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Implementation of a "Near-Peer" Mentoring Program between a High School Technology Class and a University Senior Design Engineering Class

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Abstract

Near-peer mentoring has been shown to result in improvements in student academic engagement and achievement in STEM fields due to the synergy between mentors and mentees. This paper discusses the elements of a program established between Independence High school (IHS) students in San Jose, CA and San Jose State University (SJSU) Mechanical Engineering students to expand hands-on education and to encourage a STEM pathway for technical education of both the IHS and SJSU students. This paper outlines an informal program where technically inclined high school students who are drawn to automotive technology work with SJSU seniors working on their senior design projects to design, build and test a mechanical device, tool, or machine having a useful purpose. This is the fourth year of collaboration, which focuses on automotive and transportation technology. Although numbers are too small for formal assessment, experience has shown that numerous high school students have applied to schools of higher education, and several have specifically enrolled in SJSU. Additionally, the SJSU students have benefitted from the direct hands-on help building their projects and the opportunity to teach younger students.

Introduction

High school students who are approaching graduation are often confused by the overwhelming number of job/career options facing them, or the lack thereof. In many cases, the option chosen is based on their limited life experiences from family, friends, school, teenage activities, and society. Assistance should be offered at all education levels to help students with career exposure, exploration, and career.

This paper outlies an informal program where technically inclined high school students who are drawn to automotive technology can work with SJSU Mechanical Engineering seniors to design, build and test a mechanical device, tool, or machine having a useful purpose. At the university, senior-level students must complete a two-semester team-based senior design project. In the fall, university students work on project definition and design optimization, and the spring is devoted to construction and testing. Students typically work in teams of five or six students. Over the past four years, high school students enrolled in automotive technology courses have partnered with senior design teams, becoming involved particularly in the areas of construction and testing. The IHS Automotive Technology class has been consistently heavily enrolled and currently has 240 students per semester made up of six classes per day, two educators, and 20 students per class. The curriculum covers automotive maintenance and learning of the principles of operation of electrical and mechanical components and systems. Since the high school students are enrolled in automotive technology courses, all projects are related to the transportation industry. This collaboration has demonstrated that through the informal voluntary nature of the mentor to mentee relationship, a natural organic learning takes place.

Near-peer mentoring is characterized by the pairing of individuals who are slightly further along in education or training with those who are less advanced. Research shows that near-peer mentorship relationships between college and middle/high school students help motivate students to continue on to post-high school education [1]. In fact, such relationships have benefits both for mentees, who experience improved retention and student learning, and mentors, who develop increased confidence, communication skills, and enthusiasm for higher-level learning [1]. Because of these benefits, in 2014 First Lady Michelle Obama established a “Near-Peer Mentoring Challenge”, with the goal of increasing the number of near-peer mentoring relationships between university and high school students [2].

The high school involved, Independence High School in San Jose, CA, is a diverse high school with 97% minority students (including 60% Asian and 34% Hispanic). Only 41% score as proficient in mathematics, and about half qualify for reduced-price or free lunches. Their 86% graduation rate is slightly above the state average. The ethnic breakdown of the students at SJSU is relatively comparable with 82.9% minority students (including 41.9% Asian and 27.5% Hispanic).

Motivation and Background Literature

What is mentoring? Mentoring, in terms of the subject program, is the act of providing guidance and friendship to a student who could benefit from having a role model for education, career choices, and coaching. Mentoring in general is proven to help others reach goals, improve self- esteem and achieve their potential in life.

It has been observed that students are attracted to the IHS Auto Technology elective class for various reasons; however, the following two categories stand out:

1) Vocationally oriented students to learn a valuable trade. Auto technology has traditionally had an image of low-tech vocational jobs; however, modern vehicles have systems and components that are designed, tested, and maintained using advanced technical methods covered in BS and MS programs at universities.

2) STEM oriented students who have an interest in applied sciences and specifically in automotive applications of electronics, computers, or mechanical devices. IHS offers AP classes in physics and other technical subjects. Some AP students have been encouraged by curriculum counselors to consider the auto technology classes, with the objective of applying STEM class principles on real-world applications.

This program was conceived because many students are motivated when they can see, touch, and make something in the physical world as compared to just seeing or hearing about it. Building a physical product in a project structure gives a goal and purpose to their activity.

Anderson et al. [3] cite numerous references establishing the benefits of experiential learning, which is described as a combination of concrete experience, reflective observation, abstract conceptualization and active experimentation.

Near-peer mentoring has been applied successfully for a variety of goals. For example, Edgcomb, et al. [4] describe summer research programs where undergraduate near-peer mentors are able to work with high school students and K-12 faculty. McGlynn [5] discusses how near-peer mentors can help students who are first in their families to navigate the college admissions process and motivate them to apply. Baker et al. [6] describe clubs focusing on practical STEM applications, particularly related to the transportation industry, that are run by STEM teachers and college-level peer mentors. And Walter and Verner [7] describe a small program where 12th grade students mentor small groups of 9th and 11th graders in technical drawing, CAD, and 3D printing.

Wilson and Grigorian [8] summarize the statistical evaluation of a program in Texas in 2017 whereby college mathematics students worked with high school students to put on a MathShow and make classroom presentations to high school classes on mathematics topics. There were 360 students involved who took surveys before and after the MathShow which showed an approximate 4% to 5% increase in interest in pursuing higher education after high school. In addition, there were several anecdotal stories showing the benefits to both the high school and college students. The paper focused on an important factor related to educational and career choices in STEM, namely, attitudes toward mathematics and changes in those attitudes as a result of the mathematics outreach. The near-peer mentoring cycle was depicted in Figure 1 as shown below:

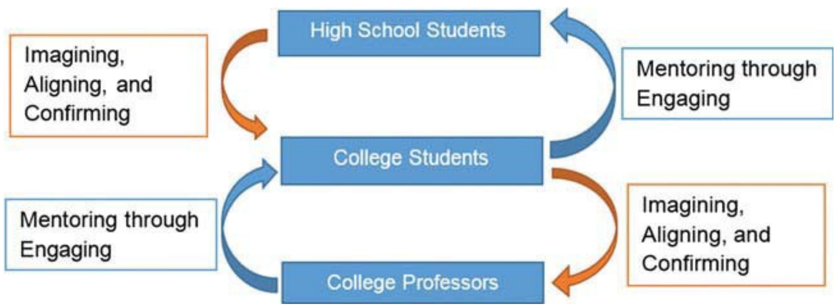

Figure 1 Near Peer Mentoring Cycle [8]

Tenenbaum et al. [9] describe a program in which undergraduates or post-baccalaeueates complete a research internship during the semester at Walter Reed Army Institute of Research or a related university lab and then can apply for a summer teaching internship. For the teaching internship, they instruct middle and high school students in science education outreach programs. Both the mentors and middle and high school students are from communities with limited resources. The mentors reported that involvement in this program helped their professional growth and maturity. The students reported that they were able to develop a rapport with their mentors that they typically could not with teachers.

Pluth et al. [10] describe a program where students in grades 6-12 come to a university campus for hands-on laboratory science activities. High school volunteers and graduate students assist with middle school labs, and graduate and undergraduate students work on outreach events, such as campus tours. A few high school students are also able to engage in experiments in research labs. To improve program sustainability, middle school students are groomed to be future high school volunteers. Assessment results show that the program helps young students envision the pathway to university and careers in the sciences.

Objective

The objective of this partnership has been for university students to gain communication and leadership skills, along with excitement for transportation careers, and for high school students to envision a pathway to higher education in technical fields. Many students who enroll in the technical education courses at high school are from lower incomes and/or have no parent who attended college [11]. It was a hope that the near-peer mentors, many of whom have similar backgrounds to the high school students, could show these students a greater range of opportunities after graduation.

This paper was written primarily to share the near-peer experience with other high schools and local universities to publicize the idea and potentially lead to funding to support the program.

Implementation Process

The primary element is for the mentor and mentee students to work together building and testing the senior project prototype and final design product. The implementation process is most successful when the SJSU students have taken the initiative to regularly contact the IHS educator to arrange meetings with his students. All meetings have been held at IHS; however, we have discussed inviting the mentees to SJSU for the engineering open house or a campus tour. During the spring semester when fabrication is underway, the SJSU and IHS students have met every Friday afternoon and after school. Strict safety protocols were in place, and all work was done under the close supervision of the high school teacher who monitored student safety. During the construction process, the mentoring process sometimes went both ways. For example, the auto technology curriculum includes a session on welding. Where the project has a need for welding, the high school students have taught the university students the basics of welding.

A secondary element of the program which facilitates engagement between mentors and mentees is for the SJSU ME students to make periodic intuitive lectures to the high school class on topics such as strength of materials, machine design, mechatronics, and electrical systems. These lectures are made to the whole class, rather than to individual teams. The class educator has seen that the high school students pay attention in class when the mentoring students are presenting.

Several times during the semester, both the SJSU and IHS educators observe the technical presentations and participate in design review sessions. During the Spring 2020 semester, a productive design session was held which greatly improved the design and lowered the cost with beneficial input from both SJSU and IHS students.

Implementation of the program is most successful when the SJSU students are naturally motivated to interact and share experiences with the mentees, such as a natural interest in teaching. The major factor for success is to have one or more SJSU students join the team who have this initial interest. It would be beneficial during the initial meetings to describe the near-peer program and encourage those who have this interest to join the team. The major practice to avoid is procrastination during any phase of the project. The schedule requires completion of the product by the end of the spring semester, which is a firm date. Each sequential phase of the project impacts the completion date, so project management by the SJSU students is essential.

The near-peer program implements the steps tabulated in Table 1.

Development of Project Ideas

Project ideas are developed by the SJSU advisor and IHS educator which meet the following criteria:

1. Practical device or machine serving a useful function to schools, community, businesses
2. Requires applying engineering course material
3. Related to auto or transportation technology
4. Challenging within minimal budget and a two semester schedule
5. Topic that will excite both auto tech high-school and four-year university students

Projects are discussed below. Some photos of students are shown in Figure 2.

- 2017/18: A near-peer team designed and built a weld tensile tester using two 20 ton hydraulic jacks to pull-test a weld sample. High school challenged each other in class to see who had the strongest weld. The SJSU students discussed strength of materials and enjoyed the opportunity to try welding.
- 2018/19: Two student teams partnered with the Valley Transportation Authority (VTA) to address two labor intensive bus maintenance issues applicable to more than 200 transit buses. With the help of IHS students, the SJSU students designed, built, and tested prototypes, including material fabrication, assembly and testing in both IHS and SJSU shops.
    - Team 1: Students completed an automated machine to clean the wheels/rims from busses when tires are removed and changed. The rims were rotated, brushes applied, and cleaning solvent sprayed. VTA expects to install the machine in the maintenance shop resulting in labor savings.
    - Team 2: Students completed a device to measure the brake pad thickness on the outer and inner pads to avoid removal of the wheels and brake components to manually measure the pad thicknesses. Again, reducing labor costs will result.
- 2019/20: This year two teams are partnering with a Lexus dealership on two projects:
    - Team 1: Students are designing an apparatus to lift and remove a 200-pound high voltage battery from Lexus hybrid vehicles. The removal requires lifting vertically, tilting and withdrawing from the mid-vehicle location and is designed around a four-bar linkage mechanism. Electric actuators are used to

Table 1: Program timing and elements

Timing	University	High-school	Success Metric
Prior to start of fall semester	Identify senior project advisor interested in implementing program	Identify class and educator interested in participating in program	Obtain buy-in from enthusiastic advisor and educator
Prior to start of fall semester	Brainstorm several project ideas through contacts and individual interests. Obtain an outside sponsor to give more credibility to the projects. Prioritize each project idea.		Propose interesting projects with related sponsors
First week of fall semester	Present project ideas to senior class and promote the values of joining the project team.	Speak in general about pathway for students interested in mechanical systems.	Attract 4 to 6 engineering students per team
First month of fall semester	Team develops product specifications through interviews with the sponsor.	Describe the near-peer program to class	Measurable project specifications developed
First two months of fall semester	Project team prepares and makes classroom presentation to high-school class about mechanical principles applicable to the project.	Students engage with the SJSU students during and after presentation and self-select as a team member	Secure enthusiastic high school team members
End of fall semester	Complete product design and plans to build and test prototype. Advisor evaluates team member's performance and issues semester grade.	Critique design and building plans	Complete the prototype design and construction plans; input from high-school students incorporated to benefit project
First month of spring semester	Continue refining design using analysis and testing. Make a second high-school classroom presentation.	Engage in the classroom presentation and become familiar with final product design.	All members able to communicate and explain the design and function of the product.
Second month of spring semester	Identify university and high school student's expertise related to building and testing the product		Determine individual contributions to construction and testing by high school and college students.
One week before end of spring semester	Complete questionnaire on CANVAS regarding "success" of project and recommendations. Obtain information about plans after graduation	Complete questionnaire regarding "success" of project and recommendations. Obtain information about plans after graduation	Obtain positive comments of near-peer program. Post-graduation plans positively affected by program.
End of spring semester	Complete fabrication and testing of product and celebrate completion of successful project.		Satisfy sponsor's expectations of function, cost, and schedule. Each individual has significant, successful contribution.
End of spring semester	Evaluate team members' performance and issue semester grade.	Informally discuss the value of the program with class.	Advisor and educator satisfied with the program

move the mechanism and are operable by one technician versus two technicians currently used, resulting in labor savings.

- Team 2: A student team is designing a work platform for auto technicians to comfortably access the engine compartment or roof mounted components with tools, lighting, and services within arms-reach. Currently, technicians must lean over the engine compartment and often complain of back strain that should be reduced with the work platform. New model trucks and SUVs are significantly higher off the ground and taller than older vehicles making it more awkward to service or repair.

Senior Project Team: IHS and SJSU Students: Testing vehicle on dynamometer:

Figure 2: Photographs of SJSU/IHS student teams

Experience from IHS Students

IHS has existing programs to encourage graduating students to apply and enroll in technical disciplines in higher education. The CTE (Career Technical Education) is made up of STEM Academy, auto technology, and construction disciplines. Since the near-peer program presented in this paper has a similar goal, it is difficult to quantify its efficacy by itself. Unfortunately, we do not have data showing the rates of students who go on for further education for students involved in this program compared to the broader group of students in CTE.

The following positive anecdotal experience is offered from one IHS student. David had a love affair with cars, so when he enrolled at IHS on San Jose's East Side, he went directly to the highly- regarded automotive technology class. In addition to learning about mechanical and electrical components in cars, David participated in a near-peer mentoring program where students from his class worked with SJSU Mechanical Engineering students completing their senior design capstone projects. David was inspired. He applied, was accepted, and enrolled at SJSU. Three students from the Auto Tech program plan in Spring 2020 to pursue engineering at SJSU.

Experience from SJSU Students

SJSU senior design students have participated in this program for four years. They have worked with the high school students in all cases and reported that it is satisfying to help them and promote engineering as a career option. Some feedback received from the SJSU students is that the lectures must not be too detailed or deep because of the knowledge level of the high school students. It is necessary for the presenters to check how the students are receiving the presented material. Generally, more intuitive rather than technical is more successful in holding the high school students' attention. Future work should include developing a questionnaire for both the mentors and mentees to better judge the success of the program.

Conclusions and Recommendations

The near-peer program being implemented by SJSU and IHS has been rewarding and beneficial to all involved. It is an informal program that is easy to implement by the relevant educators having interest and follow-through. Minimal supporting resources are needed since it is within the related curricula. This paper was written primarily to share this simple near-peer experience with other high-schools and local universities with the objective of giving high school students, particularly those from groups typically under-represented in universities or whose parents did not attend college, exposure to engineering students and projects. This exposure provides a fulfilling experience for graduating seniors and potentially results in increased enrollment in engineering at institutions of higher-education.

It is recommended that existing engineering projects classes consider affiliating with a local high school at whatever level of effort is practical for the educators, students, and administrators to implement. Contact between students who are mutually working on a hands-on project will organically lead to this near-peer relationship and hopefully to a pathway from high school to a university and a technical career.

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