primarily to the student who did not pass the course. There is again no statistically significant difference in the grades received by the students who pass the online section and those in the face-to-face section.

Table 5. Comparison of grades received by student who completed the class for the online and face-to-face sections of Fall 2015 Engineering Graphics course.

Section	Grade in Graphics Class		
	Mean	Median	Stand Dev
Online	3.04	3.00	0.72
Regular	2.83	3.00	0.91

Results of Student Surveys

At the time of the administration of the survey, only 9 students in the online class were still active, and only 11 students in the face-to-face class were still active. For the face-to-face section, 8 of the 11 active students completed the survey. For the online section, all 9 active students completed the survey.

Student Background: The online students had a different profile than students in the FTF course who responded to the survey. The former were much less likely than the FTF students to be taking all their courses at Cañada College and although they had more semesters ahead of them before transfer than the FTF students they were more likely to have transfer plans in engineering. Additionally, the online students were more diverse in terms of whether and how much they worked and in terms of how much time they reported spending on the course/week. By contrast, the FTF students, with one exception, spent the same amount of time on the course each week, most of them did not work and only one of them worked more than 20 hours a week.

Online Students' Preparation and Experience: More than half of the online students reported enrolling because they wanted to take the course from Professor A while one-third took the course because their schedules did not allow for them to take the class FTF. While one-third of the class had no previous online course taking experience, the students who had taken classes online in the past had a strong track record of completing these courses with a passing grade. All the students who had prior online experience found the class to be highly effective (5 responses) or effective (1) compared to previous online courses they had taken. They attributed their satisfaction to the effectiveness of Professor A and the resources he had developed for the course. The only major technical problem that several online students experienced concerned downloading SolidWorks.

Course Resources*:* The online and FTF students differed in their identification of most effective course resources. The online students gave the highest ratings to the video lectures and video tutorials and to emailing the instructor. The largest number of FTF students found the assistance from the tutors to be the most helpful followed by written lab handouts, emailing other students and in-class lectures. Students in the FTF course varied considerably in their assessment of the text book as a resource with some giving it the highest and some the lowest rating. Four students in the online course gave the text book the lowest possible rating of effectiveness. The online students differed in their assessment of the effectiveness of the tutors with three students giving this resource the two lowest and three others giving it the two highest ratings. The remaining online students identified the tutors as a non-applicable resource, probably because they lived too far away or could not make it to the college when the resource was available.

The online and FTF students also differed in their identification of resources they access when they have questions. The online students rated as their top sources emailing the instructor followed by office hours with the instructor. For the FTF students emailing the instructor was the option that was rated least likely by the largest number of students. The largest number of FTF students identified asking other students for help as their most likely course of action followed by consulting sources on their own.

The least likely course of action for online students was the forum. This was followed by bringing questions to the course tutors and asking other students for help – both of which may have received a low rating because of logistics in accessing the tutor and in not having the FTF interaction with other students.

Two thirds of the online students preferred Web Access compared to 43% of the FTF students. Only three online students reported using the forum and it was not clear from the responses whether the FTF students had access to or knowledge about the forum. In explaining their limited use of the forum, the online students noted that they preferred emailing the professor (3 responses) or liked to figure things out themselves (2). The FTF students – who may or may not have had access to the forum – exhibited a similar response pattern with two students noting they prefer emailing with their professor and another two stating they like to figure things out on their own. Interestingly though, several students from both classes expressed interest in expanding the use of the forum and proposed as strategies that the forum should be mandatory or that students should get points for postings.

Lab Experience*:* Students in both courses gave the lab experience high ratings for helping them understand the material. In the online course all students gave the labs the highest or second highest rating of effectiveness with two thirds assigning the labs the highest possible rating. The large majority of the FTF students also assigned high ratings to the overall lab experience but with more students giving the lab activities the second-highest rather than the highest rating for effectiveness.

In breaking down the overall assessment of the lab experience into more detailed impressions, a large majority of students in the online course “strongly agreed” to seeing connections between the lecture and the lab, to having sufficient guidance to do the labs, and to understanding the lab objectives before and at the end of the lab activities. Similarly, the majority of online students “strongly agreed” that the labs helped them understand concepts introduced in the videos/books as well as additional concepts not covered by these sources.

For the FTF students, a majority of students agreed with all these areas of inquiry, although the agreement was not as strong as was the case for the online students so that most students agreed rather than “strongly agreed” to seeing connections, having sufficient guidance, etc. Two of seven students in the FTF class indicated they did not have sufficient guidance on how to do the labs and that they did not understand the learning objectives for the lab before starting the lab activity.

In pointing to their favorite lab activity, four online and two FTF students identified the first SolidWorks lab. Three of the online students, in explaining what was the most important thing they learned from the labs, spoke about the problem solving approaches they have learned and three referred to learning skills that are used by engineers. By contrast, and in response to the same question, the FTF students were more likely to point to their satisfaction with the software programs. The overall assessment of the lab experience from the majority of students in both courses was very positive with many students noting how satisfied they felt from having had the experience of designing something and using tools that “real engineers” use.

5. **Conclusions and Future Plans**

The pilot implementation of the online Engineering Graphic course at Cañada College was successful. Students in the online course performed at least as well (if not better) than the students in the face-to-face section in the identical tests that were given to both groups. The percentage of students who completed and passed the course was higher for the online section than the face-to-face section. Results of the student survey also indicate a high rate of satisfaction with the online course and the resources available for the course. Among the five online students who have previously taken at least one other online class, the online graphics class was rated highly effective (4 responses) or effective (1) compared to other online classes they have taken. The results of the student surveys also indicate a higher overall satisfaction with the course and the lab experience among online students when compared to the face-to-face students.

Limitations of the study presented in this paper include small sample sizes and the variability of conditions brought about by two different instructors teaching the two sections of the course; the online section was taught by a full-time, more experienced instructor who also developed the course materials, and the face-to-face section was taught by an adjunct instructor who taught the graphics course for the first time. As a future plan, further similar studies at Cañada College will be conducted in Fall 2016 with the same experienced, full-time instructor teaching both the online and face-to-face sections in order to better understand the effectiveness of the curriculum in both delivery modes. Additionally, the curriculum materials will also be tested at the CALSTEP partner institutions College of Marin and Monterey Peninsula College. One resource that will be developed more fully is the online forum, which was not efficiently used in the pilot implementation. For ease of replication of the course, students in the online class need to rely less on emailing the instructor and more on using the online forum. Many of the course materials will also be updated for the latest version of the software, and improvements will be made based on student feedback. The sketching videos and other resources will be redone using a better camera. All course materials are now available in formats that can be edited by instructors who want to use them in their courses. Prospective users of these resources can use their own voice to create their own version using the captions as scripts.

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Appendix A. Student Survey Questions

Background

* What is your gender?

* What is your ethnicity/race?

* This semester (please check the one box that best describes you):

I'm taking all my courses at Cañada College
I'm taking several courses at XXXXXXXXX, and other courses at other colleges
Engineering Graphics is the only course I am taking at XXXXXXXXX

* How many total semester units are you enrolled in this semester? Please include in your count Engineering Graphics and units you are taking at other colleges.

* Do you plan to transfer to pursue a baccalaureate degree in engineering?

* How many additional semesters (including the current semester) do you think you need to complete before you can transfer?

* Have you been to/visited in person the engineering program you are most interested in attending after you transfer?

* Have you ever had an internship or a job that was directly related to engineering?

* On average, how many hours a week do you work? If you do not work, please write "0".

* Please indicate your agreement with the following statement: I have my life organized so I have enough time to study and do well in my class
* On average, how many hours do you spend on the class each week. Please include in your estimate everything from time spent watching videos to lab assignments, attending office hours, completing assignments and being in class (if you are taking the class from Prof. B)

* Please check the one box that best describes you: I participate in Engineering Graphics as:

An online student enrolled in Dr. Enriquez's class
A classroom student enrolled in Prof. Wong's class

Questions for On-Line students

* Why are you taking Engineering Graphics online? (Please check the box that best describes your main reason for taking the class online)

I wanted to take the class from Prof. A
Class scheduling conflict so I could not take the face-to-face class
I live too far from campus to attend the class in person
I prefer online delivery over classroom instruction
Other

Please describe other:

* How many courses have you taken online, not counting Engineering Graphics? If Engineering Graphics is your first online course, please select "0" below.

* How many of the courses you signed up to take online did you complete with a passing grade?

* Compared to other online courses you have taken, how effective do you think Engineering Graphics is in terms of helping you learn the required material and concepts?

Very effective (compared to other online courses)
Effective (compared to other online courses)
Not effective (compared to other online courses)
Not applicable - this is my first online course
Other (please specify)

* Please explain in one or two sentences what makes Engineering Graphics more or less effective as an online learning experience than other online courses you have taken? If this is your first online course, simply write N/A in the box below.

* Please check whether you have experienced any of the following problems as an online student:

Difficulty downloading AutoCAD
Difficulty downloading SolidWorks
Difficulty downloading or accessing resources posted on Web Access
Difficulty joining online office hours
Difficulty seeing or following the pencil/pointer in the videos

Please describe any other difficulty you experienced using the online resources/technology

Your Use of Course Resources

* Please rank the following resources in terms of how useful they are for you in terms of understanding the class material and completing the assignments with 1 being LEAST useful and 5 being MOST useful. Check N/A if you do not use or know of a resource listed. Note that some resources, such as "in-class lectures" are only available to students who take the class in person (and not online). If you are an online student, you should choose N/A for "in-class lectures

Video lectures
In-class (face-to-face) lectures
Text book
Lecture notes
Video tutorials
Office hours with the instructor
Assistance from tutors
Archived office hours sessions
FAQs posted online
Online forum posts (reading other people's questions and answers)
Emailing questions to the instructor
Emailing questions to the tutors
Emailing or otherwise getting help from other students
Written lab handouts

* Please describe in one-two sentences what makes the resource you gave the highest rating in the question above so effective for you

Your strategy for getting help/solving problems

* What do you do when you have a question about an assignment or something else related to the class? Please rate each of the following ways in which to get help with a question using a scale from 1-5 where 1 is your least likely course of action and 5 is your most likely course of action for getting help with your question

Email my professor to ask for help
Ask the question in class (please write N/A if you are an online student)
Bring the question to the next office hour with my professor
Bring the question to the course tutor(s)
Ask another student in the class for help
Look for answers in the archived office hours
Look at FAQs
Post the question in the forum
Consult a range of sources on my own

Your use of technology and online resources

* For online discussions, what type of technology do you prefer? (Choose one that best describes your preference)
WebAccess
Facebook
Google+
Other

* Have you used the forum this semester (to post questions and answer questions from other students)?
Yes
No
My class does not have a forum

* If you have not used the online forum or only used it on a very limited basis, why are you not using it (more)? Please check only the most important reason listed below.

I frequently post questions, so this doesn't apply to me
Takes too much time, too cumbersome
I don't want everyone to see my questions
My professor is available to answer questions by email, so there is no need to go to the forum
Time management -- I only start the problems right before they are due
I like to figure things out myself
Other

Please describe other in one-two sentences

* What changes could we make to increase your participation in the class Q&A Forum?

Your lab experience

* Please assess the overall impact of the labs on your understanding of the class material on a scale from 1-5 where 1 is not at all helpful and 5 is extremely helpful

* Which was your favorite lab?

* What did you like best about the lab you identified as your favorite in the previous question?

* Please indicate how much you agree with the following statements:
    - There is a strong connection between the lecture/class component and the lab activities.
    - I have sufficient guidance on how to do the labs.
    - I understand the learning objectives for the lab before I start the lab activity.
    - I understand the learning objectives for the lab when I conclude the lab activity.
    - Doing the labs make me understand the concepts that have been introduced in the videos/book/classroom
    - Doing the labs taught me additional skills and concepts not covered in the videos/book/classroom.

Your Group Project Experience

* In a couple of sentences, please describe how you collaborate with your team mates on the group project. How often do you meet? Where/how do you meet (on-line --e.g. Google Hangouts, in person, most communication by email, FaceTime, etc)?

* Please explain in one or two sentences, how the group project has contributed to your learning experience in the class? (for example: "the group project has helped me learn how to lead a team" or "the group project helped me learn different ways to approach the material")

* Please explain in one or two sentences any challenges you have encountered with the group project.

Your overall impressions

* Thinking back at the class as a whole, what do you like best about Engineering Graphics?

* Thinking back on the lab component of the class, what is the most important thing you have learned from the labs?

* What is one idea you have for how to make Engineering Graphics better?

Anything Else?

Please record below anything else that you think is important about your Engineering Graphics experience that has not already been covered in the survey.