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Strengthening Community College Engineering Programs through Alternative Learning Strategies: Developing an Online Engineering Graphics Course

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Abstract

Community colleges play an important role in educating future engineers and scientists, especially students from traditionally underrepresented groups. Two-plus-two programs and articulation agreements between community colleges and four-year institutions allow community college students to take their lower-division courses at local community colleges and then transfer to a university to complete their baccalaureate degrees. For many small community colleges, however, developing a comprehensive transfer engineering program can be challenging due to a lack of facilities, resources, and local expertise. As a result, many community college students transfer without completing the necessary courses for transfer, making timely completion of degrees difficult. Through a grant from the National Science Foundation, three community colleges in California collaborated to develop resources and teaching strategies to enable small 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. The biggest challenge in developing such strategies lies in designing and implementing courses that have lab components. This paper focuses on the development and testing of the teaching and learning resources for Engineering Graphics, which is a four-unit course covering the principles of engineering drawings, computer-aided design, and the engineering design process. The paper also presents the results of the 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 conducted in both the online and face-to-face courses 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

One of the main recommendations of the 2012 President's Council of Advisors on Science and Technology (PCAST) report, "Engage to Excel," is to address the retention problem in the first two years of college in order to produce additional STEM (Science, Technology, Engineering, and Mathematics) professionals in the next decade needed to retain the nation's historical preeminence in science and technology[1]. The California Community College System, with its 112 community colleges enrolling approximately over two million students—representing over 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, interest in online education has been increasing due to wider acceptance of its potential benefits including increased access and success for nontraditional students[4], increased potential for individualized and student-centered learning, increased 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, and the number of students enrolled in at least one online course continues to increase at institutions of higher education[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 in the state, it has become increasingly more difficult for small community college engineering programs to offer all the required transfer courses because of low enrollment due the divergence and increasing variability of transfer courses required by different majors and different universities[11]. To address this issue and increase the viability of supporting these engineering 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 survey of enrollments in engineering courses at the JEP partner institutions shows an overall enrollment increase of 52.1% from 2010 to 2016 despite the fact that over the same period, total enrollments at the JEP partner institutions decreased slightly. However, courses requiring laboratory components have been difficult to develop and offer online in these colleges. For instance at Cañada College, although enrollments in lecture courses have increased over 100% due to a dramatic increase in online enrollment, enrollments in lab courses have only increased 23%[12].

In 2014, inspired by the success of the Joint Engineering Program in strengthening community college engineering programs, three colleges in Northern California, Cañada College, College of Marin, and Monterey Peninsula College collaborated to develop the Creating Alternative Learning Strategies for Transfer Engineering Programs (CALSTEP). CALSTEP is a three-year project funded by the National Science Foundation through the Improving Undergraduate STEM Education (IUSE) Program, and one of its main objectives 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[13], Engineering Graphics[14], Materials Science[15], Circuits[16], 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.

In developing the CALSTEP online laboratory courses, consideration was given to the thirteen objectives for engineering educational laboratories defined by the ABET/Sloan Foundation effort[17,18]. CALSTEP curriculum development also 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[5,19-24].

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, the results of the implementation of the course at Cañada College in Fall 2016, and a comparison of these results with those of the pilot implementation in Fall 2015 as described in a previous paper[14].

2. Developing an Online Engineering Graphics Course

Among the issues and concerns identified by faculty when designing and implementing online courses include issues include time commitment[25,26], use of technology tools[27], implementing effective pedagogical strategies[28,29], and the switch in faculty role to facilitator of learning[25,30]. Additionally, the course design and instructional tools also depend on whether the online class is to be delivered synchronously or asynchronously[31]. One challenging aspect of online teaching and 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 higher dropout rates in online courses[32-36]. The Engineering Graphics course that is the focus of this paper is completely online and asynchronous. While the course was developed by an engineering instructor who has previously developed and taught the face-to-face version of the course and has taught various engineering lecture courses synchronously, 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[37].

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 2015-16 academic year, the college enrolled 10,075 unique students, with Hispanic students as the largest single group at 45.2%, followed by white students at 26.8%, and Asians at 16.4%. 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 statewide-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 that support the Graphics course, the instructor decided to develop new resources for the class in order to design a course that would best serve community college engineering students intending to transfer to a four-year program. 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. Most commercially available products focus on either AutoCAD or Solidworks but not both. If available commercial products were to be adapted for the course, costs to students would be prohibitive, especially if they have to pay for both AutoCAD and SolidWorks resources. 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. Furthermore, 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[38].

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 24 lecture videos and 32 video tutorials were created. The videos were designed to be short because short videos have been found to be more engaging[39]. 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 CASTEP 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 at Cañada College in Fall 2015 and implemented again in Fall 2016. 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. For the Fall 2015 pilot implementation, Table 1 shows a comparison of the online section and the face-to-face section of the Engineering Graphics course. 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 F2F 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 F2F 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 F2F 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	Fall 2015 Online Section	Fall 2015 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; students use their own computers and 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
Final Project	Design challenge completed in groups of 3 or 4	Completed in groups of 3 or 4; focused mostly on preparing working drawings

For the Fall 2016 implementation, Table 2 shows a comparison of the online section and the face-to-face section of the Engineering Graphics course. Both sections were taught by the engineering instructor (Professor A) who developed the online course using 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 F2F 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 identical, with F2F students completing their quiz during class session and online students submitting their quizzes online through WebAccess. For the tests, identical questions and problems were given to both sections, with about half of the online students taking the tests at the same time as the F2F students taking the tests during the F2F class sessions (MW, 2-5 p.m.) and the rest of the online students taking their tests in the evening of the same day. Identical homework sets were also given to students in both sections. In addition to laboratory exercises, quizzes, homework, and tests, identical final design group projects were also given to students in both sections. Throughout the semester, two drop-in tutors were available on campus to assist students from both sections in completing their labs and assignments outside of class.

Table 2. A comparison of class characteristics for the online and face-to-face sections of Engineering Graphics in Fall 2016

Class Characteristics	Fall 2016 Online Section	Fall 2016 Face-to-Face Section
Number of students (as of census date)	12	18
Instructor	Professor A	Professor A
Lecture Delivery	Asynchronously through pre-recorded videos	In-person, twice a week for 1.5 hours per meeting
Laboratory Exercises	Asynchronously; students use their own computers and 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
Final Project	Design challenge completed in groups of 3 or 4	Design challenge completed in groups of 3 or 4

To standardize the grading of the tests and the labs for the Fall 2015 implementation, 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 Implementations

Comparison of Student Characteristics

Table 3 shows a comparison of the academic characteristics (number of semester units completed 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 for both the online and face-to-face sections. 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 previous academic performance of the two groups of students in Fall 2015.

Table 3. Comparison of the number of semester units completed cumulative GPAs for students in the online and face-to-face sections of the Fall 2015 Engineering Graphics course

Characteristics	**Fall 2015 Online**			**Fall 2015 Face-to-Face**		
	Mean	Med	St Dev	Mean	Med	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

Table 4 shows a similar comparison of the academic characteristics of students in the online and face-to-face sections in Fall 2016. Just like the Fall 2015 data, the online students, on average, have completed more units than students in the face-to-face section. The average cumulative GPAs are also nearly identical for the two groups of students in Fall 2016.

Table 4. Comparison of the number of semester units completed cumulative GPAs for students in the online and face-to-face sections of the Fall 2016 Engineering Graphics course

Characteristics	**Fall 2016 Online**			**Fall 2016 Face-to-Face**		
	Mean	Med	St Dev	Mean	Med	St Dev
Units Completed	78.4	72.5	39.4	66.5	57.0	23.9
GPA	3.26	3.28	0.37	3.23	3.23	0.47

Comparison of Student Performance in the Graphics Class

Due to scheduling conflicts in Fall 2015, two different instructors taught the two sections of Engineering Graphics course. 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 5 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. 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 5 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 5. Comparison of the test scores received by students in the online and face-to-face sections of the Fall 2015 Engineering Graphics course

Test Items	**Fall 2015 Online**			**Fall 2015 F2F**		
	Mean	Med	St Dev	Mean	Med	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 F2F sections is statistically significant [$t(1,16) = 2.73$, $p<0.015$].

Fall the Fall 2016 implementation of the curriculum, identical test questions were given to the online and face-to-face sections. Table 6 is a comparison of the scores on the three tests and the overall course grade for the online and face-to-face sections of the course in Fall 2016. None of scores have statistically significant difference between the groups of students. Even for Test 2 scores, which has the largest difference, there is no statistically significance difference between the scores achieved by the online and face-to-face students [$t(1,23) = 2.73$, $p>0.61$].

Table 6. Comparison of the scores received by students in the online and face-to-face sections of the Fall 2016 Engineering Graphics course

Tests	**Fall 2016 Online**			**Fall 2016 F2F**		
	Mean	Med	St Dev	Mean	Med	St Dev
Test 1	84.82	88.00	7.86	83.94	84.50	10.56
Test 2	77.00	79.00	13.26	79.72	82.50	15.36
Test 3	87.18	85.00	8.38	87.39	89.00	9.67
Overall Grade	85.81	89.50	10.05	86.48	90.25	10.47

Table 7 shows a comparison of student retention and success for the online and face-to-face sections of Fall 2015 and Fall 2016 Engineering Graphics course. The number of students is the number enrolled in the course as of census day. 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. A direct comparison of the results for Fall 2015 shows better results for the online section compared to 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.

For Fall 2016, of the 12 students in the online section, 11 completed and passed the class, corresponding to identical retention and success rates of 91.7%. The student who dropped the class did so early in the semester and not because of poor academic performance. All of the 18 students in the face-to-face section completed and passed the course. When compared to the previous years' student outcomes, Fall 2016 success and retentions for both online and face-to-face sections are significantly higher than those for Fall 2015, as well as those for the previous six academic years (last column of Table 7).

Table 7. Comparison of student retention and success for the online and face-to-face sections of Fall 2015 and Fall 2016. The last column is the average values for the previous six academic years (Fall 2009 to Fall 2014).

	Fall 2015		Fall 2016		2009-2014
	Online	F2F	Online	F2F	F2F
Number of Students	12	19	12	18	27
Retention	9	11	11	18	23.3
Success	9	10	11	18	22.2
Retention Rate	75.0%	57.9%	91.7%	100%	85.8%
Success Rate	75.0%	52.6%	91.7%	100%	81.7%

Results of Student Surveys

For both years of the Engineering Graphics curriculum, a student survey as administered at 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. For the Fall 2015 implementation, 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. For the Fall 2016 implementation all students who are still active at the end of the semester (18 for the face-to-face section and 11 for the online section).

Student Background

For both Fall 2015 and Fall 2016, the online students had a different profile than students in the F2F course. The former were much less likely than the F2F students to be taking all their courses at Cañada College and had more semesters ahead of them before transfer than the F2F students. Additionally, the online students were more diverse in terms of whether and how much they worked. Students in both face-to-face and online sections reported comparable average number of hours spent on the course but the variations in the hours spent on the class are high for both groups. For instance, for Fall 2016, the average number of hours spent on the course was 13.22 (with a standard deviation of 11.02) for the face-to-face students and 12.0 (with a standard deviation of 12.32) for the online students.

Online Students' Preparation and Experience

For the Fall 2015 pilot implementation, 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 F2F. 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.

For the Fall 2016 implementation, three out of the 11 online students took the course online because of scheduling conflicts, another three students live too far from the campus to attend the class in person, and two students prefer online delivery over face-to-face instruction. Eight out of the eleven online students have previously taken and successfully completed at least one online course. All the students who had prior online experience found the class to be highly effective (4 responses) or effective (4) compared to previous online courses they had taken. Two students had difficulty in downloading SolidWorks, and two students had difficulty joining the online office hours.

Course Resources

For the Fall 2015 pilot implementation, the online and F2F 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 F2F 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 F2F 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.

Unlike the Fall 2015 implementation, there was a greater agreement in the identification of most effective course resources in the online and face-to-face sections for the Fall 2016 implementation. Both groups of students identified video lectures, video tutorials, emailing the instructor, office hours with the instructor, lecture notes, and written lab handouts as very effective course resources. Both groups identified the textbook as least effective course resource.

Online students rated emailing or getting help from other students to be more useful compared to the ratings given by face-to-face students to this resources. For both sections of the course, students differed in their assessment of the effectiveness of the tutors.

The Fall 2015 online and F2F 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 F2F students emailing the instructor was the option that was rated least likely by the largest number of students. The largest number of F2F 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 F2F interaction with other students. For the Fall 2016 survey results, the online students rated emailing the instructor as the most likely course of action when they have questions, followed by consulting a range of resources on their own. For the F2F students, asking the question in class is the most likely course of action, followed by emailing the instructor. For both online and F2F students, posting the question in the online forum is the least like course of action.

For the Fall 2015 survey results, two thirds of the online students preferred Web Access compared to 43% of the F2F students. Only three online students reported using the forum and it was not clear from the responses whether the F2F 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 F2F 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. For the Fall 2016 survey results, majority of the students (7 out of 11 for the online section and 14 out of 18 for the F2F section) preferred Web Access as the technology for online discussions. However, only 3 out of 11 of the online students and only one out of 18 face-to-face (F2F) students reported using the forum. In explaining their limited use of the forum, the online students noted that they preferred emailing the professor (4 responses for online and 7 responses for F2F) or liked to figure things out themselves (3 for online and 4 for F2F).

Lab Experience

For the Fall 2015 student surveys, 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 F2F 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 F2F 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 F2F 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 F2F 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 F2F 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.

For the Fall 2016 survey results, 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 more than half assigning the labs the highest possible rating. The large majority of the F2F students also assigned high ratings to the overall lab experience with 70% of students giving the lab activities the highest rating for effectiveness. A large majority of students in both online and F2F sections "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 the 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. The levels of agreement in the effectiveness of the labs, their satisfaction with the lab experience and the connection between the lecture and the lab are similar for the online and F2F students. In pointing to their favorite lab activity, three online and three F2F students indicated that they enjoyed all the labs; several students identified various labs involving SolidWorks as their favorite. The overall assessment of the lab experience from the majority of students in both courses was very positive with many students noting how they enjoyed learning new skills that can be applied to the real world.

5. Conclusions and Future Plans

The pilot implementation of the online Engineering Graphic course at Cañada College in Fall 2015 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, with all of the online students who have previously taken an online course rating the online Graphics class to be more effective or effective compared to previous online courses that 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. A serious limitation of the study presented in this paper from the Fall 2015 implementation is 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. The lower retention and success rates for the F2F section compared to those for the online section may be attributed to the limited teaching experience of the adjunct instructor who taught the F2F class. In fact, this instructor taught the same Graphics course using the same curriculum in a F2F setting in Spring 2016 at College of San Mateo, which is one of the three community colleges in the San Mateo Community College District together with Cañada College and Skyline College. For the Spring 2016 Graphics class at College of San Mateo, out of the 28 students 26 were retained and 23 passed, or a retention rate of 92% and a success rate of 83%. These rates are significantly higher than those for the Cañada College F2F Graphics class taught by the same instructor.

The implementation of the online Graphics curriculum at Cañada College in Fall 2016 was also successful. With the same instructor teaching both the online and face-to-face sections, there were no statistically significant differences in the student performance and outcomes for the two sections. With the updated Graphics curriculum, the retention and success rates for both the online and face-to-face sections were significantly higher than those for Fall 2015 (both online and F2F), and also higher than the previous Graphics courses for six academic years from 2009 to 2014, which were all offered in the traditional face-to-face format. The course resources developed for the online Graphics course (PowerPoint lectures, lecture videos, video tutorials, laboratory exercises, and homework assignments), which were also made available to the face-to-face students have been effective in promoting student success in both the online and F2F sections. The results of the end-of-semester survey show very positive perceptions of the usefulness of the course materials and high levels of satisfaction with the course for both the online and face-to-face students.

As a future plan, further similar studies at Cañada College and at the CALSTEP partner institutions College of Marin, Monterey Peninsula College, and Skyline College will be conducted in order to better understand the effectiveness of the curriculum in both delivery modes. Additionally, the curriculum materials will be promoted to other community colleges in California through a two-day summer teaching workshop that will be held at Cañada College in 2017. One resource that will be developed more fully is the online forum, which was not efficiently used in the past implementations of the curriculum. 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. All course materials are now available in formats that can be edited by instructors who want to use them in their courses. For videos of lectures and tutorials, prospective users of these resources can use their own voice to create their own version using the captions as scripts.

Although the curriculum materials developed so far have been proven to be effective in both traditional and online delivery formats, and the course materials are available free to instructors, the cost of offering the Engineering Graphics course in its current format may still be prohibitive for small community college engineering programs. Although AutoCAD is currently free for students and institutions, purchasing institutional licenses for SolidWorks and the yearly maintenance agreement costs may be prohibitive for small engineering programs with limited budgets. As a future plan for the CALSTEP project, course materials will be developed using Autodesk Inventor as the main software program to replace current course materials needing SolidWorks. This will allow instructors and colleges to adopt CALSTEP Engineering Graphics curriculum with minimal investments needed, increasing access to this important course needed by students to be competitive when applying to transfer to four-year engineering programs.

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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 CañadaX, and other courses at other colleges
  Engineering Graphics is the only course I am taking at CañadaX
* 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 Professor A's class
  A classroom student enrolled in Professor B'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.