ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36686

Development of a High School Engineering Pathways Program (Work in Progress, Diversity)

Rick Hill (Assistant Dean for Research & External Initiatives)

Dr. Richard Hill is a Professor and Assistant Dean in the College of Engineering & Science at University of Detroit Mercy. Dr. Hill received a B.S. degree in Mechanical Engineering from the University of Southern California in 1998, and an M.S. degree in Mechanical Engineering from the University of California, Berkeley in 2000. He joined the faculty of Detroit Mercy in 2008 after receiving a Ph.D. degree in Mechanical Engineering and an M.S. degree in Applied Mathematics from the University of Michigan, Ann Arbor. His research interests lie in the areas of vehicle control, the formal synthesis of discrete control logic, and modular and hierarchical control. Dr. Hill also has a strong interest in diversifying the STEM pipeline and leads the innovating Detroit's Robotics Agile Workforce (iDRAW) program in partnership with underserved Detroit-area high schools.

Jocelyn Maria Bennett Garraway (Associate Professor & Director, School Counseling)

Development of a High School Engineering Pathways Program (Work in Progress, Diversity)

Richard Hill[1] and Jocelyn Bennett-Garraway[2]
[1]Department of Mechanical Engineering and [2]Department of Counseling and Addiction Studies
University of Detroit Mercy

Abstract

This paper describes the development of an engineering pathways program for underserved high school students. The **innovating Detroit's Robotics Agile Workforce (iDRAW) program** is administered by the University of Detroit Mercy and is in its third year of working with two local high schools. The students are predominantly low-income and from populations historically underrepresented in STEM. The goal of the program is to increase interest in STEM-related careers while reducing barriers to entering such fields. The program aims to provide on-ramps to a range of careers across disciplines (mechanical, electrical, software, etc.) requiring different levels of educational attainment (4-yr university, 2-yr college, apprenticeships, etc.). In the first two years of the program, there were 97 qualifying graduates with nearly half going on to study a STEM discipline in college and over a quarter choosing to major in engineering or computer science at a 4-year university. Of the qualifying graduates, 55% were Latinx, 5% were Black, and 37% were Arab American. Preliminary data shows the program correlated with a modest increase in STEM career interest and students perceived the program to help them prepare for their future, though the program might not have had a positive impact on student self-efficacy in STEM.

Keywords

broadening participation, engineering education, high school

Introduction

It is well established that the domestic need for a qualified, technical workforce is increasingly important, and increasingly unmet. This need is especially acute in the greater Detroit area with its historical reliance on the automotive and manufacturing industries. Such need provides an imperative to improve pathways for our nation's youth to enter STEM fields. This is true, in particular, for students from groups historically underrepresented in STEM professions. As of 2017, only 4.1% of engineering bachelor's degree in the U.S. were awarded to Black students and only 11.1% to Hispanic students [1]. Since 14.5% of the undergraduate college population in 2017 was Black and 19.4% was Hispanic according to U.S. Census data [2], it is apparent that significant disparities exist.

This paper describes the development of the **innovating Detroit's Robotics Agile Workforce (iDRAW) program**, an engineering pathways program for underserved high school students

whose goal is to broaden participation in engineering and technology-related careers, led by the University of Detroit Mercy. This goal is hardly unique, yet similar efforts have historically been impeded by a number of issues: students have a perceived lack of interest in engineering, students lack the pre-requisite academic skills to succeed in engineering, high school teachers lack the skills and confidence to teach engineering, and teaching engineering can be expensive and material intensive. Many of these obstacles are particularly challenging in school districts attended by large numbers of students historically underrepresented in STEM. These districts often lack resources and teachers additionally feel pressure to focus on core academic subjects and standardized tests.

A two-week summer camp or a one-semester elective course cannot remedy the substantial challenges facing these students. Consequently, this comprehensive program seeks to engage with students over multiple years to address a range of barriers. The program has many facets and leverages an invested consortium of partners including educational institutions, community organizations, and local industry to increase access to these fulfilling and well-compensated careers. The program seeks to connect to the students through their interests, backgrounds, and experiences, while increasing their academic preparation. This is achieved through (1) technical dual enrollment courses taught within the high schools by existing teachers and (2) extracurricular and summer experiences. The high school teachers are developed through summer training and a unique model where a University of Detroit Mercy instructor co-teaches with the high school teacher for one year.

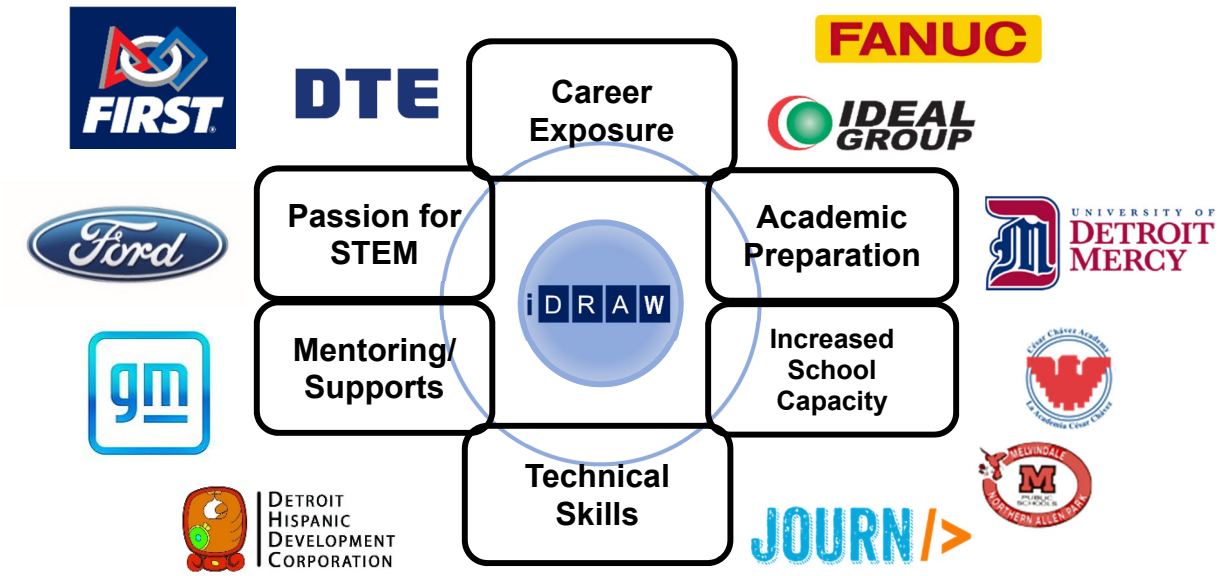

Figure 1 Graphic of the iDRAW program ecosystem

The program is in its third year of working closely with two local high schools, Melvindale High School and Cesar Chavez Academy High School. In this time, 246 unique high school students

have earned college credit. While the COVID-19 pandemic has severely impacted the program's launch, there have been significant successes and important lessons learned to guide the improvement of the program in the future that will be detailed in this paper.

Research questions

The overall purpose of this study is to determine if there is a relationship between continual participation of underserved high school students in engineering dual enrollment courses and STEM co-curricular activities with student STEM self-efficacy, career interest, and post-secondary destinations. The following research questions encapsulate our investigation:

1) Does participation in engineering dual enrollment courses have significant impact on underserved high school students' STEM self-efficacy and career interest?
2) Is there a correlation between the degree of participation of underserved high school students in engineering dual enrollment courses and STEM co-curricular activities with application to and admissions into post-secondary STEM education and career programs?

Cultivating student interest

Low-income and underrepresented students in the local area face a range of barriers that can inhibit their ability to enter STEM fields. Foremost among these limitations are: a lack of exposure to STEM careers, that students may think that science and engineering isn't interesting or fun, or that the students think they don't have the capacity to be successful in STEM [3]. Research shows this to be especially true for women and underrepresented minority students that typically do not have as many role models [3] [4].

One of our primary approaches to cultivating student interest is by connecting the material to the students' interests and backgrounds. The IDRAW program is centered thematically around robotics. This was done because robotics is attractive to many students, but also because it is a broad field that touches on many disciplines and has many applications. The program has leveraged existing extracurricular initiatives at the schools and activities that have significant investment from some of our local partners. The FIRST Robotics Competition (FRC)[1], in particular, was chosen as a cornerstone because it is exciting to students and because it had significant financial and volunteer support in place. Our program tries to recruit students from these programs, while encouraging our students to participate in the extracurricular programs as well. This includes connecting our students to different summer camps and other out-of-school enrichment activities. Our region includes many such opportunities that we can readily leverage.

In addition to exciting students through the science and technology, we also seek to demonstrate to the students how STEM connects to their backgrounds and how these technical skills can help their communities. This approach is still in its formative stages, but will leverage the work of [5] [6] [7] on culturally-relevant computing, and through implementation of more applied projects that connect to the community.

[1] https://www.firstinspires.org/robotics/frc

Another approach is to demonstrate the career opportunities available in STEM. This is especially important since the students may have little connection to professionals in these fields through their families and communities. Connections between the dual enrollment course content and different career paths are threaded throughout the curriculum. Furthermore, the courses integrate periodic guest professionals. These external speakers share how they use the content the students are learning in their everyday jobs, but more importantly, the guests share information about their path into their field. A concerted effort is made to find speakers of diverse backgrounds, including those who share similarities with the students they are speaking with. The program also aims to include industrial field trips. This aspect has been impeded by the COVID-19 pandemic, though physical visits have been successfully supplemented with virtual fieldtrips.

Building on the career education the students receive in the classroom, the iDRAW program also seeks to connect participating students to summer work experiences. We have been fortunate to have committed industrial and community partners with the ability to hire high school students for paid summer internships as part of our consortium. These partners include Ford, FANUC, DTE Energy, and JOURNi. In the summer of 2021, 13 current or just graduated high school students were hired, as well as four program graduates who had just finished their first year of college. Some of the positions allow the students to apply technical skills they have learned in the program, such as computer programming, but all provide the students exposure to a professional work environment and help the students to develop their identity as a professional. These experiences are especially valuable for underrepresented students who have little exposure to such environments from parents and relatives, or from within their communities. The experience of performing a job and observing professionals who look like them and come from similar backgrounds as them can help an underrepresented student build confidence leading them to envision themselves in such a role while motivating them to work through barriers to reach such positions [8].

In addition to exposing students to careers, the iDRAW program also seeks to provide more immediate pathways into post-secondary education. This is also achieved through guest speakers and field trips, as well as through one-on-one assistance with college advising, applications, and financial aid. The confidence the students develop through their success in college-level dual enrollment coursework can help students feel more prepared to pursue post-secondary educational opportunities. The program also employs current college students as teaching assistants in the dual enrollment courses, providing near-peer role models to help the students to see themselves in the next stage of their academic path.

Some students have a natural interest in technology and gravitate to participating in the program, though we still need to rely on counselors and school teachers to help with recruitment. The goal is to attract students who may not have considered a career in STEM to become involved as well. Currently, the Detroit Mercy co-instructor embedded in the high schools visits other academic courses to market the program, but also to lead lessons where academic learning outcomes are taught through engineering applications. A goal is to develop high school teachers to integrate such lessons into their courses independently. The college credit and bump in GPA scale of the courses commensurate with other honors and AP courses have also attracted some more academically-inclined students to enroll in the courses. As the benefits of the program become more widely known, it is hoped that word-of-mouth will help to drive enrollment.

Curriculum

Part of the impetus for the development of this program was the observation of our partners that our efforts with extracurricular programming, such as FRC and summer camps, were successful in getting students excited about engineering and technology, but did not necessarily prepare the students to be successful in pursuing STEM careers. For the two high schools we have worked with in our pilot, only 9.3% of students at one school and 16.3% at the other met College Readiness Benchmarks based on SAT scores during the 2018-2019 academic year (pre-pandemic). Furthermore, only 27.5% and 30.6% of the respective schools' graduates enrolled in a 4-year college or university within one year of graduation [9].

These observations motivated the development and launch of a series of three year-long dual enrollment courses. These courses teach technical skills such as programming, electronics, mechanisms, and computer aid design (CAD), but also help to prepare the students for the academic rigors of a range of post-secondary educational opportunities. The courses aim to prepare students for careers across different domains (software, electrical, mechanical, etc.), as well as for careers requiring different levels of educational attainment from skilled trades and information technology (IT), to jobs as technicians or engineers. A basic understanding of electricity and circuits is valuable to an electrician as well as to an electrical engineer.

The dual enrollment courses further seek to scaffold the students' academic preparation by integrating assignments and content related to what they are learning in their math, science, and language arts classes. The engineering applications can help motivate the students to learn the academic content, while the inquiry-based nature of the curriculum can help provide insight. We have observed many existing technical elective courses offered in high schools to follow a model of project-based "doing" rather than project-based "learning." The students follow a series of steps laid out in a manual and produce a cool project, but they don't necessarily understand what they have done and wouldn't necessarily be able to apply those skills in a different context. It is the aim that the projects in our courses provide students the opportunity to learn the underlying theory, while also practicing high-order skills such as problem solving and design.

There is a range of quality engineering curriculum available that is appropriate for high school students. Our goal was not to re-invent the wheel, but rather to leverage curriculum used in existing Detroit mercy courses with other materials to produce organized, coherent courses aligned with recognized standards that could be replicated across different high schools in a sustainable manner. To the extent possible, we designed our courses to use curriculum that was free and that required low-cost materials and freely available software. This stands in contrast to some other high school engineering programs, such as Project Lead the Way (PLTW) [10], that require schools to pay for curriculum year after year.

In each of the three years of the program's existence, a new dual enrollment course was launched. It is the intent that each course could be taken independently without one course standing as a pre-requisite for another. So far, it has been common for students to enroll in these courses as early as their sophomore year, though we could envision advanced freshman also being successful. Each semester of a class has the potential to earn a student one college credit. The following discussion describes the details of the courses.

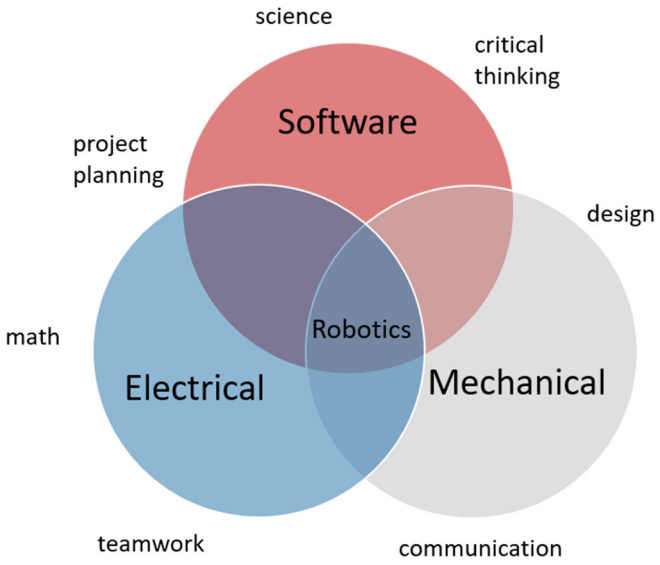

Figure 2 Illustration of program curriculum technical domain areas and related skills

Introduction to Computer Science Principles – This course aligns with the Advanced Placement Computer Science Principles (AP CSP) exam and employs curriculum from Code.org [11]. This approach was chosen because of the quality of the curriculum, its consistency with the overall goals of our program, and its ease of implementation. The AP CSP course is a good entry point for students without any programming background and provides exposure to concepts relevant to a broad range of careers including everything from IT support technician to electrical engineer to software developer. Students learn about topics such as how information is encoded and transmitted, the structure of the internet, as well as basic programming concepts. The course also involves reading comprehension and writing, thereby supporting students' language arts development. Part of the curriculum examines the societal impact and ethical considerations of technology. This aspect of the course provides the opportunity to connect to issues facing the students' communities, while the project-based nature of the course allows students to envision applications that could help their communities. Typically, this course would qualify for elective credit, but would not replace the first programming course required in computer science and engineering degree programs. The curriculum from Code.org[2] is free and web-based, such that the students don't need expensive computers or specialized software. For example, the course can be run very well using just Chromebooks.

Introduction to Engineering Design and CAD – One semester of this course corresponds to a one-credit class at Detroit Mercy (ENGR 1020) required of engineering students that teaches students how to read and create standard engineering drawings, including orthographic projection, dimensioning, and pictorials. Such courses are common to engineering programs. In this particular course, the students learn how to use the 3-D modeling software SolidWorks. This aligns with what is taught at Detroit Mercy, is commonly used in industry, and can lead to certifications such as the Certified SolidWorks Associate credential. A drawback is that the

[2] https://code.org/educate/csp

software is not free and requires computers with a certain level of performance[3]. In this case, the high school students in the dual enrollment course could use the university's site license, though the course also could be taught with free web-based software, such as Onshape. The other semester of the course complements the CAD instruction with additional content on design, material science, and the manufacturing of engineered products. These topics serve to increase the students' interest, broaden their exposure, and provide opportunities to support their academic development. For example, the students get to learn about the innovative field of additive manufacturing in an academically meaningful way, while using 3-D printers to bring some of their CAD designs to life. The course leverages curriculum from the ASM Materials Education Foundation[4] to teach the students about material science, selection, and testing. This content helps reinforce and build upon learning outcomes from the students' chemistry and physical science courses, as well as allowing them to apply concepts from their math courses.

Introduction to Mechatronic Systems – Mechatronics combines traditional fields of mechanical engineering, electrical engineering, robotics, and control systems. In this course, students learn about the elements of mechatronic systems and develop their own intelligent projects. This includes learning the basics of electricity and electronic circuits, as well as how to transmit and convert forces and motion by mechanisms and other means. Students learn how to program microcontrollers to interface with the physical world through different sensors and actuators (motors). One semester of this course corresponds to a required one-credit engineering course at Detroit Mercy (ENGR 1023) that introduces students to computing and engineering through the use of technology to solve applied problems. The dual-enrollment course spreads this content out and provides additional scaffolding. The curriculum of this course also aligns with the Mechatronics Career and Technical Education (CTE) standards of the State of Michigan, which can open up additional sources of funding for the high schools. Many similar high school courses employ off-the-shelf kits from different providers such as Lego and Vex. We have developed our own curricular kits employing the Arduino Uno and standard electrical components in order to keep costs down, avoid obsolesce, keep the underlying technology from being hidden from the students, and to allow students to apply the technology to open-ended projects. Mathematics topics from geometry, algebra, and pre-calculus supplement the mechatronics content to reinforce the students' mathematical foundation and are taught in part through use of the computing software MATLAB.

While each of the dual enrollment courses can be taken independently, the Mechatronics course does touch on concepts introduced in the other two courses. Furthermore, the Mechatronics course requires Algebra II to be at least a co-requisite because of some of the math instruction integrated into the course. In this manner, it is the most advanced of the three courses.

Capacity building

The development and launch of the iDRAW program has been supported by a substantial three-year Marshall Plan for Talent grant from the State of Michigan. The goal of the work is to build the capacity of the high schools and the teachers to sustain the program with minimal support after the conclusion of the grant. Several challenges can exist that can inhibit the ability of a

[3] https://www.solidworks.com/support/system-requirements
[4] https://www.asmfoundation.org/teachers/resources/

school to offer high-quality instruction on topics related to engineering and technology. These include that high school teachers are typically trained in traditional academic disciplines such as math, science, or language arts, and don't have a background in engineering or computer science. Another challenge is that the day-to-day demands of teaching, lesson-planning, and grading allow teachers very little time to create (and learn) entirely new courses. These challenges can be especially burdensome at under-resourced schools.

Some other programs, such as PLTW [10] and Code.org [11], employ one to two weeks of training in the summer to prepare high school teachers to teach new curriculum. In our program, we offer a similar level of professional development during the summer, but then additionally provide a Detroit Mercy co-instructor for the entire first year the course is taught. This level of support provides in-depth training from a subject matter expert over an extended period, while relieving the teacher of some of their teaching duties so that they have the space to learn the material at a deeper level themselves. A program that also employs a co-teaching model that helped to inspire our approach is the Informatics Diversity-Enhanced Workforce (iDEW) program founded in 2015 at Indiana University-Purdue University Indianapolis (IUPUI)[5].

This added level of support, in addition to the stipend provided by the grant, has enabled the program to recruit veteran teachers to take on these added duties. In each of the three years of the grant, two new teachers have been trained (one at each school) to offer a new technical elective. Of the four teachers trained the past two years, three have been able to continue successfully teaching their courses with minimal support. One teacher struggled with the material and ultimately left the high school where they were teaching. In our third year, the two new high school teachers have done very well with the training and we fully expect them to be successful going forward. The following figure summarizes the rollout of the three dual enrollment courses.

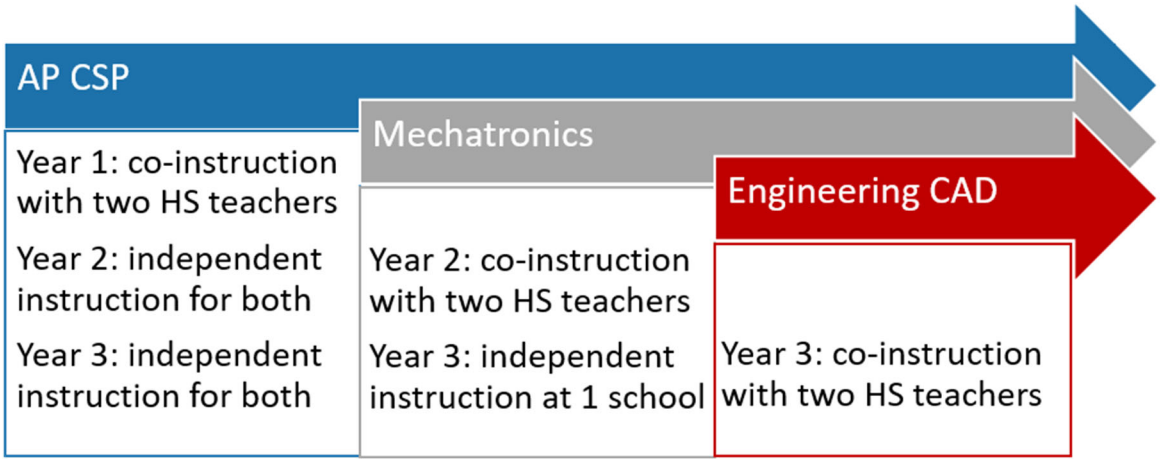

Figure 3 Dual enrollment course roll out

Our experience has demonstrated that the high school teachers don't need any specialized background related to engineering or computer science to be successful. If a teacher is able and willing to learn new content and has some facility with technology, using computers and software programs, etc., we believe they can develop into quality program instructors. Of the six

[5] https://soic.iupui.edu/idew/

teachers that have participated in our program, four are primarily science teachers and two are primarily liberal arts teachers. Three of the six had taught a technical elective previously, including the one teacher who did not remain in the program. A surprising find through our work has been the ease of leveraging the technical experience of teachers from their prior careers, including one who worked as a petroleum engineer, and one who worked in the automotive parts design industry.

In order to be able to continue to offer college credit for the courses without the university instructor present, we have required that the high school teacher have a master's degree. We have accepted an advanced degree in education or education technology. Between the master's degree and the specialized training the teachers receive, we have been able to qualify the teachers to be adjunct instructors of Detroit Mercy.

Outcomes

As this is a new program model, we have continually evaluated the iDRAW program and sought to adjust its implementation to improve student outcomes. The impact of the COVID-19 pandemic has complicated the program's development, but we have been able to identify significant successes and look forward to continued improvements.

During the first two and half years of the program, 246 unique students have earned 443 college credits. The following table summarizes the level of participation in the program.

Table 1 Summary student enrollment data

	Students beginning Semester 1	Semester 1 credits earned	Students beginning Semester 2	Semester 2 credits earned	Semester 1 → Semester 2 retention
Year 1	80	70	72	53	90%
Year 2	131	115	93	84	71%
Year 3	118	121	102	In progress	86%

In the first year of the program, four sections of AP CSP were offered using the co-instruction model, two sections at each high school. The drop in the number of earned credits between semester 1 and semester 2 from 70 to 53 during the first year is largely attributed to the onset of the COVID-19 pandemic. Students were given the option to switch the course grading option to pass/fail, but many students were struggling with personal challenges related to demands of supporting their families including having to work paid jobs and take care of younger siblings, in addition to issues with technology and adjusting to remote and asynchronous instruction. In the face of these challenges, some students chose to drop elective courses, such as this one, and focus on their core academic courses required for graduation.

The second year of the program saw the addition of the dual enrollment Mechatronics course, while the AP CSP course was taught independently by the two high school teachers trained during the first year. Two sections of AP CSP were offered, as well as three sections of Mechatronics. The added course helped to grow the number of students enrolled in the program, including six students who took both courses, and 12 students who returned from the first year. This year saw considerably higher rates of attrition. We attribute the poor 71% retention rate in part due to pandemic and the fact that both high schools remained virtual the entire year. Both schools observed decreases in student performance across the curriculum. We also observed that there were some challenges in the enrollment process due to changes in schedules and difficulties with communication that led to some mismatch between the courses and the students who enrolled.

The enrollment process for the third year addressed some of the deficiencies from the previous year. This led to a little more selectivity and a decrease in the total number of students enrolled, even with the addition of the third dual enrollment course. However, the number of students taking multiple courses rose to 19 and the number of students returning from a previous year increased to 29. Two sections each of AP CSP and Engineering CAD were offered, in addition to three sections of Mechatronics. The improved enrollment process combined with the fact that the first semester of the third year was taught almost entirely in person, we believe, has contributed to the increase in the rate of retention to 86%.

An advantage of employing an Advanced Placement curriculum for our computer science course is that it provides an objective benchmark to measure student performance against. During the first year of the program when the course was co-taught with a university instructor, the students performed well as compared to Michigan and global averages. Of the 43 students that submitted full AP portfolios that year, 33 received a passing grade (3 or higher). This pass rate of 77% exceeded the Michigan average of 74% and the global average of 72%, which is encouraging considering the performance of other underserved schools. That year, the overall pass rate was 52% for Black students and 61% for Hispanic students, as compared to 72% and 83% for white and Asian students, respectively [12]. Of all the Hispanic students who passed the AP CSP exam in the state of Michigan that year, 21% were students in our program. We anticipate that more of our students would have completed the AP Exam if not for the onset of the COVID-19 pandemic. In addition to the high pass rates, the average scores were also strong. Our students had an average score of 3.30, compared to 3.17 and 3.09 for Michigan and overall, respectively.

In the second year of the program, AP exam participation and scores were significantly worse. Only 22 of 45 eligible students took the exam and only 8 students passed the exam for a pass rate of 36%. There are likely multiple contributing factors to this decrease in performance, foremost among them being that the entire academic year was remote at both schools with significantly reduced amounts of synchronous instruction. Other factors include that the high school teachers taught the course independently, that there were changes to the exam from the previous year, and that the students taking the course were diluted by the addition of the dual enrollment Mechatronics course as an option. Overall, the students taking AP CSP in the second year were younger than the students in the first year since more senior students ended up taking the Mechatronics course. Student academic performance will continue to be examined as the high schools return to in-person instruction.

Research Question 1 - Does participation in engineering dual enrollment courses have significant impact on underserved high school students' STEM self-efficacy and career interest?

We have assessed this research question based on results of student surveys given at the beginning and end of the 2020-2021 academic year. Looking at STEM self-efficacy, we consider the students' academic confidence as well as their efficacy related to STEM skills and knowledge, specifically. Comparing responses only for the 80 students that completed both the pre- and post-survey, we found some interesting results. The survey employed a Likert scale employing the responses: strongly disagree, disagree, neutral, agree, and strongly agree, corresponding to numerical values from 1 to 5.

Somewhat surprisingly, the evidence does not show an improvement in the students' STEM self-efficacy from the beginning of the school year to the end. In response to the statement, "*I would do well if I were to get a job in a STEM-related field*," the average response decreased from 3.64 at the beginning of the year to 3.49 at the end of the year, with 23 students seeing a decrease in their response compared to 16 students who had an increase. For the related statement, "*I am academically prepared to complete STEM coursework at a college or university*," a similar trend was exhibited. The average student response decreased from 3.65 to 3.56 over the course of the year, with 22 students showing a decrease as compared to 17 students with an increase.

One possible explanation for the decrease is the challenge of being in a pandemic and taking rigorous, hands-on courses remotely for the entire year. Another hypothesis is that the students were more confident in their STEM skills at the beginning of the year because they had not taken a rigorous technical or engineering-related course in the past. Looking at the data though, the eight students we have surveys for that took the dual enrollment AP CSP course the year previous also did not show an increase in average response to these two questions.

Despite the lack of gains in student self-efficacy, there did seem to be positive impact from participation in the dual enrollment courses in terms of the students' perception of the impact of the courses and in career interest. In response to the retrospective statement on the end-of-course survey, "*My iDRAW course(s) have helped prepare me for college*," the average student response was 3.87, where 4 corresponds to *Agree* and 3 to *Neutral*. The students' average response to the statement, "*My iDRAW course(s) have increased my interest in a STEM career*," was 3.6, which also indicates a modest positive impact. Comparing the pre- and post-survey responses to the related statement, "*I know of some STEM-related career options that I am interested in,"* the average student rating increased from 3.44 to 3.66.

Research Question 2 - Is there a correlation between the degree of participation of underserved high school students in engineering dual enrollment courses and STEM co-curricular activities with application to and admissions into post-secondary STEM education and career programs?

To examine this research question, we looked only at graduates who "completed" a dual enrollment course. Since there were a significant number of students during the 2019-2020 school year that withdrew at the end of their course because of the onset of the pandemic, we counted those students who earned credit during the first semester as having "completed" the course. Otherwise, a student needed to pass two semesters of dual enrollment courses to be counted. According to these conditions, the program has graduated 97 students during its first

two years of existence. Within this group, 55% are Latinx, 37% are Arab American, 5% are Black, and 3% have some other classification.

Examining the impact of the dual enrollment experience, 45% of the graduates went onto pursue a STEM-related career path following high school graduation. This includes 27% who matriculated to a 4-year university to study engineering or computer science. Of the 10 students who completed two dual enrollment courses, 80% went onto study a STEM discipline at a 4-year university, while 60% enrolled in a computer science or engineering discipline, specifically. These populations are small, and the data is somewhat clouded by the impact of the COVID-19 pandemic, but the results indicate a promising correlation between program participation and pursuit of STEM career paths.

Looking at the program graduates who additionally participated in a STEM-related co-curricular activity, such as a competitive engineering design team, club, summer camp, or internship experience, there were 47 such students. We did not count internships that occurred the summer following graduation, though going through the hiring process and being selected could in of itself be impactful for the students. Of these students, 57% pursued a STEM opportunity post-graduation, while 34% matriculated to a 4-year university to study engineering or computer science. This data demonstrates the addition of participation in a co-curricular activity further increased the likelihood that a student would pursue a STEM career path. This correlation increases further for students that participated in more than one qualifying activity. Of the 13 such students, 69% chose to pursue a STEM career path, while 54% went on to study engineering or computer science at a university.

Overall, we find this data quite promising in indicating the program's potential to increase underserved students' likelihood to pursue a STEM degree in college, in general, and to enroll in engineering and computer science programs, in particular. Based on data from the 2015-2016 academic year, only 18% of awarded bachelor's degrees were in STEM, with rates even lower for African American (12%) and Hispanic students (15%) [13].

While many program graduates have gone on to STEM degree programs at universities, very few students have chosen to pursue alternative post-secondary opportunities such as trade schools, apprenticeship programs, boot camps, and non-credit bearing certifications. Specifically, only one student enrolled in a trade school. Four students matriculated to 2-year community colleges in a STEM field, but all plan to transfer to a 4-year university, rather than finish with a terminal associates degree as a technician, or equivalent profession. We maintain that STEM-related post-secondary opportunities besides attending a 4-year university would benefit a significant portion of the students in our program. We hypothesize that we need to present these options to the students more often and starting earlier in the students' high school careers. So much of the information the students receive and the infrastructure in place in the high schools steer students toward attending college that it may be difficult to get a student to consider other options once they reach their senior year of high school. Anecdotally, we have followed up with a few program graduates who ultimately did not attend college, or who dropped out of college, and they seem more receptive to hear about these alternatives than they did when they were in high school.

Conclusions and future work

In the first two and half years of our high school STEM pathways program pilot, we have demonstrated promising results in spite of the challenges presented by the COVID-19 pandemic. Based on student surveys from the 2020-2021 academic year, participation in the dual enrollment courses and co-curricular activities of the iDRAW program has demonstrated a positive impact on STEM career interest and students' perception of impact of the program on their preparation for college and a potential career in a STEM-related field. Somewhat surprisingly, these surveys did not show an increase in student STEM self-efficacy. This needs to be investigated further and possibly reflects the impact of the pandemic and the fact that the courses were taught remotely for the entire year.

The potential of the iDRAW program to impact student career choices is further demonstrated by the fact that nearly half of program graduates have chosen to pursue a STEM-related degree program following graduation and over a quarter have specifically matriculated to an engineering or computer science degree program at a 4-year university. An area of improvement for the program would be to increase the rate at which students pursue alternative educational pathways, such as trade schools and apprenticeship programs.

Going forward, we will continue to support the two high schools we have been working with, Melvindale High School and Cesar Chavez Academy High School. Specifically, we can assist the teachers with any curricular questions, as well as with any issues regarding equipment and software. We will continue to help teachers find guest speakers, fieldtrip opportunities, and will connect students to external opportunities offered by our partner organizations. Moreover, we will help continue to develop school culture outside of our individual program classrooms by efforts to train counselors and to work with the schools' administrations to create plans to develop career and technical education across their districts.

In fall 2022, we will employ new grant funding under the CSforAll program of the National Science Foundation to grow the program to three new high schools. Specifically, we will work with two Detroit Public School Community District high schools, Martin Luther King Jr. High School and East English Village Preparatory Academy, as well as nearby Hamtramck High School. Some key characteristics that we have identified for a successful partner include: willing high school teachers, a committed administration with identified liaison, a sufficiently large student body, and some demonstrated academic success and commitment to STEM. The school personnel are necessary to sustain the program once the grant funding steps down, not only to teach the courses, but also to navigate the internal bureaucracy of the schools. This includes scheduling courses, recruiting students, helping with equipment and software needs, arranging fieldtrips, bringing in external speakers, etc. In terms of the student body, we need at least 30 students with the interest and academic preparation to fill each of the three dual enrollment courses on a yearly basis. This amounts to approximately 90 students across 10^{th}, 11^{th}, and 12^{th} grade each year. This level of commitment is achievable for many under-resourced schools in the Detroit region and nationally. We look forward to continuing to build on the successes that the program has achieved so far.

Acknowledgements

This work was supported in part by a Marshall Plan for Talent grant from the State of Michigan, as well as funding from the Ford STEAM organization. Special thanks goes to Dr. Andrew Lapetina and Ms. Joy Mohammed for their contributions to the implementation of the program and survey administration and data collection.

References

[1] J. Roy, "Engineering by the numbers," American Society for Engineering Education, 2018.

[2] U.S. Census, "Current Population Survey, School Enrollment Supplement, October 2007 and 2017," 2018.

[3] J. Morales-Chicas, M. Castillo, I. Bernal, P. Ramos and B. L. Guzman, "Computing with relevance and purpose: A review of culturally relevant education in computing," *International Journal of Multicultural Education,* vol. 21, pp. 125-155, 2019.

[4] C. Lancaster and J. X. Yonghon, "Challenges and supports for African American STEM student persistence: A case study at a racially diverse four-year institution," *The Journal of Negro Education,* vol. 86, no. 2, pp. 176-189, 2017.

[5] M. Lachney, "Culturally responsive computing as brokerage: Toward asset building with education-based social movements.," *Learning, media and technology,* vol. 42, no. 4, pp. 420-439, 2017.

[6] R. Eglash, W. B. A. Babbitt, K. Bennett, B. Callahan, J. Davis, J. Drazan, C. Hathaway, D. Hughes, M. Krishnamoorthy and M. Lachney, "Culturally Situated Design Tools: Generative justice as a foundation for STEM diversity," in *Moving students of color from consumers to producers of technology*, IGI Global, 2017, pp. 132-151.

[7] M. Lachney, A. Bennett, R. Eglash, A. Yadav and S. Moudgalya, "Teaching in an open village: a case study on culturally responsive computing in compulsory education," *Computer Science Education,* pp. 1-27, 2021.

[8] L. Tsui, "Effective strategies to increase diversity in STEM fields: A review of the research literature," *The Journal of Negro Education,* vol. 76, no. 4, pp. 555-581, 2007.

[9] MI School Data, "Michigan's Official Education Data Source," [Online]. Available: mischooldata.org. [Accessed 31 January 2022].

[10] R. H. Tai, "An examination of the research literature on Project Lead the Way," PLTW, 2012.

[11] H. Partovi, "A comprehensive effort to expand access and diversity in computer science," *ACM Inroads,* vol. 6, no. 3, pp. 67-72, 2015.

[12] B. Ericson, "A Deeper Look at Women of Color (Black, Hispanic/Latinx, and Native American) and AP CS in 2020," 2020. [Online]. Available: https://cs4all.home.blog. [Accessed 31 January 2022].

[13] C. de Brey, L. Musu, J. McFarland, S. Wilkinson-Flicker, M. Diliberti, A. Zhang, C. Branstetter and X. Wang, "Status and Trends in the Education of Racial and Ethnic Groups 2018," National Center for Education Statistics, 2019.

[14] K. A. Scott and M. A. White, "Compugirls' standpoint: Culturally responsive computing and its effect on girls of color," *Urban Education,* vol. 48, no. 5, pp. 657-681, 2013.

[15] Community for Advancing Discovery Research in Education, "STEM Smart Brief: Preparing and supporting STEM educators," National Science Foundation, 2012.