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Original Paper

Innovation Teaching in Engineering Program at Nashoba Valley Technical High School

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Abstract

Global consumer electronic device market status and future forecast of growth in 2019-2025 is presented in complete Reuters review (https://www.reuters.com/brandfeatures/venture-capital/article?id=76507). With added commercial electronic products the market will exceed $152 Billions by 2022. The dynamics of electronic industry is incomparable market of chemical products, steel and even automotive. Even more impressive is the dynamics of solar panels manufacturing and installation. Last year solar cells produced about 1% of annual US electricity production. However in 2020 it will be already 2% of electricity produced in US. Availability of educated manpower of all levels from production line operators to technicians testing and installing the hardware and design engineers is the most important factor in existing trends of electronic industry. Only well-educated and inventive technical personnel could participate in design and fabrication of electronic products, which basically are modified or changed every two years. Our study summarizes joint work of University of Massachusetts and Nashoba Valley Technical School in developing innovative skills in high school students, who specialize in electrical engineering.

Keywords

Innovation, education, electrical engineering, technicians

1. Introduction

Consumer electronics include devices used for entertainment such as flat-screen TVs, DVD players, video games, remote control cars, etc., communication telephones, cell phones, e-mail-capable laptops, etc., and home-office activities, e.g., desktop computers, printers, etc. The most illustrative in the customer electronics market is the cell phone products, which change their performance and quality almost every half year. Added to consumer electronics should be market for robotics, collection of solar cells, MEMs and medical health equipment. Electronics device market growth is also characterized by the improving purchasing power of individuals across emerging economies coupled with the growing penetration of energy-efficient appliances.

At 5th Conference on Electronic Market Health (Retrieved from https://www.i-scoop.eu/drivers-spending-industry-4-0-market-2022/) analysis of the total spending predictions we see that the electronic industry market, from the mentioned technology spend perspective, is expected to reach $152.31 Billion by 2022. In 2016 the overall market was valued at 66.67 Billion USD, the press release states. Between 2017 and 2022 the forecasted Compound Annual Growth Rate (CAGR) reaches a double-digit percentage of 14.72%.

The production of electricity in US last year reached a level of 400 terawatt, of which 1% was produced by solar panels. However in 2020 amount of electricity generated by solar panels will double.

More than ever before educational institutions are obligated to equip their students with ability to handle the complexity of electronic products, with capability to improve and modify these products, get used to changes - not only with the products but also with modifications of production technology. In this study will analyze two decades of innovative education of Nashoba Valley Technical School supervised by students and faculty of UMass University in close cooperation with teachers and instructors of high school. We describe the innovative successes of high school students in design of large-scale robots and student interaction with engineers of leading electronic company Raytheon. We recently described (Mil'shtein, 2009; Mil'shtein & Tello, 2018) innovative education of electrical engineering students at UMass, however the methods and introduction to innovation of high school students is very different from what could be done in college environment.

2. Innovation Elements in High School Education

It would be right to start with narrowing the subject of discussion on evoking and educating innovation not of every student in high school, but groups studying engineering in vocational high school. Our innovative education program is precisely targeting students inclined to learn technical disciplines. Clear understanding of basic difference of the goals of professional education in colleges versus education in high school did help us to generate the program of innovative education for high schools. Students accepted for college of engineering already target certain engineering fields, and they are equipped with knowledge of basic science, physics, chemistry, etc. They are focused on in-depth fields of study in electrical engineering, mechanical engineering, civil engineering etc. Students of high school are in the process of acquiring knowledge in basic science. Moreover they often did not selected yet the professional field they will want to work. That basic difference between groups of high school students and attendees of colleges motivated us to create a program is completely different goals for high school students. Engineering colleges are exposed to certain products manufactured by companies (Mil'shtein, 2009), it is very natural for them to attempt to improve the performance of the product, also significant modifications (design of a new product) is usually targeted. Interestingly enough, incomplete basic education of high school students allows them to be more innovative with design novel devices. Practically lack of detailed engineering education makes high school students less enthusiastic if the goal is to improve existing device or system. Quite opposite, they are very enthusiastic participating in design of novel device or programming new machinery. Below we will illustrate teaching of innovation on two examples, program of robotic designs and development of solar/electric vehicles.

3. Engineering Program at Nashoba High Technical School

Nashoba Valley Technical School is a free public high school that focuses on vocational and technical specialties for its students over four years of study. At present, the school offers twenty different programs from culinary arts to advanced manufacturing. Students alternate between academic classes for one full week and their chosen technical area for the following week. Our Engineering and Robotics program, like all at Nashoba, operate one week with students from grades 9 and 11, the other with students from grades 10 and 12. Academic coursework for the engineering students is quite rigorous, and tracks very closely with the engineering courses across their four years. Advanced placement courses in physics, calculus, chemistry, and English language arts are all standard for our engineering student cohorts. After graduation, the majority of our students move on to colleges and universities to pursue additional engineering education.

Careers in engineering are extraordinarily diverse, so course of study while in the engineering and robotics programs cover a variety of engineering fields. The school year is organized into trimesters and each trimester introduces students to a specific field. These skills are documented based on a state mandated framework that specifies minimum requirements (http://www.doe.mass.edu/cte/frameworks/). In their third and fourth years, students have opportunities to expand their knowledge in an area of engineering that is interesting to them via self-selected projects.

Topics by year for Engineering and Robotics students are as follows:

Year 1: Career Exploration; Introduction to Engineering Design

Year 2: Principles of Engineering; Civil Engineering & Architecture; Solid Modeling; Mechatronics

Year 3: Digital Electronics; Computer Integrated Manufacturing; Junior Project

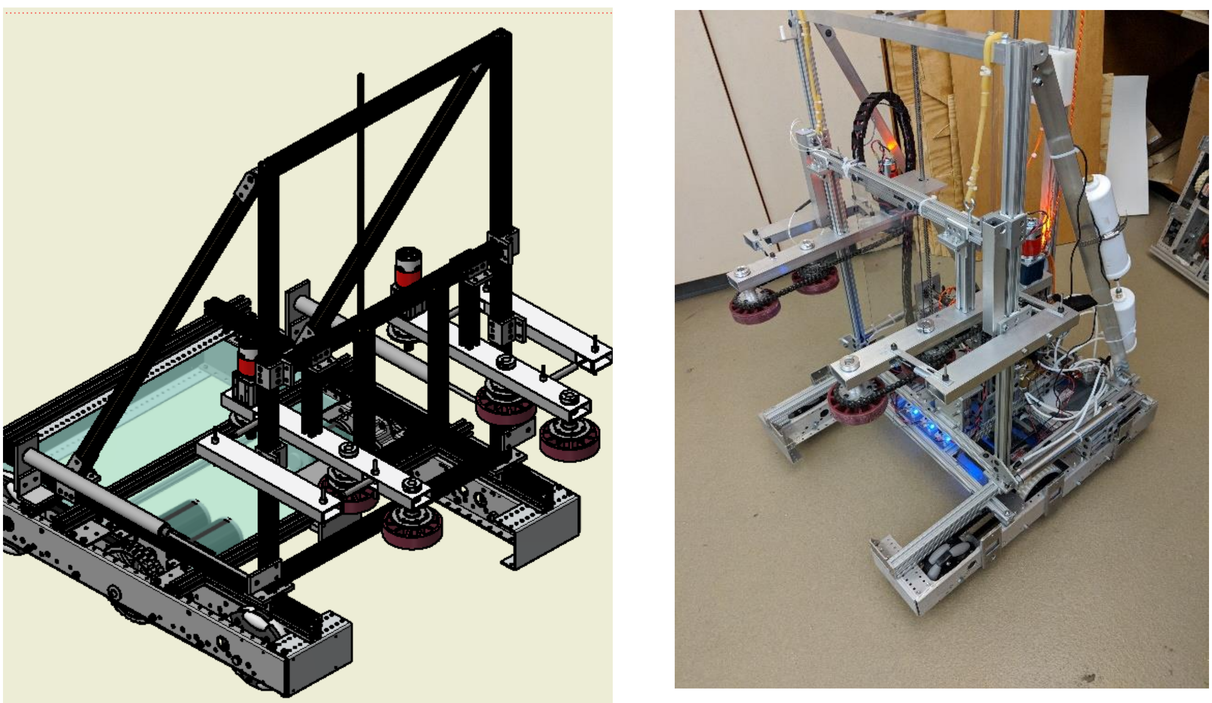
Year 4: FANUC Robot course; Senior Capstone Project

Our physical facilities are excellent. An industry advisory board meets with our program instructors regularly, and discusses equipment, improvements, and employment outlook. Based on this advisory relationship, our administration plans budgets and pursues grants from local and federal agencies. This has been tremendously successful, as STEM career related funding is very popular currently. Facilities for students include 1:1 laptops, a variety of 3-D printing technologies, CNC mill, router, and lathe, plastic injection molding equipment, tensile testing, CMM, and several robotics platforms. We have a dedicated theory classroom adjacent to our laboratory and shop facility.

4. Project Success Stories: Clean Energy and Robotics

Robotics competitions have provided large, complex, and interesting design projects for our engineering and robotics students. Our school has participated in the FIRST Robotics Competition for several years thanks to sponsorship from local electronics industry partners. Students from all four years join the extra-curricular project and grow into a high-functioning team in the end. Projects are designed to challenge teams to solve several problems while playing a collaborative game with and against other teams on a field of play. Mentor engineers from our sponsors provide basic support for learning new concepts, but the student team is responsible for all decisions and work that goes into the finished product.

Students build a robot of their own design. They are responsible to fabricate, procure, assemble, wire, program, debug, test and redesign their creation across a short build season. There are many unknowns, failures, and frustrations along the way. In addition to the acquisition of technical knowledge, students must learn about leadership, responsibility, finances, communication, cooperation and time management. The amount of confidence that these students develop is impressive. The group develops from a collection of nerdy introverts into a high functioning team. This ability to think, plan, and execute does not get lost over time – they know that problems can be solved and obstacles overcome. Figure 1 presents the frame and mechanical system (Figure 1a) for moving the robot on the ground and perform other moves.



a) Solid Model of Planned Robot Design b) Working Robot Design

Figure 1. Two Stages of Robot Design: a) Moving Metal System, b) Electronic Controls Installed

The installed electronic control and final design (Figure 1b) presents the robot of approximate size 24” x 24” x 60” (inches) and approximate weight 115 lb.

Robot Team Project Planning & Manufacturing (this is what we ask our students to do step-by-step):

1. Project challenge and rules are released
2. Team reviews rules of the game and develops strategy
3. Brainstorming sessions develop decision matrix and decide specific functions
4. Functions assigned to sub-groups who prototype and propose solution(s)

a. Software and communications

b. Electrical controls, sensors and wiring

c. Discreet mechanisms for motion (electric of pneumatic)

d. Basic chassis and Power Train

5. Final design decisions made and sub-system given OK to proceed
6. Sub-groups finalize design, request materials, fabricate parts, and create assemblies
7. Integration of assemblies, final wiring, plumbing, and testing
8. Test robot in mocked-up project space, repair, revise, and adjust as needed
9. Develop bill of materials, Spare parts kit, field repair
10. Team decides on key roles for competition – driver, programmer, safety captain, pit boss, and communications specialist
11. Competitions occur across several day and team is challenged with repairing, modifying, and playing the game

Note. all work and decision making is managed by student team members. Mentors advise and assist with technology, training, and safety.

A significant part of teaching innovation is created in cooperation with undergraduate and graduate students of UMass Lowell, who themselves already demonstrated innovative skills. It is difficult to underestimate the mutual benefits of cooperation of high school and university groups. UMass students are learning how to teach and, most important, how to formulate the goals of novel design projects.

Over the past several years, UMass Professor S. Mil’shtein has championed efforts to enhance learning for our high school students, particularly those in the Engineering and Robotics programs. With a focus on clean energy technology, Prof. S. Mil’shtein organized and executed several projects which resulted in enhanced student innovation, education, and success. Graduate students from Prof. Mil’shtein’s electronics laboratory at University of Massachusetts Lowell developed curriculum and project plans that were very beneficial to our student. The combination of electrical engineering topics (motors, motor controls, solar electricity generation, energy storage, and transmission) provided high school students with understandable and scalable knowledge that they put to practice.

A particular challenge was presented to a group of third year students – design, build, assemble and test an new vehicle, namely solar/electric trike for transportation handicapped or elderly individuals (see

Figure 2) or novel machine, i.e., economical solar-electric lawn tractor (see Figure 3) learned the necessary electrical engineering details to select and source a battery system, hub-motor, solar panel, motor control and charging electronics. The high school team 3-D modeled the frame assembly, analyzed structural strength, and fabricated the vehicle to their design. Wheels, drive motor, solar panel, batteries, and steering were all specified and assembled by the student led team. In the end, a lawn tractor was built, tested, and completed by the team of high school students and their mentors from the university. All of the students, who voluntarily joined this With weekly theory sessions guided by graduate students, the team of high school students.

Figure 2. Solar/Electric Trike for Transportation Handicapped or Elderly Individuals

5. Clean Energy Education Program

Having already two years of experience our current focus is in shaping of unique teaching and training program focused on clean energy education. Nashoba Tech is the first high school in the country introducing such program.

Figure 3. Solar/Electric Tractor (Lawnmower)

Production of energy by clean resources constitute in United States and across the world about 1% of annual production of electricity. Fabrication of solar panels of windmills, design of combined systems of solar panels and windmills, their installation and maintenance became to be very visible parts of world market. Urgent needs of trained technical personal, knowledgeable about clean energy production, familiar with methods of installation of this novel technology, understanding the rules of integration of clean energy sources into grid manifest itself in number of job openings across the country. Speedy expansion of clean energy into all aspects of society life and economy will continue through years to come. The proposed program is focused on training of critically needed workforce.

The program is based on biweekly classes 1.5 hours long, were basic principles of clean energy technology are discussed and numerical problems are solved by students.

Based on knowledge acquired in classes Nashoba students will participate in experimental work with solar panels, combination of solar panels and windmill, design of solar/electric machinery such as lawnmowers, transportation carts, equipment helping disabled people, etc. should be scheduled after classes and consist of experimental measurements, testing of given systems and highly encouraged novel designs produced by Nashoba students. Design of mentioned above machinery, the manufacturing and testing will follow suggestions and recommendations of high school students, their selection of parts and way to perform machining. High school students will be obligated to present their designs, the efficiency of hardware and cost of production before a selected design would be approved by Nashoba teachers and UMass team. Even in programming for operation of selected systems will be based on suggestions of high school students. The list of new clean energy systems would at no point replicate existing products on the market. That way Nashoba high school students will develop real innovation skills in design and assessment of novel clean energy systems.

UMass students, supervised by Prof. S. Mil'shtein, would implement teaching of the program. Biweekly classes for the period September 2018 - June 2019 will not only cover the lectures supported by video material on basics of solar cells, windmills, motors, power electronic elements, but special lab exercises on testing, evaluation of performance of designed systems.

6. Conclusions

Through the use of complex projects, our students learn to think along multiple lines of inquiry when solving problems. It gives them insight into the interconnectedness of systems, controls, feedback and function. As part of clean energy program in coming academic year we will engage high school students in design of novel combination of solar panels working together with windmill and the new system to be integrated into the grid. With mentoring and guidance, students learn responsibility, self-sufficiency, and collaboration skills vital to the workforce of today. Students want to be independent, and we can help them develop a can-do attitude along with skills needed to meet the demanding work in technology fields. With a basic understanding of technology and tools, young and inquisitive minds have tremendous capacity. When this is coupled with inventive and competitive projects, these learners become innovators and inventors.

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