Student Interest and Performance in Dual Enrollment Engineering Courses

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Abstract

Engineering courses required of all first-year engineering students at the University of Cincinnati were made available to regional high schools through dual enrollment. This program has allowed the university to develop authentic and meaningful relationships with high schools and increase students' interest in studying engineering. Participation more than doubled in the first six years the program was available and continues to increase. There is little in the education literature regarding engineering dual enrollment program so this paper seeks to provide a benchmark upon which other research can build upon. Student data was analyzed using an independent samples t-test to compare academic performance of high school students to university students. Analysis shows that students who took engineering courses in high school perform just as well as traditional students do in those courses. Students who took the first course in a two-course sequence in high school perform just as well on the second course as students who took the first course in college.

Key words: Dual enrollment, academic performance, quantitative analysis

Introduction

Context

Dual enrollment is a program that allows students to earn college credit while still in high school. One common form of dual enrollment is for students in high schools to concurrently enroll in a college or university course and receive both high school credit and college credit for the same course. These programs require a partnership between a school and a college or university. While Advanced Placement and International Baccalaureate programs can also enable high school students to earn college credit, dual enrollment courses are associated with a specific course at a specific college and result in a transcript record.

Dual enrollment was initially used to provide academically advanced students an opportunity for a richer educational experience than most high schools could provide (Cassidy et al, 2010, An, 2013; Howley et al, 2013). Increasingly, dual enrollment is viewed as an opportunity to increase and diversify the population of students who pursue college degrees (Gross, 2016; Howley et al, 2013). More recently, states and even the federal government have seen dual enrollment as a possibility for shortening the time needed to obtain a college degree and lowering the cost of a college education (Hughes, 2016; Allen and Dadger, 2012).

Dual enrollment courses have traditionally been in topics that serve large numbers of students, such as English composition, humanities and college algebra. There has been a concerted effort by community colleges to provide career and technical related dual enrollment courses (see for example Zinth, 2014). The opportunity for high school students to earn college credit for engineering courses (specifically those not associated with career and technical education) has been limited but is growing. For example, the University of Arizona (Rogers et al, 2014) has had a program since 2008 that allows students to earn credit for ENGR 102 the introduction to engineering course required by UA. The University of Texas system likewise provides a pathway for students to earn dual enrollment credit through the "Engineer Your World" program (http://engineeryourworld.org/courses/dual-enrollment/). Many other colleges are also beginning to offer dual enrollment engineering courses.

This paper provides a benchmark study on student participation in engineering dual enrollment courses and student academic performance in these courses. The paper also provides data on academic achievement of students who earned college credit in the high school engineering courses once they matriculated into an engineering program at the University of Cincinnati (UC) in the College of Engineering & Applied Science (CEAS). The purpose of the paper is not to make definitive claims regarding the merits of dual enrollment or to put forward substantive arguments regarding performance of students in dual enrollment courses. Rather, the purpose is to provide useful data and relevant observations so that others can develop a robust research approach for subsequent studies.

Review of the Literature

The opportunity for high school students to earn college credit through a concurrent enrollment option has been in practice since the late 1970s. It was generally implemented to allow high achieving high school students the chance to participate in more challenging coursework than was available to them in their high schools (Puyear et al, 2001; An, 2013; Johnson and Borphy, 2006). Another commonly cited reason for the creation of dual enrollment programs was to facilitate a better transition between high school and college (Bailey, Hughes and Karp, 2002; Kim and Bragg, 2008). More recently, dual enrollment programs have been seen as a means for improving access to college education (Howley et al, 2013), with some particular attention paid to individuals who have traditionally not gone to college (Swanson, 2008; Hoffman et al, 2008).

In the 2010-11 academic year, approximately two million enrollments, representing over 11% of the secondary school population, were reported in dual enrollment with 82% of high schools participating (Thomas et al, 2013). This is a significant increase from the roughly 5% of students who participated in dual enrollment for the 2002-03 academic year (Waits et al, 2005). Gross (2016) reports that participation is increasing by about 7% per year with a growing number of participants coming from low-income and minority students. Zinth (2014) reports that approximately half of the students participate in dual enrollment courses with a career and technical education focus.

There are a variety of models for implementation of dual enrollment programs (Hughes et al, 2005) that involve a variety of instructional approaches (Andrews, 2001). These include courses taken at high schools by (certified) high school instructors, courses taken at colleges by college instructors, courses taken at high schools taught by college instructors, and other arrangements. Flores (2013) reports that a variety of settings can result in appropriate rigor and outcomes when sufficient attention is paid to implementation. Hebert (2001) found that in courses where high school teachers taught the college course in the high school, better learning outcomes were achieved than for other means of implementation.

There is a growing body of literature on the benefits (and shortcomings) of dual enrollment. These benefits were summarized by Allen (2010) to include: enhancing the curriculum available to students, improving the transition between high school and college, and reducing the time and cost to obtain a college diploma. Allen and Dadgar (2012) report that participating in dual enrollment reduces students' time to degree and increases a student's college GPA. Swanson (2008) concludes that dual enrollment leads to higher persistence in college programs and results in students being more likely to seek out a college degree. Karp et al (2007) studied dual enrollment in New York and Florida and found that dual enrollment participation improved high school graduation rates and increased the number of students who enrolled in college programs. Crouse and Allen (2014) and Jones (2014) both report that dual enrollment results in higher college GPA for first-year students. Kanny (2014) found that first generation college students experienced greater benefits on first-year grades than other groups.

The literature on student participation and performance in dual enrollment specific to engineering courses is sparse. Larrick (2012) reports briefly on a description of engineering dual enrollment between Kent State University and eleven high schools but presents no data on enrollment or student achievements. The University of Arizona has offered a dual enrollment engineering course since 2008 (Rogers et al, 2014). They report that enrollment has grown from 20 students in 2008 to over 300 students in 2014. The population is approximately 20% female with significant Hispanic participation. Rogers et al (2017) report that the dual enrolment engineering course is more efficacious at promoting female interest in pursuing engineering as compared to other STEM courses.

Dual Enrollment Engineering Courses

The College of Engineering and Applied Science at UC has collaborated with regional high schools to enable these schools to provide engineering courses to their students since 2007 (Rutz et al, 2008). Initially the high school engineering course provided only high school credit. Beginning in fall of 2012, the university provided a dual enrollment pathway with a reduced tuition rate that allowed qualified students to earn both high school credit and college credit for the course. Students had the option of taking the course for high school credit only or for both high school and college credit by registering for the college course and paying the reduced tuition rate. The state of Ohio launched the College Credit Plus (CCP) program for dual enrollment for the 2015-2016 school year. Prior to the CCP model, high school students could earn college credit through either: 1) a dual enrollment course with a local college that required families to pay the tuition or 2) a post-secondary education option where the school district paid tuition funds to colleges. The CCP model provided a dual enrollment pathway that all Ohio schools were required to use. The CCP model used state funding to cover the costs of the college tuition; individuals were no longer required to pay.

From 2012 through 2019, CEAS required three engineering courses of all first-year students. Two of these courses were made available to regional high schools as dual enrollment options. In 2019, the College modified the curriculum and learning outcomes for first year students resulting in the need to modify the courses. This paper analyzes aspects of the dual enrollment courses from 2012 through 2018 as this provides a case study not impacted by the changes in curriculum.

CEAS provided opportunities for high school students to participate in two semester long dual enrollment courses, ENED 1020 Engineering Foundations and ENED 1090 Engineering Models I. These courses were required of all students pursuing undergraduate degrees in the college. In our implementation model, both dual enrollment courses were collaboratively led by college faculty and high school teachers. The teachers received training on course content and pedagogy, and they led all in-class sessions in the high schools. Didactic content for both courses was created by college faculty and was provided via eLearning technologies. The content was presented in modules that included short videos, reading material and links to more extensive description of concepts. Students would view this content either during classroom time or as homework using a flipped classroom model depending upon how the high school teacher choose to implement the course. The college did not require that high school students follow an identical syllabus or schedule to the college students. The college did require that high school students master the same learning outcomes as the college students and that student outcomes were assessed in a similar manner and with similar grading scales.

ENED 1020 Engineering Foundations served as an introduction to all fields of engineering and included content related to the various disciplines as well as engineering design, engineering ethics, communication, teamwork, problem solving, and synthesis. The course included hands on projects that allowed students to explore engineering disciplines and applications. The college had four distinct projects required of traditional students that focused on bridges, fuel cells, electronic communications and signal processing applications. These projects required specific resources that high schools did not have, and which most high schools could not afford. For the dual enrollment course, high schools included engineering design projects selected by the high school instructor that were appropriate given the resources available and that enabled students to meet the learning outcomes. These projects were implemented in-person at the high schools and required some out-of-school work. Projects varied by school but common examples included: designing and using solar ovens, a bridge design and build project, and using sensors to collect data that was then analyzed. Assessment of learning outcomes was based primarily on performance of the projects; neither the traditional course nor the dual enrollment course included tests or exams. High school juniors and seniors could participate in ENED 1020, depending on the circumstances at each participating high school. ENED 1020 was not a pre-requisite for ENED 1090, but if both were offered in a high school, ENED 1020 was always taken first.

ENED 1090 Engineering Models I was a course designed to develop good problem-solving techniques and to illustrate how engineers use mathematics to solve a variety of practical and often complex problems. The course required application of fundamental theory from algebra, trigonometry, and calculus to relevant engineering applications chosen from a variety of disciplines. MATLAB® was introduced and progressively developed as a programming tool to enable students to explore engineering concepts, to investigate solutions to problems too complex for hand solutions, and to develop an appreciation of the power and limitations of computer tools. Special attention was given to graphical visualization of concepts and to numerical approximation techniques and the errors associated with approximations. The course included a multi-week design project with students working in teams and presenting their solutions to other student teams. Assessment of learning outcomes included traditional homework assignments, a midterm and final exam. Dual enrollment students took the same midterm and final exam as traditional students. ENED 1090 was available to high school seniors.

The college convened regular meetings with teachers from the participating high schools. These meetings helped to develop a community of practice among the participants and were a significant means of support from CEAS to the high schools. Participants shared issues, lessons learned and best practices for implementation of projects. These meetings helped to develop relationships between the college and high schools and resulted in increased interaction among all participants. The meetings also facilitated discussions on student and teacher satisfaction and ideas for improving implementation of the courses.

Establishing a Research Foundation

The college's experience with dual enrollment courses provides an opportunity to begin to assess certain research questions related to the efficacy of these programs. In particular:

1. Do students who take dual enrollment engineering courses in high school do as well as traditional engineering students in these courses?
2. Do students who take dual enrollment engineering courses in high school and then matriculate into an engineering degree program perform as well in follow-on courses as traditional engineering students?
3. Do students who take dual enrollment engineering courses in high school perform as well during their first year in college as traditional engineering students (those who do not take dual enrollment engineering courses)?

Dual Enrollment Data and Evaluation

Participation

The College of Engineering and Applied Science began offering high school engineering courses in the fall of 2007 and dual enrollment courses in the 2012-2013 academic year. The enrollment in the dual enrollment courses (number of students in each course and total) is shown in Table 1 along with the total number of schools participating in dual enrollment. In each school, a sub-set of the total number of students participating in the high school engineering course enrolled in the college course for dual enrollment credit. The total number of students (dual enrollment and high school credit only) increased from just over 500 in 2012 to over 700 in 2017. Some schools chose to offer only ENED 1020 and not both courses. Because ENED 1020 provided an introduction to engineering fields while ENED 1090 provided applications of mathematics to engineering, high schools concluded that ENED 1090 would be of interest to fewer students. There was a significant increase in participation in ENED 1090 in 2017-18 because a specific high school joined the collaboration and promoted both courses among the student body.

Because of the interest in dual enrolment, the results of this study are important for understanding if dual enrollment courses provide appropriate and adequate preparation for students who matriculate into engineering programs.

Table 2 shows the number of students who participated in dual enrollment courses and then matriculated to a degree program at UC's College of Engineering & Applied Science. For purposes of this benchmark study, minority is equivalent to non-Caucasian. Incomplete information was available to add greater specificity to minority designations.

	AY 12-13	AY 13-14	AY 14-15	AY 15-16	AY 16-17	AY 17-18
Schools	11	11	12	12	17	19
ENED 1020	119	169	176	192	243	250
ENED 1090	23	29	39	61	58	136
Total Students	142	198	215	253	301	386

Table 1. Participation in Dual Enrollment

Started Fall of	Total	% Female	% Minority
2013	30	23%	7%
2014	91	14%	7%
2015	48	23%	10%
2016	81	32%	9%
2017	99	24%	16%

Table 2. Students Matriculating into UC Programs

Student Academic Performance

Table 3 lists the average grade obtained for ENED 1020 for students who took ENED 1020 as a dual enrollment course in high school, then matriculated into a UC program. The grades are listed by the term the students matriculated into a UC engineering degree program. For example, the data for fall of 2015 might include students who took dual enrollment ENED 1020 in the fall of 2012, 2013 or 2014 then matriculated in 2015. The data is presented in this way so that the grades could be compared with the cohort of students who matriculated that same academic year. Also shown are the average grades for students who took ENED 1020 at UC for that same fall. The total number of students does not include students who withdrew from the course. Grades are based on a 4.0 scale.

Table 4 lists the average grade obtained for ENED 1090 for students who took it as a dual enrollment course in high school, then matriculated into a UC program. As with Table 3, the grades are listed by the term the students matriculated into a UC program. Also shown are the average grades for students who took ENED 1090 at UC for that same fall. The total number of students does not include students who withdrew from the course.

Research Question 1

Research question 1, "Do students who take dual enrollment engineering courses in high school do as well as traditional engineering students in these courses?" can be answered using the data in Tables 3 and 4. An independent samples t-test was performed comparing the average grades of high school students with the average grades of college students for the same courses taken in the different settings. Given that this is a benchmark study, an α=.05 was deemed sufficient. The assumption is made that the two groups are both normally distributed but with unequal variance. The null hypothesis is accepted if the averages are shown to be equivalent (H_0: HS Avg = UC Avg) while the alternative is accepted if the averages are shown not to be equal (H_1:HS Avg $\neq$ UC Avg).

The effect size was also calculated for each set of data. Because the differences in sample sizes are large, the Hedges g, also known as the corrected effect size, was used (NIST, 2018). NIST recommends 0.2 as a small effect while 0.5 indicates a medium effect. Table 5 shows the t-test results for ENED 1020.

For all years, for both ENED 1020 and 1090, the high school students' performance in the course was statistically equal to, or greater than, the performance of traditional college students for that same year.

For ENED 1020, the data for 2013 and 2014 suggest that the average grades are not equivalent (H1 is true): 2013 $t(1121)=2.32$, $p=.02$ and 2014 $t(1283)=3.13$, $p=.002$; both with moderate effect sizes ($.2<g<.5$). The statistics for years 2015-2017 suggest that grades

	ENED 1020 through dual enrollment		ENED 1020 at UC	
Fall of	Avg. Grade	n	Avg. Grade	n
2013	3.88	27	3.73	1096
2014	3.84	83	3.69	1202
2015	3.67	44	3.75	1208
2016	3.74	73	3.72	1373
2017	3.77	89	3.71	1253

Table 3 Average Grades for ENED 1020

	ENED 1090 through dual enrollment		ENED 1090 at UC	
Fall of	Avg. Grade	n	Avg. Grade	n
2013	3.50	4	3.16	1108
2014	3.50	18	3.23	1234
2015	3.47	15	3.27	1232
2016	3.59	23	3.12	1372
2017	3.42	36	3.09	1300

Table 4. Average Grades for ENED 1090

Fall of	HS Avg	UC Avg	t	df	p	Hedges g
2013	3.88	3.73	2.32	1121	0.02	0.21
2014	3.84	3.69	3.12	1283	0.0017	0.20
2015	3.67	3.75	1.19	1250	0.23	0.11
2016	3.74	3.72	0.37	1444	0.71	0.025
2017	3.77	3.71	1.36	1330	0.17	0.13

Table 5. Comparison of Means for Performance in ENED 1020

Fall of	HS Avg	UC Avg	t	df	p	Hedges g
2013	3.50	3.16	-	-	-	-
2014	3.50	3.23	2.42	1250	0.016	0.28
2015	3.47	3.27	1.00	1245	0.32	0.21
2016	3.59	3.12	4.37	1393	1.35E-05	0.48
2017	3.42	3.09	3.14	1334	0.0018	0.33

Table 6. Comparison of Means for Performance in ENED 1090

are equivalent (H0 is true). For ENED 1090, the statistics were not calculated for 2013 since the population size of the high school students was so small. For the remaining years, there were statistically significant differences in the means for 2014 ($t(1250)=2.42$, $p=.016$), 2016 ($t(1393)=4.37$, $p<.001$), and 2017 ($t(1334)=3.14$, $p=.0018$) and no significant difference for 2015 ($t(1245)=1.00$, $p=.32$). The effect size is moderate for all years.

Research Question 2

For most undergraduate degree programs in CEAS, students are required to take a two-course sequence in Engineering Models, ENED 1090 and ENED 1091. ENED 1091 is not available as a dual enrollment course. There is a group of students then who completed ENED 1090 in high school as a dual enrollment course and then took ENED 1091 at UC. Table 7 lists, by year, the average grades obtained in ENED 1091 for students who took ENED 1090 in high school and then took ENED 1091 at UC in a particular academic year. Also shown are the average grades for all students who took ENED 1091 in the spring of that academic year (the normal term for students to take 1091). The number of students does not include students who withdrew from the course. The data is listed by year of matriculation into a degree program. Students who matriculated in fall of 2013 most likely enrolled in ENED 1091 in spring of 2014. The grades listed are for the spring term of the students' freshmen year.

An independent samples t-test was performed to compare the average grades of students in the common course (ENED 1091) who took the pre-requisite course (ENED 1090) in the different settings. Given that this is a benchmark study, an $\alpha=.05$ was deemed sufficient.

Table 8 provides the results of the t-test analysis and an analysis of the effect size using the Hedges g metric.

The data in Table 8 allows us to address research question 2, "Do students who take dual enrollment engineering courses in high school and then matriculate into an engineering degree program perform as well in follow-on courses as traditional engineering students?" The data in Table 8 indicate that students perform as well in follow on courses whether they took a pre-requisite course in high school or college. Statistics were not calculated for 2013 or 2015 because of the small number of high school students in the population but the remaining years we accept that the averages are equivalent (H_0). The effect size is small for all years.

Research Question 3

Table 9 provides another indication of the academic performance of students who participated in dual enrollment courses. The table lists the average GPA at the end of the first fall term of study for students who took an engineering dual enrollment course and then matriculated into the college of engineering during a particular

Students started Fall of	Students who took 1090 in high school		All students who took 1091	
	Avg. Grade in 1091	n	Avg. Grade in 1091	n
2013	2.66	2	3.10	673
2014	3.26	13	3.30	846
2015	3.19	9	3.25	1025
2016	3.40	16	3.28	1005
2017	3.25	25	3.35	1082

Table 7. Average Grades for ENED 1091

Fall of	HS Avg	UC Avg	t	df	p	Hedges g
2013	2.66	3.10	-	-	-	-
2014	3.26	3.30	0.16	857	0.87	0.042
2015	3.19	3.25	-	-	-	-
2016	3.41	3.28	0.48	1019	0.63	0.14
2017	3.28	3.35	0.45	1105	0.65	0.078

Table 8. Comparison of Means for Performance in ENED 1091

Students started Fall of	Students who took dual enrollment		All students	
Fall of	Avg. GPA	n	Avg. GPA	n
2013	2.60	24	2.91	965
2014	2.79	68	3.00	1071
2015	2.69	28	2.99	1048
2016	2.87	44	3.00	1223
2017	2.80	52	3.07	1159

Table 9. First Semester GPA

Fall of	HS Avg	All Students	t	df	p	Hedges g
2013	2.60	2.91	1.79	987	0.074	0.38
2014	2.79	3.00	1.83	1137	0.068	0.26
2015	2.69	2.99	1.57	1074	0.12	0.39
2016	2.87	3.00	0.89	1265	0.37	0.16
2017	2.80	3.07	2.26	1209	0.024	0.34

Table 10. Comparison of First Fall Term GPA

academic term. The table also provides the average fall term GPA for all freshmen who matriculated into the college that same academic term.

An independent samples t-test was performed to compare the average first semester GPA of students who had participated in dual enrollment courses (HS Avg) to the average first semester GPA of all freshman students (All Students) for a particular academic year. Given that this is a benchmark study, an α=.05 was deemed sufficient. Table 8 provides the results of the t-test analysis and an analysis of the effect size using the Hedges g metric.

The data in Table 10 allows us to address research question 3, "Do students who take dual enrollment engineering courses in high school perform as well during their first year in college as traditional engineering students (those who do not take dual enrollment engineering courses)?" The data in Table 10 indicates that for 2017 there was a statistically significant difference between the average fall GPA of students who participated in dual enrollment courses and the average fall GPA for all first year students (t(1209)=2.26, p=.024). For fall 2017, the performance of students who participated in dual enrollment was lower than for all first year students. All other years we accept the GPAs are equivalent (H_0). The effect size is moderate for all years.

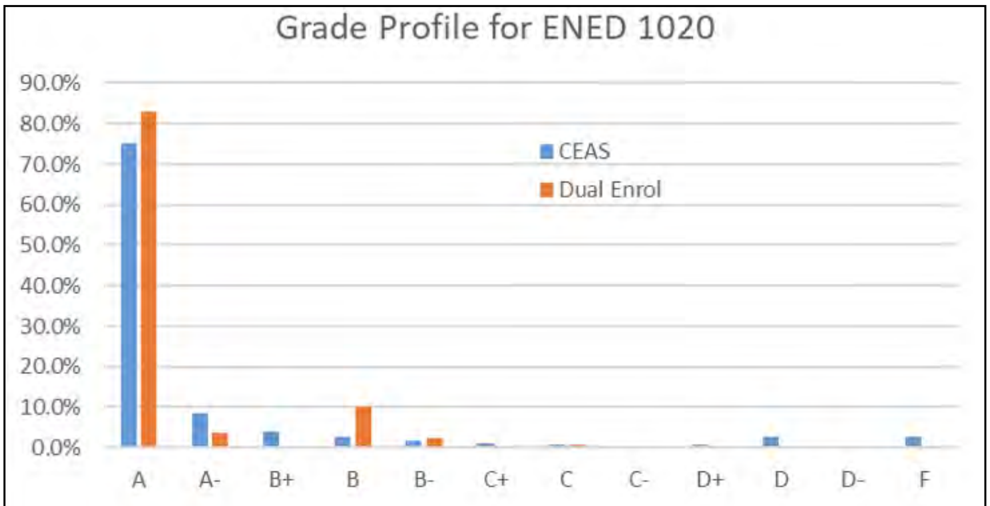

Figure 1. Grade Distributions for ENED 1020 Fall 2016

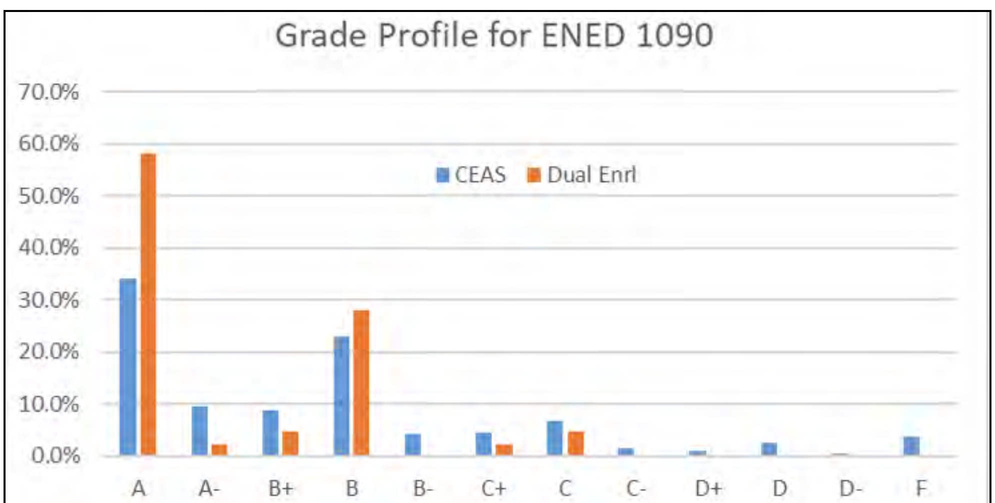

Figure 2. Grade Distribution for ENED 1090 Fall 2016

Discussion

The college and the collaborating high schools began this collaboration in order to provide opportunities for high school students to better understand the practice of engineering with the goal that more students would choose to pursue engineering in college and for their careers. As schools in the region learned of the initiative, more sought to provide the opportunity to their students and enrollments have grown. When a dual enrollment pathway became available in 2012, the interest among regional high schools to offer the program accelerated. The data presented illustrates that providing the opportunity resulted in many students participating in engineering courses while in high school, with many earning college credit for engineering coursework.

It can be instructive to examine grade distributions of students to help understand if courses in the high schools are achieving the same results as the comparable course in the college setting. Figure 1 shows the grade distribution for students who took ENED 1020 during one year of the study, fall of 2016. Data in Table 5 indicate the average grades of high school students are statistically equivalent to the average grades for college students in that course during that year.

Figure 2 shows the grade distribution for students who took ENED 1090 that same academic year. Data in Table 6 on the other hand, indicate the grades are not statistically equivalent between high school students and CEAS students for that course in that year. The figures provide a means of visualizing these conclusions.

Based on the data in Tables 5 and 6, this benchmark study concludes that high school students who took engineering courses in a high school setting through dual enrollment do as well as college students who take the same course in the traditional college setting. The answer to research question 1 is "yes", at least for this set of courses and the cohorts of students included in this study. These findings are consistent with other similar studies (Andrews, 2004 and Hanson, 2001) but specifically for engineering courses. Recognizing that different colleges of engineering will have varying expectations and learning outcomes for first-year courses, it is important to not infer that this finding will extend to all situations. The data in those two tables suggest that high school students' average grades are equal to or better than the average grades for college students and that the effect size is moderate. In this benchmark study, we do not explore the causes for this difference, though several factors could be at work, including:

- Students who elect to take dual enrollment courses in high school might be academically more qualified than traditional students who matriculate to an undergraduate engineering program

- Characteristics of the high school setting result in better student performance

The more significant finding relates to the performance of high school students who took engineering courses through dual enrollment and then matriculated into an engineering program. One of the common concerns regarding dual enrollment is that the courses do not prepare students as well as the same course taken in the college setting. So if the answer to research question 2 is "no", then we could conclude that the high school courses do not prepare students adequately. For each year where sufficient participation occurred, the data in Table 8 indicate that the students who took the dual enrollment courses do as well in follow-on courses as students who took the prerequisite courses in college. This study concludes that the dual enrollment courses offered did adequately prepare students to perform well in the courses that follow for UC engineering students.

When comparing first term grade point averages (Tables 9 and 10) a somewhat different picture emerges. While the differences are not statistically different except for 2017, the average first term GPA for students who participated in dual enrollment courses is lower than the average first term GPA for all students. The answer to research question 3 appears to be "no." This result is not consistent with findings reported by An (2013), Jones (2014) or Crouse and Allen (2014). These researchers report first year GPA rather than first term GPA so a more consistent analysis is needed before reaching definitive conclusions regarding this research question.

The college and participating high schools met routinely as a community of practice. One of the purposes of this community was to evaluate satisfaction with the program and improve practices. Several items of significance to this paper include:

- Students participating in the high school engineering courses have high interest in pursuing a STEM discipline in college.
- In looking at pre and post course attitudes, participation in the high school engineering course has a slight negative effect on interest in pursuing engineering in college, as students better understand the rigor of the discipline.
- Students who are reticent about learning through non-traditional means come to appreciate a project-based approach to learning.
- The initial offering of the course required significant work for the teachers to implement the project-based approach. However, teachers subsequently applied the project-based approach from the engineering course to other courses they taught.

Conclusions

This study illustrates that dual enrollment courses in engineering topics are popular with students and high schools and the interest in these is likely to increase. Students who participated in dual enrollment engineering courses performed as well as their counterparts who took the same courses as a matriculated college student. Students who took an engineering pre-requisite course in high school are as well prepared as students who took the pre-requisite course as a college student.

Well-constructed and implemented dual enrollment courses can have positive outcomes for students, high schools and colleges. These courses are effective at providing high school students better understanding of engineering as a discipline and as a career. They may also be one mechanism to improve the preparation of students who matriculate into engineering programs.

References

Allen, D. and Dadger, M. (2012). Does Dual Enrollment Increase Students' Success in College? Evidence from a Quasi-Experimental Analysis of Dual Enrollment in New York City. *New Directions for Higher Education.* 11-19.

Allen, D. (2010). Dual Enrollment: A Comprehensive Literature Review and Bibliography. *City University of New York. Available* at https://www.cuny.edu/academics/evaluation/library/DE_LitReview_August2010.pdf.

An, B. (2013). The Influence of Dual Enrollment on Academic Performance and College Readiness: Differences by Socioeconomic Status. *Re High Educ*. 54: 407-432. https://doi.org/10.1007/s11162-012-9278-z.

Andrews, H. (2001). The Dual-Credit Explosion at Illinois' Community Colleges. *Community College Journal.* 71(3), 12-16.

Andrews, H. (2004). Dual Credit Research Outcomes for Students. *Community College Journal of Research and Practice.* 28(5), 415-422.

Bailey, T., Hughes, k. and Karp M. (2002). What Role Can Dual Enrollment Programs Play in Easing the Transition Between High School and Postsecondary Education? Paper prepared for the Office of Vocational and Adult Education, U.S. Department of Education. Community College Research Center and Institute on Education and the Economy. Columbia University.

Cassidy, L., Keating, K. and Young V. (2010). Dual Enrollment: Lessons Learned on School-Level Implementation. *SRI International*. https://www.sri.com/work/publications/dual-enrollment-lessons-learned-school-level-implementation

Crouse, J. and Allen, J. (2014). College Course Grades for Dual Enrollment Students. *Community College Journal of Research and Practice* 38(6). https://doi.org/10.1080/10668926.2011.567168.

Flores, A. (2013). Dual Enrollment Programs: A Comparative Study of High School Students' College Academic Achievement at Different Settings. EdD Diss. Texas A&M University – Corpus Christi.

Gross, N. (2016). Two Places at Once: The Growth of Dual Enrollment. Education Writers Association. Accessed June 8, 2018. https://www.ewa.org/blog-higher-ed-beat/two-places-once-growth-dual-enrollment.

Hanson, S. (2001). Running Start: 2000-01 Annual Progress Report. Olympia, WA: State Progress Report. Available at https://eric.ed.gov/?id=ED466246.

Hebert, L. (2001). A Comparison of Learning Outcomes for Dual-Enrollment Mathematics Students Taught by High School Teachers Versus College Faculty. *Community College Review* 29(3).

Hoffman, N., Vargas J., and Santos, J. (2008). On Ramp to College: A State Policymaker's Guide to Dual Enrollment. Jobs for the Future. Boston, MA.

Howley, A., Howley, M., Howley, C., and Duncan T. (2013). Early College and Dual Enrollment Challenges: Inroads and Impediments to Access. *Journal of Advanced Academics* 24(2): 77-107. https://doi.org/10.177/1932202X13476289.

Hughes, T. (2016). The Impact of High School Dual Enrollment Participation on Bachelor's Degree Attainment and Time and Cost to Degree. PhD diss., Old Dominion University. http://digitalcommons.odu.edu/efl_etds/27.

Hughes, K., Karp, M., Bunting, D., and Friedel, J. (2005). Dual Enrollment/Dual Credit: It's Role in Career Pathways. In *Career Pathways: The Next Generation of Tech Prep.* 227-255. Available at https://ccrc.tc.columbia.edu/publications/dual-enrollment-career-pathways.html.

Johnson, T. and Borphy, M. (2006). Dual Enrollment: Measuring Factors for *Rural High School Student Participation. Rural Educator.* 28(1), 25-32.

Jones, S. (2014). Student Participation in Dual Enrollment and College Success. *Community College Journal of Research and Practice* 38(1). https://doi.org/10.1080/10668926.2010.532449.

Kanny, M. (2014). Forks in the Pathway? Mapping the Conditional Effects of Gender, First-Generation Status, and Pre-college Academic Achievement in the Impact of Dual Enrollment Course Participation on First-Year Student Engagement and Grades in College. PhD diss. Available at https://escholarship.org/uc/item/43q1t1bp.

Karp, M., Calcagno, J., Hughes, K., Jeong, D., and Bailey, T. (2007). The Postsecondary Achievement of Participants in Dual Enrollment: An Analysis of Student Outcomes in Two States. Community College Research Center, Teachers College, Columbia University. Available at https://files.eric.ed.gov/fulltext/ED498661.pdf.

Kim, J. and Bragg, D. (2008). "The Impact of Dual and Articulated Credit on College Readiness and Retention in Four Community Colleges. *Career and Technical Education Research* 33(2), 133-158.

Larrick, T. (2012). Dual Enrollment: A STEM / Engineering Initiative. ASQ Advancing the STEM Agenda in Education, the Workplace and Society. Session 1-4. Available at http://rube.asq.org/edu/2012/06/career-development/dual-enrollment-a-stem-engineering-initiative.pdf

NIST. 2018. Hedges g. Accessed October 1, 2018. Available at https://www.itl.nist.gov/div898/software/dataplot/refman2/auxillar/hedgeg.htm.

Puyear, D., Thor, L., and Mills, K. (2001). Concurrent Enrollment in Arizona: Encouraging Success in High School. *New Directions for Community Colleges*. 33-41.

Rogers, J., Rogers, A. and Baygents, J. (2017). Impact of Dual Credit Introduction to Engineering Course on Female High School Students' Self-Efficacy and Decisions to Follow a Career in Engineering. *Proceeedings of the American Society for Engineering Education*.

Rogers, J., Vezino, B., Baygents, J., and Goldberg, J. (2014). ENGR 102 for High School: An Introduction to Engineering, AP type course taught in high schools by high school teachers. *Proceedings of the 121st ASEE Annual Conference and Exposition*. Indianapolis, IN.

Rutz, E, Lein, B., Shafer, M., and Brickner, S. (2008). Accessible STEM Education. (2008). *Proceedings of the ASEE Annual Conference and Exposition*. Pittsburgh, PA

Swanson, J. (2008). An Analysis of the Impact of High School Dual Enrollment Course Participation on Post-Secondary Academic Success, Persistence, and Degree Completion. PhD diss. The University of Iowa.

Thomas, N., Marken, S., Gray, L., and Lewis, L. (2013). Dual Credit and Exam-Based Courses in U.S. Public High Schools: 2010-11. NCES 2013-001. US Department of Education. Washington, DC: National Center for Education Statistics.

Waits, T., Setzer, J., and Lewis, L. (2005). Dual Credit and Exam-Based Courses in U.S. Public High Schools: 2002–03. NCES 2005-009. U.S. Department of Education. Washington, DC: National Center for Education Statistics.

Zinth, J. (2014). CTE Dual Enrollment: A Strategy for College Completion and Workforce Investment. Education Commission of the States. Accessed June 8, 2018. https://careertech.org/resource/cte-dual-enrollment-strategy

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