Career and Technical Education and Its Relation to Engineering Technology Pathways in Marine Mechatronics

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Abstract

Students coming from families with low household incomes often cannot afford to rely on a regular pathway from high school to the university because of college tuition rates. Other students might not seek out available opportunities in their guidance counselors' offices to learn about existing scholarships or learn about different engineering technology or engineering careers. There are also students who realize that a four-year university degree is not always necessary to find a career that matches their skills and talents. They may also have another education path to receive a technician, engineering technology, or engineering degree, such as a technical or dual enrollment program, with the option to return to college later. Career and Technical Education (CTE) opportunities can assist students in breaking out of the poverty cycle, as many technical jobs offer salaries higher than minimum wage. An important factor of technical education success, and filling the technical pipeline to further education, is to provide integration of industry knowledge with traditional, academic training related to the core requirements necessary for further education. Some programs have embedded mechatronics curriculum in their current classes. Some high schools participate in robotics competitions, which can serve as an excellent pipeline to the STEM workforce, especially in the area of advanced manufacturing, mechatronics, and robotics. This paper will provide an overview of various

opportunities related to engineering technology pathways, more specifically career-related information related to mechatronics.

Introduction

Certain students find it difficult to seek jobs outside their small towns or counties, or to enroll in technical schools located outside of their school districts [1]. Even if an excellent CTE program exists in proximity of students' homes, they can attend CTE programs only if they live in the city in which that school belongs. Nevertheless, some technical schools might have students from a 600-mile radius. Many technical programs are targeting low income families, in particular single parent families, so that the students can reach financial independence [1]. Fifty percent of students coming from high-income families obtain an undergraduate degree by the age of twenty five, while only ten percent of students from low-income families do the same [2, 3]. Many rural students also find it challenging to gain experiences needed for their future jobs because of the lack of opportunities in their counties. Other students have a hard time realizing the relevance of a high school education if it does not provide them with real life credentials for specific jobs like many of the CTE programs offer, by providing them with a career objective as early as high school, or by providing career and technical exploration opportunities as early as middle school [4-6]. Generally, CTE programs around the nation are on the decline. A decrease of around 11 percent since 1990 has been reported in CTE teacher preparation programs [7]. Only about 17 percent of students enroll in CTE classes [8].

It is also important to match CTE opportunities with career aspirations [9]. Various science, technology, engineering and mathematics (STEM) jobs will be held by CTE graduates [10]. However, some government funding agencies do not necessarily recognize CTE programs as STEM programs for the purpose of obtaining funding [11]. Traditional vocational education does not provide students' academic skills needed to enroll in further post-secondary education [5]. Recent developments in CTE stress the importance of combining hands on, practical learning with academic learning, which is necessary for qualification for further education [5, 12]. Changing the way these programs are perceived by students and having role models who went through the whole pathway is equally important for their enrollment rates [13]. Some studies suggest integration of more mathematics into CTE curriculum will benefit students and their future careers, since they will be more college ready, not just hands on trained, as only 44 present of U.S. graduates in 2013 were ready for college level math courses [10, 14]. Common Core and college readiness need to be integrated with CTE programs for students to have enough requirements to further engage in postsecondary education [12, 15, 16].

Field trips and job shadowing count as graduation requirements in some technical schools for the purpose of providing these students with job ready skills that are highly sought by industry [1]. Hands on and work-based experiences that lead to certificates have been reported to decrease student dropout rates [4]. Critical thinking, problem solving, communication and collaboration skills are additional elements related to CTE program success [14, 17]. Furthermore, having multiple opportunities available to students, having a sense of community and business partnerships, having successful leadership related to grant writing and fund raising to sustain the programs, having policies in place, and providing professional training to staff have been reported as key factors for long term success of CTE programs [4, 13, 18]. Another benefit related to CTE programs is the understanding that students should be prepared to engage in lifelong learning due to the constant changes in today's global market [5].

Career and Technical Education in Commonwealth of Virginia

The Commonwealth of Virginia has developed strong programs for gifted and talented students through 23 Governor's Schools, as of the 2013-14 school year [19]. However, there is still a gap related to the general student population, in regards to a lack of core skills and abilities among high school graduates. CTE education is noted as a promising avenue for improvement of their STEM literacy and other applied learning related 21st century skills, as defined by NGA Center for Best Practices [20]. CTE programs are integrating academics and career and technical education, work-based learning, and a focus on the development of transition agreements to postsecondary education through career pathways. They have embedded Standards of Learning (SOLs) and Virginia's Workplace Readiness Skills in their competencies. A current trend is that students enrolled in CTE program obtain a degree, certificate or a credential, and that they have more options that would enable them to be eligible for high demand, high wage jobs. The Technical Diploma option was recently approved to replace the Standard Diploma and provide an appropriate CTE sequence. Career and Technical Education in Virginia has the following career clusters: Agriculture, Food & Natural Resources; Architecture & Construction; Arts, A/V Technology & Communications; Business Management & Administration; Education & Training; Finance; Government & Public Administration; Health Science; Hospitality & Tourism; Human Services; Information Technology; Law, Public Safety, Corrections & Security; Manufacturing; Marketing; Science, Technology, Engineering & Mathematics; and Transportation, Distribution & Logistics [21]. These career clusters are aligned with the National Career Clusters Framework.

Virginia also offers 350 different programs for industry credentials, which are available to students as part of the Virginia's Credentialing Initiative. These credentials can be full industry certification, recognized by industry, trade or professional organizations, such as Project Lead the Way – STEM, or National Automotive Technicians Education Foundation (NATEF). They can also be stackable credentials that will lead to the future full industry certification. CTE also provides a national standardized assessment of knowledge related to the specific career pathway through the Occupational Competency Skills Assessment. It also enables students to acquire necessary State License or Workplace Readiness Skills for Commonwealth Certification, which is recognized by the employers in the Commonwealth of Virginia. The growth of the total number of CTE completions, as a result of this initiative, is shown in Figure 1 [22].

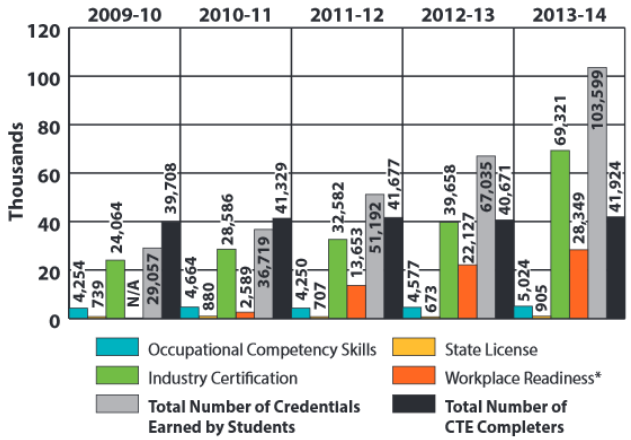

Figure 1: Credentials earned by students in the Commonwealth of Virginia 2009-14 [22]

Mechatronics-Level 1 Assessment: Mechatronics has recently been added to the list of required skills in the different career clusters, such as in the Manufacturing career pathway: Maintenance, Installation and Repair. The demand for employees in the field of mechatronics is predicted to grow by nearly 21 percent in the next ten year period [20]. A related certification is the Mechatronics Assessment, Level 1, which was developed by the National Occupational Competency Testing Institute - NOCTI [23, 24]. Related occupations for this pathway include Communication System Installers/ Repairers; Instrument Control Technicians; Security System Installers/Repairers; Electrical/electronic installer; Shop Mechanic; Auto repair mechanic; and Auto Service Technician [25].

Career and Technical Education in Virginia Beach

Even middle schools in the advanced public school system, such as one in the Virginia Beach Public Schools system, offers courses under the Technical and Career group (elective courses) Technology Education, 6 (Introduction to Technology), 7 (Inventions and Innovations), and 8 (Technological Systems), which are nine-week courses for grades 6 to 8 that introduce students to basics of technology systems, tools, machinery, energy sources, technology systems, such as transportation or communication, then teach them the engineering design process and provide them with hands-on problem based activities. By the end of this group of courses students work in teams to solve problems, construct models, and learn to operate machines and use computers to describe or control systems. Middle school also offers computer skills and keyboarding classes that cover basic operational skills, word processing, multimedia, spreadsheets and desktop publishing.

The high school curriculum is more diverse and offers a wide range of choices for students, including engineering related courses. Virginia Beach Public Schools, for example, offers a set of technical oriented courses grouped as Experiential Learning courses. There is an articulation agreement between the public school district and ODU and students that take a certification exam in courses from these programs can get college credit in Engineering Technology or Engineering Education programs at ODU. These programs are offered by regular high schools and include: Basic Technical Drawing Engineering Drawing, Communication and Information Technology, Control Technology, Pre-Engineering, Principles of Technology, Production Technology, Technical Design and Illustration, or by Advanced Technology Center

which offers: Engineering Design and Architectural Design, Engineering Technology I and II, Modeling and Simulation with 1 year of Basic Technical Drawing [26]. Virginia Beach Public schools include these among their high schools and STEM Academy, which has a curriculum designed for careers related to STEM engineering technology, information and entrepreneurship technology. In this particular school, students can select one strand and complete a comprehensive pathway towards a corresponding associate industry certification.

Dual Enrollment Courses in High School

Dual enrollments are collaborations between high schools and colleges where juniors and seniors are permitted to enroll in actual college courses on college campuses, Advanced Placement courses, or International Baccaulerate (IB) Program courses [27]. Nineteen percent of high school students were taking college-level coursework in 2006, compared with seventeen percent in 2005, due to the increase in the number of students taking Advanced Placement, dual enrollment, and International Baccalaureate programs [20]. One of the programs developed to strengthen the pathways to postsecondary education is the International Baccalaureate (IB) program. It has been reported that four year graduation rates for students enrolled in this program are 79 percent, compared to 39 percent of students who are not enrolled in this program [5].

Dual Enrolment Courses and Mechatronics Pathways

Virginia Beach Public Schools offer dual enrollment courses at the Advanced Technology Center in Electronic Systems I & II, Electricity I & II and Electronic and Robotics Technology, which can be transferred to the Mechatronic program at Tidewater Community College, Chesapeake, VA, starting in the spring of 2015. The Advanced Technology Center in Virginia Beach is a STEM education facility that offers students a college-like experience and a comprehensive technical education. Students may be registered at their home high school while taking half-day classes at ATC. They can also prepare for national certifications and get college credit upon satisfying the specific requirements. If students do not continue with community college or university education, they can directly enter the job market with the knowledge and certifications required by employers today. The classes and programs offered at ATC are aligned with the demands in today's industry, especially with those in the Hampton Roads area.

Another dual enrollment course that focuses on CNC programming and mechatronics was developed for Portsmouth Public Schools, Portsmouth, Virginia, with Tidewater Community College, Chesapeake, Virginia and Old Dominion University. This project was funded by the Workforce Investment Act Incentive Grant program for the partnership between Opportunity Inc., Workforce Development Board of Hampton Roads, Tidewater Community College and Old Dominion University Department of Engineering Technology, and STEM Education and Professional Studies. Two grants were awarded: "Development of Foundation of Mechatronic Course" in 2013 and "Mechatronics Teacher Camp: Foundations of Mechatronics Professional Development Workshop for Career and Technical Education Teachers" in 2014.

A short course called "Foundations of Mechatronics" was developed and disseminated to Career and Technical Education teachers from the Hampton Roads region in the summer 2013 at the Advanced Technology Center in Virginia Beach in summer 2013. There were ten CTE teachers who participated in the workshop and received CTU credit. They all received the Spark Fun Inventor Kit with Arduino Uno microprocessor. Learning modules that would be designed as a result of this grant were: 1) Introduction to Mechatronics and Mechatronic Systems; 2) Electric Circuits and Components; 3) Electrical Energy Sources; 4) Electrical Power

Considerations; 5) Semiconductor Electronics; 6) System Response; 7) Analog Signal Processing - Op Amps; 8) Digital Circuits; 9) Microcontrollers; 10) Sensors; and 11) Applications of Mechatronics. Teachers were given teaching slideshows for these lectures, assignment activities, and additional handouts and reference lists. It was also suggested that they use labs that come with the Spark fun Inventor Kit.

Mechatronics in Career and Technical Education in Hampton Roads

Tidewater Community College (TCC), in collaboration with Old Dominion University (ODU), is developing and implementing a set of standards and building an educational pathway from an Associate of Applied Science degree (A.A.S.) to a Bachelor of Science degree (B.S.) in Engineering Technology with an emphasis on Mechatronics. The project, funded by the Office of Naval Research, has integrated pathway components starting from high school education, moving to the community college, and then to undergraduate engineering technology education. The first effort will reach out to high school students by exposure to possible mechatronics careers through dual enrollment classes that introduce students to mechatronics educational pathways. The second effort will focus on mapping out needed competencies for maritime mechatronics technicians and maritime mechatronic engineering technologists. Students in high school are competing at various levels of mechatronic related activities, ranging from building autonomous robots and programing them to understanding how electromechanical systems are built. Examples of such activities are given in Figure 2.

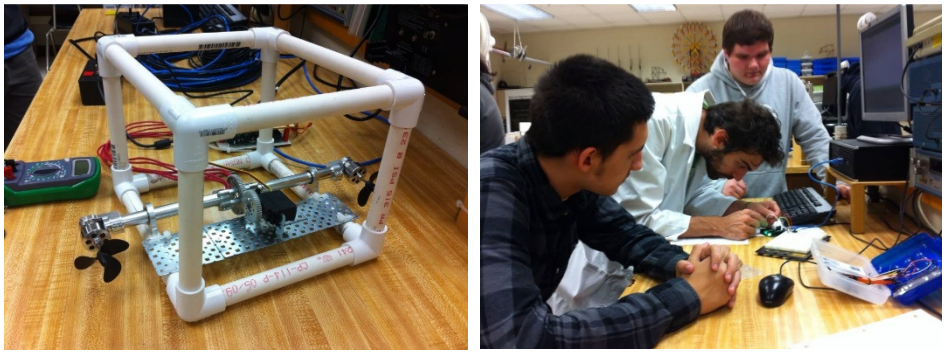

Figure 2: Mechatronic related activities and Granby High School, Norfolk, Virginia and undergraduate student helping high school students in learning mechatronic concepts

Granby High School has three courses that are embedding mechatronics and robotics in the Student Learning Outcomes: Principles of Technology 1, Principles of Technology 1, Engineering Studies and Engineering III Concepts. Engineering Concepts and Processes III is the third course of a three-course sequence that will enable students to solve real-world problems. This course focuses on building an engineering team, working with case studies, managing projects, applying logic and problem-solving skills, delivering formal proposals and presentations, and examining product and process trends. In addition, students continue to apply their engineering skills to determine whether they are good candidates for postsecondary educational opportunities in engineering. Students will participate in STEM-based, hands-on projects as they communicate information through team-based presentations, proposals, and technical reports. Students will take the NOCTI Pre-Engineering certification test at the completion of this course.

Marine Mechatronics Pathway

This project of embedding marine mechatronics as one of the available pathways for CTE students, community college students and engineering technology students is in its first year. Curriculum will be developed in response to the needs of the maritime industry, which will be analyzed using the Developing A Curriculum method (DACUM) and a Modified Delphi method [28]. In the first year, Modified Delphi Panel was conducted with industry practitioners to gage the most important elements of future marine mechatronics curriculum on this three levels. During year one Round I of the modified Delphi method began with the development of a questionnaire to identify the quality indicators for the Mechatronics Curriculum. The questionnaire gave directions and definitions that were critical to the participant as well as to the study so that every panel member was using the correct format when completing the questionnaire. It also used the same definitions of key terms used in the instrument. Examples of related indicators from the review of literature were presented to aid the participants in format for typing a new indicator or modifying an existing one, as well as to start the brainstorming process. Participants remained anonymous to each other, avoiding influences of reputation, authority, or affiliation. Mechatronics activities described in this paper were embedded in the school year 2015-16 in Granby High School. After the curriculum is developed, various data will be collected to measure the project's success. It will take years after its implementation to collect longitudinal data related to the how many students completed each level of marine mechatronics education, what types of jobs did they get, how many of them landed the job in the area of their training. For this project, a comprehensive evaluation plan is a central feature of this project and is based on the project goals, objectives and activities. The evaluation is considering the resources, techniques, procedures, and strategies employed to accomplish the goals and objectives of the project (which is mainly curriculum development), as well as the outcomes of the activities and their impact on the participants. The evaluation plan examines accountability, effectiveness and impact.

Many schools are presently offering or are planning to offer courses or programs in mechatronics [29]. The need has been identified for development of new programs for mechatronics certificates [29, 30], mechatronics technicians [31] and mechatronic engineering technologists [32] at various community colleges [31] and mechatronics courses at universities across the country [29, 32-36] and worldwide [37-40]. At the university level, first Engineering Technology program which offered mechatronics education degree was Purdue University Calumet in Hammond, Indiana as a result of NSF ATE program funding [32].

Moreover, the shift towards integrating mechatronics education as one of the STEM academic areas can be seen in various NSF ATE awards funded from 1995 until now. Some examples are: project "Shaping High-Quality Integrated Nebraska Education (SHINE)" at Central Community College, Grand Island [41], "Meeting Workforce Needs for Mechatronics Technicians" at Purdue University Calumet, Hammond, IN [42]; "Learning Product Design through Hands-on Mechatronic Projects" is a partnership among Carnegie Mellon University and Polytechnic Institute of New York University (NYU Poly) [43]; "The Technician of the Future: Mechatronics as a Statewide Transferable Skill Set Supporting Green Industry" project at Linn Benton Community College, Albany, OR [44]; "The Discover STEM-Generation Innovation project" at Owensboro Community & Technical College (OCTC) [45]; "Mechatronics and Innovation for Rural Technicians" [46]; "The Engineering of Engineering Technicians (E2T)" at Virginia Western Community College [47], etc.

Therefore, developing mechatronics curriculum became one of the important topics in various states in the U.S.A. mainly driven by industry since many international companies already have mechatronics training programs in place. Some of this programs are mimicking European models of engineering education such as German dual system which already has CTE education as a core of future formation of engineering [48]. Some of the main principles that are basis of such dual methodology are based on "Leonardo concept" that sees engineer as one multifaceted profession, ranging from skills, craft based competencies to the advanced math applied engineering skills [49]. In many European countries, there are two main types of CTE, one more vocational with lower levels of math and science, and other track more technical with high level math and science courses, which is more seen as a preparation for engineering and technology careers. It is very typical to have student obtain a technician degree while in high school and then moving on to the higher education path. That curriculum integrates industry based competencies with academic skills which are needed for success at university level. In that sense, Virginia is following a trend which is seen recently as a result of various efforts across the country to strengthen the advanced manufacturing workforce by having more pathway based approach when it comes to technical education.

Conclusion

Many high schools across the country have a wide range of Career and Technical Education courses that can be selected among electives from the STEM cluster that are related to engineering technology, ranging from pre-engineering to power and transportation technology, materials technology, technical drawing, and electronics. Some of these courses can be considered for credit for corresponding community college courses. However, not all schools have CTE courses that are from these career clusters. Students are still bound to attending high school only in their school attendance zones. Additionally, there is a limitation in terms of credit hours that a student can take, as all these courses will fall under elective category of courses and students can only take a limited number of elective credits. If students have academies in their high schools and they are enrolled under specific academy programs, they have to register for academy related courses and have even less flexibility in selecting a CTE course. Counseling is crucial in this respect, in order to guide a student towards a particular engineering related pathway, and to identify the sequence of courses that must be taken. There is still a lot of work to be done for other cities that do not have STEM academies, governor's academies, or advanced technology centers. In these other cities, students are limited to taking CTE courses in other career clusters, not necessarily the ones related to mechatronics or other areas of STEM, such as engineering or technology.

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