The state of high school engineering education; a North and South perspective

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Abstract

High school students have many options to receive engineering education before college. Among the options are nationwide programs like Project Lead the Way, teachers using their own personal engineering curriculum, engineering and robotics competitions, and a student's personal experience. Many students also come to an engineering program with no previous exposure to engineering.

One of the authors recently moved to North Carolina from Michigan to teach at Western Carolina University. This paper will provide an anecdotal perspective of high school engineering education in mid-Michigan and western North Carolina, to discuss the amount and types of training available and the depth of the concepts introduced in the training.

The scope of this paper is high school programs in Michigan and North Carolina. No conclusions will be made regarding the effectiveness of these programs on preparing the students for collegiate engineering success, but current research will be referenced.

Keywords

Engineering education, high school, Project Lead the Way, FIRST Robotics, North Carolina

Many paths to an engineering education before college

Today's students have many avenues for gaining experience in engineering before entering college. Some students are exposed to engineering and technology in the form of working with their parents or relatives on projects. Welding, carpentry, automotive repair, and plumbing can all be functionally learned through exposure.[7,8]

Other students take pre-engineering courses at their high school or through Career Technical Education center. These students can earn college credits and possibly an Associate degree through the training received. A separate branch of engineering education is through STEM competitions. This paper will focus on FIRST Robotics but several additional competitions exist with an eye on inspiring students to become engineering college students. Experience in engineering can have two benefits, the first that students can be more successful in an engineering program at the college or university level.[15,16] The other benefit is students being prepared to enter the workforce as engineers.

Because of the authors' experience with mid-Michigan and western North Carolina, these two regions are the focus of this paper. For the purposes of this paper mid-Michigan is defined as Flint, Michigan and the immediate schools in a 50 mile radius. Western North Carolina will be

defined as Asheville area schools and then everything to the west of I-26 south of Asheville and west of US Route 25 north of Asheville.

When the Michigan Department of Technology, Management and Budget published its report *Michigan's Hot 50 – Job Report through 2028* five different engineering disciplines were highlighted with a projected growth rate from 2018-2028 between 1.0 and 8.6 percent.[14] North Carolina's Department of Commerce published a similar report titled *North Carolina Employment Projections 2018-2028.* The NC report showed an Architecture and Engineering occupational group with a 7.4 percent projected growth between 2018 and 2028.[9]

Gaining engineering experience through Project Lead the Way curriculum

Project Lead the Way Engineering is nationally recognized curriculum built to help students adopt an engineering mindset and work on ideas to solve real world problems.[10] The program focuses on building skills that students can take to an engineering career but also use to help solve problems no matter what career path is taken. PLTW Engineering has ten different year-long pathways that a school can adopt, encompassing introductory engineering courses, manufacturing, programming and sustainability.[13]

Using the PLTW School Search tool and focusing on engineering, four high schools were found to be using the curriculum in western North Carolina. Three of those schools are in Asheville and one is in Hendersonville. A similar search for Michigan schools showed eleven different high schools offering the engineering curriculum in a 20-mile radius of Flint, Michigan.[11] Studies have found that there is not a correlation between students who engage in Project Lead the Way curriculum and students who enter engineering programs in college. However, one study showed that minority male students who were enrolled in at least one year of PLTW curriculum were more likely to persist from freshman to sophomore years than those without the PLTW year.[19]

FIRST Robotics and engineering experience

FIRST (For Inspiration and Recognition of Science and Technology) is a series of programs for students aged 4 thru high school senior. The vision of FIRST is to give students mentor-based competitions that build STEM skills while also gaining self-confidence, communication and leadership skills. FIRST Robotics is the high school competition that runs a different game every year, and encourages a high school to find one or more corporate sponsors with engineers to mentor the students through a build season. Students do not earn college or high school credit for participation in FIRST Robotics.[18] However, the program does have a robust system of awarding scholarships for students to attend college for STEM majors.

A search for FIRST Robotics teams within a 50-mile radius of Cullowhee showed that seven teams are active in western North Carolina. It should be noted that two South Carolina schools also showed up in this twenty mile search but were not counted due to the paper's focus on NC schools. An identical search focused on Flint, Michigan and a 50-mile radius showed 205 different teams in Mid-Michigan.[17] This comparison shows a far greater number of Michigan opportunities for engineering and STEM exposure but some special circumstances apply to the state. At one point Michigan had strong support and funding from the Governor for new and old

teams. Additionally, the FIRST in Michigan organization still works to promote robotics and STEM with a vision of at least one sustainable robotics program in every Michigan school.[3]

Studies have shown that students engaged in after-school robotics activities (including FIRST Robotics) have more interest in STEM concepts, STEM careers, and more understanding of the role of science and technology in their lives.[2]

Technical centers as engineering education institutions

In both Michigan and North Carolina many technical education centers exist with strong Career Technical Education (CTE) programs. These programs, when aligned with a college or university, can give students opportunities to earn college credits or up to an Associate degree. Engineering content might be more focused on a trade skill, such as manufacturing, robotics, or mechatronics.[4,6] In general these tech centers operate at the county level, but some larger schools with more resources can run their own CTE programs.[1,12]

Each center has its own vision for the students who attend; generally a mix of building up the students' skills in STEM concepts and problem solving, and preparing students to enter college with a strong STEM background. Specific programs are often tied to CIP codes to show that the funding and effort used to train the students will relate to a specific occupation as they enter the workforce. Some schools partner with local industry, gaining funding from corporations to teach specific skills that will help the students be successful at those corporations as they enter the workforce.[5]

The full experience of teaching engineering to high school students

Anecdotally, the author's experience teaching engineering concepts to high school students occurred in the 2020-21 academic year. The engineering teacher for Davison High School had a Covid-related issue and the school needed to fill a position quickly. The author committed to a two-month teaching trial that turned into a full semester and later went on to the end of the academic year. The high school used the Project Lead the Way (PLTW) curriculum. Courses taught were Introduction to Engineering Design (IED), Principles of Engineering (POE), and Computer Integrated Manufacturing (CIM.) Project Lead the Way teachers are required to go through 'Core Training' that helps to frame the course and the learning objectives for students. Starting a month into the academic year, however, required the author to join a PDP course where a cohort of new teachers without Core Training all met every other week to talk about their classes. Funding was available for one PLTW PDP course and Introduction to Engineering Design was chosen because that class contained the most students.

Introduction to Engineering Design was a full classroom of students ranging from 9th to 12th grade. The students fell all across the spectrum of engaged learners, some were more than happy to do any assignment with minimal direction and some would do two or three assignments a month and this occurred with me standing over their shoulder. The IED course blended several engineering and design concepts without bias toward any specific industry. The course was split up into four sections: Design and Problem Solving, Assembly Design, Thoughtful Product Design, and Making Things Move. Math concepts up to algebra were present in several sections of

the course. All of the curriculum was inside a PLTW learning management system for the students, and many assignments were multi-day projects with concepts that fit into tiered assignments. Students did not enjoy assignments where they were required to read large blocks of text on their own. Students performed better when the large amounts of self-paced writings were pared down and highlights from each section and task were presented. Students enjoyed CAD modeling over any other skill learned during the class. With this knowledge in hand assignments could be tailored toward multi-day operations where the basic skills and concepts happened one day and the modeling acted almost as a reward the next day. The framework of problem statement, brainstorming, concept sketching and then creating the CAD model was reinforced several times throughout the year.

Principles of Engineering students were in the 11th or 12th grade. These students ranged from highly engaged to highly unmotivated. Concepts of energy, machine systems, fluid power, strength, durability and kinematics were explored with the students. This course mostly revolved around building projects using VEX construction kits and then taking data using sensors. The data could be saved and analyzed. Students liked different parts of this course, some liked programming the machines, some liked building the machines, some liked analyzing the data, and some liked working the equations and analyzing the systems.

Computer Integrated Manufacturing students were the most advanced and consisted of only three students in the 11th and 12th grades. These students were all highly motivated with high aptitude. The CIM students enjoyed all of the projects assigned during the school year and the course focused on g-code programming, CAM software, machining, and building. Several projects were built to fulfill tasks, with a full complement of the design process from requirements to brainstorming to concept selection to CAD design to build. Two of these students also really enjoyed CAD modeling, and would use any free time to create models using Autodesk Inventor software.

Although the author only received PLTW training for the Introduction course the experience of many of the other new instructors was similar. Several instructors from different states and backgrounds were pulled in with short preparation times to teach the course. Although the PLTW curriculum is written for students using Fusion 360, Instructors used different CAD programs including Inventor, SolidWorks, AutoCAD, and OnShape. Other instructors also had the experience that students preferred CAD modeling over most other skills, and students would stick with primarily extrude-revolve type projects if not pushed to use more sophisticated skills. As every educator knows, the last two academic years have been completely unpredictable, and the fact that these students engaged in pandemic learning both online and face-to-face probably taints these observations.

The next steps in understanding high school engineering education effectiveness

The immediate next step in understanding the depth that high school students are receiving from their pre-engineering courses or activities. After working with the university institutional review board a survey will be sent to students in our institution who attended pre-engineering courses in high school, through CTE, Project Lead the Way, or after-school robotics programs. A similar survey will be sent to students at a Michigan college. The survey will seek to understand how effective they feel their training was in preparing them for an undergraduate degree in engineering, and for an engineering position in the field.

One aspect of pre-college engineering training that is hard to quantify is exposure to technology skills from a parent, other relative or workplace. Many teens are able to work on vehicles, conduct home repairs, program drones or remote control vehicles, or even weld at their home or workplace. These practical skills can be more valuable than curriculum work when it comes to taking abstract concepts and applying them to real-world problems. The survey will also try to quantify which students have previously worked on their technology skills on activities at home or in the workplace not associated with classes or STEM competitions. Correlation will be looked at between these students and whether these technology skills transfer to more success in the engineering curriculum, and whether these students perceive their technology skills as relevant to their courses.

Additional research will be done regarding other STEM competition programs beyond FIRST Robotics, and engineering prep curriculum beyond Project Lead the Way.

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Dr. Granda is a Colombian native raised in Puerto Rico and earned his PhD from the University of Tennessee Knoxville in Industrial and Systems Engineering. He is currently a faculty member in the School of Engineering + Technology at Western Carolina University. Nelson has leadership experience working as the U.S. Mid-Atlantic Region Young Professional Chair, and a Board member of the Sustainable Development Division for IISE. Before becoming an assistant professor, Nelson worked for several years in the Eolic and Aerospace industry. Nelson's research interest revolved around Sustainable Development viewed through the lens of the triple

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