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An Initial Look into the Computer Science and Cybersecurity Pathways Project for Career and Technical Education Curricula

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Dr. Vukica Jovanovic is a Batten Fellow and an Associate Professor of Engineering Technology in Mechanical Engineering Technology Program. She holds a Ph.D. from Purdue University in Mechanical Engineering Technology, focuses on Digital Manufacturing, Magistar (Ph.D. candidate) degree in Indsutrial Engineering and Management, focused on Production Systems Design, and dipl.ing. degree in Industrial Engineering focused on Mechatronics, Robotics and Automation. She went through engineering pathways herself, completing master electrician degree when completing Technical School in Uzice, Serbia, focusing on pre-engineering program on high power voltage systems and maintenance of electromechanical systems. Her research is focuses on engineering pathways, career and technical education, digital thread, cyber physical systems, mechatronics, digital manufacturing, broadening participation, and engineering education. She is a Director of Mechatronics and Digital Manufacturing Lab at ODU and a lead of Area of Specialization Mechatronics Systems Design. She worked as a Visiting Researcher at Commonwealth Center for Advanced Manufacturing in Disputanta, VA on projects focusing on digital thread and cyber security of manufacturing systems. She has funded research in broadening participation efforts of underrepresented students in STEM funded by U.S. Department of Education, focusing on computer science and cybersecurity pathways, and from Office of Naval Research, focusing on mechatronic pathways. She is part of the ONR projects related to the additive manufacturing training of active military. She is also part of the research team that has multiple projects funded from NSF focusing on veteran pathways and their success in engineering. She leads the team that delivers the summer program to nine graders that focus on broadening participation of underrepresented students into STEM (ODU BLAST), funded by the Virginia Space Grant Consortium.

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Murat Kuzlu (Senior Member – IEEE) joined Old Dominion University (ODU) of Electrical Engineering Technology Department as an Assistant Professor in 2018. He received his B.Sc., M.Sc., and Ph.D. degrees in Electronics and Telecommunications Engineering from Kocaeli University, Turkey, in 2001, 2004, and 2010, respectively. From 2005 to 2006, he worked as a Global Network Product Support Engineer at the Nortel Networks, Turkey. In 2006, he joined the Energy Institute of TUBITAK-MAM (Scientific and Technological Research Council of Turkey – The Marmara Research Center), where he worked as a senior researcher. Before joining ODU, he worked as a Research Assistant Professor at Virginia Tech's Advanced Research Institute. His research interests include smart grid, demand response, smart metering systems (AMR, AMI, AMM), home and building energy management system, co-simulation, wireless communication and embedded systems. He is currently an Assistant Professor at Old Dominion University.

Dr. Otilia Popescu, Old Dominion University

Dr. Otilia Popescu received the Engineering Diploma and M.S. degree from the Polytechnic Institute of Bucharest, Romania, and the PhD degree from Rutgers University, all in Electrical and Computer Engineering. Her research interests are in the general areas of communication systems, control theory, signal processing and engineering education. She is currently an Associate Professor in the Department of Engineering Technology, at Old Dominion University in Norfolk, Virginia, and serves as the Program Director for the Electrical Engineering Technology Program. In the past she has worked for the University of Texas at Dallas, University of Texas at San Antonio, Rutgers University, and Politehnica University of Bucharest. She is a senior member of the IEEE, serves as associate editor for IEEE Communication Letters, and has served in the technical program committee for the IEEE ICC, WCNC, RWW, VTC, GLOBECOM, and CAMAD conferences.

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Dr. Linda Vahala, Old Dominion University

Dr. Linda Vahala received her B.S..degree from the University of Illinois in 1969, an M.S. degree from the University of Iowa in 1971, and a Ph.D from Old Dominion University in 1983. Her publications include articles in both plasma physics and atomic physics with an emphasis on laser interactions with plasma and with neutral/rare gas collisions. She has presented her work at various international workshops and meetings, both in Europe and in the United States. She is currently Associate Professor of Electrical and Computer Engineering at ODU. In 1995, she received the Peninsula Engineer of the Year award.

Prof. Hongyi Michael Wu

Hongyi Wu is the Batten Chair of Cybersecurity and the Director of the Center for Cybersecurity Education and Research at Old Dominion University (ODU). He is also a Professor in Department of Electrical and Computer Engineering and holds joint appointment in Department of Computer Science. Before joining ODU, he was an Alfred and Helen Lamson Endowed Professor at the Center for Advanced Computer Studies (CACS), University of Louisiana at Lafayette (UL Lafayette). He received the B.S. degree in scientific instruments from Zhejiang University, Hangzhou, China, in 1996, and the M.S. degree in electrical engineering and Ph.D. degree in computer science from the State University of New York (SUNY) at Buffalo in 2000 and 2002, respectively. His research focuses on networked and intelligent cyber-physical systems for security, safety, and emergency management applications. He chaired several conferences such as IEEE Infocom 2020, IEEE WoWMoM 2016, and IEEE Globecom Wireless Communication Symposium 2015. He also served on the editorial board of several journals including IEEE Transactions on Mobile Computing, IEEE Transactions on Parallel and Distributed Systems and IEEE Internet of Things Journal. He received NSF CAREER Award in 2004, UL Lafayette Distinguished Professor Award in 2011, and IEEE Percom Mark Weiser Best Paper Award in 2018. He is a Fellow of IEEE.

An Initial Look into the Computer Science and Cybersecurity Pathways Project for Career and Technical Education Curricula

Abstract

Computer science and cybersecurity have gained the attention of various stakeholders, industry representatives, educators, parents and students who are thinking about their future careers. Teaching computer science courses has moved into K-12 education, no longer introduced in the college classroom. There are various reasons for this trend. One is that in this way more children have access to the curriculum that integrates computer science principles, not just those undergraduate students in specific STEM majors. Other industries need different levels of computer science and cybersecurity education. There are various programs across the nation that are focusing on introducing these topics as early as elementary school through various outreach programs or even in the regular curriculum. In 2014, Governor Terry McAuliffe (Commonwealth of Virginia) established the "Cyber Virginia and the Virginia Cyber Security Commission" with recommendations that a cybersecurity workforce pipeline should start in K-12 education and that various pathways should be developed and implemented across the Commonwealth. This paper will provide an initial look into a project funded by the Department of Education that is focused on the Career and Technical Education (CTE) pathways in Computer Science and Cybersecurity. It is the first year of implementation.

Introduction

Computer science has been added to the science curricula on the high school level in the Commonwealth of Virginia in 2016 [1]. However, since there is high demand for a workforce in a region with these skills, there is greater need to develop skills in the existing high school teacher workforce in order to enable the rise of programs focused on the high school computer science and cybersecurity education. The approaches needed are related to making sure that real-time connections between school and real- life industry are available in educational programming and that students understand career pathways in the field of computer science and cybersecurity. Standards of Learning (SOLs) are now beginning in Kindergarten, adopted in 2017 [2].

There is a high level of uneasiness among students that computer science may not be for them. Many students, especially those not confident with mathematics, are also intimidated by programming and computer science. While high school students spend a lot of time gaming or using various apps on computers and smartphones, the idea that they could learn coding and develop such applications themselves does not seem realistic to most students, it may not appeal to them, or they may simply not even think of it as a potential career. Especially for students from low socioeconomic backgrounds, the limited access to hardware equipment and broadband internet, which would support this kind of learning, adds another level of barriers. From a different perspective, there are also a lack of mentors, limited availability of STEM summer programs, or limited access due to the high cost, lower family engagement due to the decreasing number of families with a stay at home parent or with flexible work schedule, and ultimately students' limited

understanding of what exactly computer science and associated fields mean. Another concern comes from the fact that some students might find it difficult to understand a complex discipline like computer science if they are only introduced to the theoretical aspects of the related subjects. However, if students are learning through a problem-based learning approach, they will likely have more success in their learning outcomes [3]. Therefore, there is a strong need for more hands-on experiences or projects, which are usually not easy to deliver for the CTE teachers, who mainly have pedagogical training and may lack training or expertise in computer science and cybersecurity training. Due to the recent development of CTE programs at the state and national level, there is currently a rising need for more teachers trained in CS. However, the development and delivery of corresponding training might be costly for local CTE programs. Computer science falls into the Science Technology or Engineering and Mathematics (STEM) CTE pathway. The idea of the project presented in this paper is to have a team of experts working on a project focused on the applications of computer science in engineering and technology. Such a project should have the ability to bridge the gap in training by providing up to date training through an educational intervention that would include professional development for teachers, along with educational modules, field trips to companies, code nights, and visits to Old Dominion University cybersecurity initiatives for local students from Norfolk Public Schools. Other engineers have already started various educational projects, such as the project started by the Hadi Partovi and his twin brother, an entrepreneur, investor, and engineer, who has work experience in the tech industry [4, 5]. Code.org is a project developed to support teachers teaching computer science in order to increase student learning and confidence in the students' computer science skills [6]. CodeVA assists school systems where there are not enough qualified teachers to deliver CS curriculum. Norfolk Public Schools are already using some of the activities developed by this non-profit organization, but professional development and a more integrated approach focused on educational pathways are still lacking.

Computer Science and Cybersecurity Job Skilled Work Shortage

New jobs are constantly being created locally in the Hampton Roads area that requires students with high tech skills, such as computer science and cybersecurity, yet employers contend that they are not able to find competent, qualified employees to fill these positions. With a high military influence in the region, both public- and private-sector computer science and cybersecurity jobs are likely to increase, and there exists a need for a minimum level of computer science literacy for entry into the job market. Introduction to computer science and cybersecurity principles need to begin at the secondary education level to adequately prepare students for higher education or technical jobs in this arena. Training and professional development opportunities for CTE teachers are crucial. The project presented in this paper will commit to develop a curriculum that can be easily implemented by high school CTE teachers and will lay the groundwork for students to be competitively prepared to join the computer science and cybersecurity job market career pathway.

Computer Science Principles and Cybersecurity Pathway for Career and Technical Education Project

This *Priority 6-Promoting Science, Technology, Engineering, and Math (STEM) Education, With a Particular Focus on Computer Science* project named "Computer Science Principles and Cybersecurity Pathway for Career and Technical Education" will establish an educational intervention in a computer science cybersecurity pathway starting with a pilot program at Granby High School's Career and Technical Education (CTE) program in Norfolk, Virginia. In the coming year, this pathway will be implemented in four other CTE programs in Norfolk Public Schools. The innovative, evidence-based, and field-initiated program is expected to modernize CTE programming in Norfolk Public Schools. The main idea is to develop, deploy, and improve an educational platform, with new educational modules, as well as multiple other components in order to better prepare students for success in the modern work field by having a curriculum focused on applications of computer science that is developed by engineers.

This project will develop supplemental educational modules that will be added to the existing instruction aligned with industry needs, as well as vertically with the courses available at Old Dominion University at the B.S. level in the area of cybersecurity. By enabling this vertical integration and involving industry stakeholders in decisions related to the module development, the researchers can guide CTE program development to improve student outcomes and in future job placement focused on computer science (CS) and cybersecurity. This will enable easier transitions of students from secondary education to postsecondary education or employment. By including industry stakeholders and postsecondary faculty in developing cybersecurity educational pathways at the secondary level, career and technical education student outcomes will be better aligned with the existing work-readiness skills and curriculum. Since Old Dominion University has been identified as a National Excellence Center for Cybersecurity education [7], the secondary cybersecurity educational pathways could lead to entry into B.S., M.S., or Doctoral programs at Old Dominion University.

More than 600,000 high-paying tech jobs are currently unfilled in the United States, most of these in the field of computer science, in areas like transportation, healthcare, education, and financial services. 90% of parents surveyed by the Department of Education recognized a need for computer science training for their children [8]. Various levels of educational programs are now focusing on the development of the skills needed by employers in the area of computer science, such as stackable certifications, updated associate degree programs, career switcher programs, industry-recognized certificates, licenses, advanced degrees, four-year degrees, and apprenticeships [9-12]. Real or perceived employer demands have led to increased competition to enter computerscience undergraduate programs and even waiting lists, such as at UW-Madison where enrollment increased by ninety-five percent from 2010 to 2015 and resulted in a waiting list of 900 students [13]. Increasing and broadening participation of underrepresented students in computer science and cybersecurity at the secondary CTE level can lead to a more highly skilled technical workforce that is prepared for careers in business, advanced manufacturing, and health care. This results in promoting innovation and economic growth in the United States. Many of these highly technical

STEM jobs result in higher wages than non-STEM jobs with similar educational requirements [14]. The main Old Dominion University Campus and Norfolk Public School district is in Norfolk, Virginia, which has multiple Qualified Opportunity Zones, as identified by Governor Northam in 2018 [15] and confirmed by the U.S. Department of Commerce (see Figure 1a). All high schools in the Norfolk Public School system have students who reside in qualified opportunity zones (their attendance zones are given in Figure 1b).

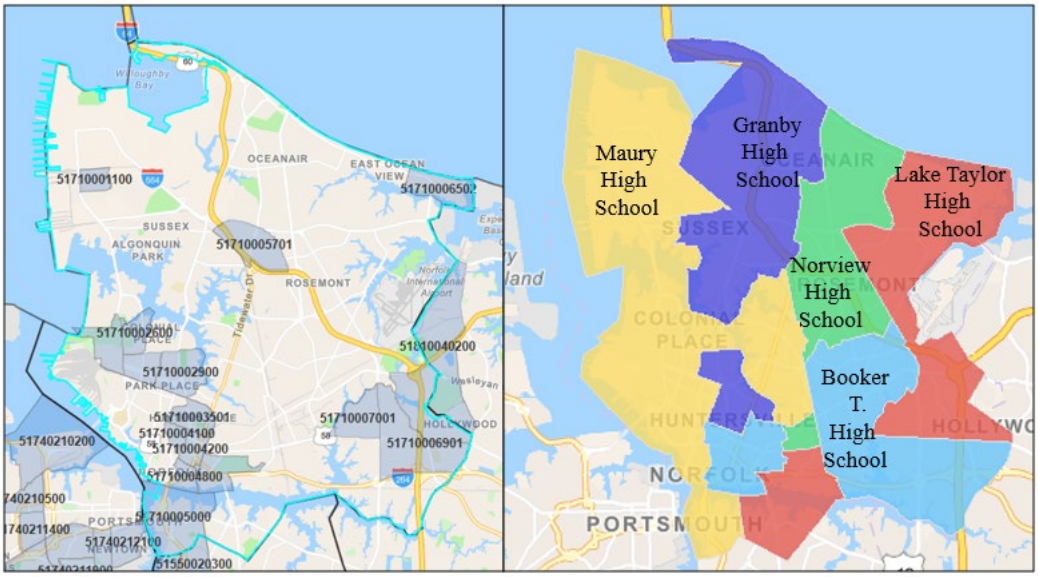

Figure 1: Qualified Opportunity Zones in Norfolk, VA [15]

Norfolk Public Schools Activities in Career and Technical Education

The work plan will develop, assess, and improve the course curriculum and hands-on activities in the area of computer science principles with Norfolk High Schools, Old Dominion University, and industry partners for the Career and Technical Education (CTE) program. Figure 2 illustrates the Computer Science and Cybersecurity Pathway for the CTE Logical Model. One of the ways to engage more underrepresented students in STEM in CTE programs focused on computer science and cybersecurity, which will be available in Norfolk Public Schools, starts with students meeting the role models of their own ethnicity and gender. Therefore, field trips will be open to all students and flyers with CTE career pathways will be distributed at the invited speaker events and during the code nights that will be open to the community.

The proposed program will focus on the following objectives: 1) Develop, assess, and improve hands-on computer science and cybersecurity educational modules that can be easily integrated into a high school curriculum; 2) Establish enrichment experiences in informal learning settings including: a) field trips to local companies that use CS and cybersecurity applications in their day to day activities - ranging from advanced manufacturing, banking, and healthcare; b) code nights involving parents and community; c) high school student participation in competitions like the Great Computer Challenge and the National Youth Cyber Defense Competition; and 3) Establish professional development experiences for high school CTE teachers through face to face and distance learning workshops.

Getting the Project Started

The project officially started in fall 2019 and got its "kickoff" with a getting to know each other afternoon at the Granby High School where project team, college students, teachers and students from the high school met in the school's library. The high school girls' robotics team introduced themselves and discussed their achievements. Students in the culinary classes treated the guests with in-house lunch. The group of college students were to serve as role models, to answer questions regarding college, and to get to know the high school teams for which they may later serve as coaches.

Figure 2. Project kick off at Granby High School Lunch and Learn

After this first meeting the project team and high school teachers discussed the equipment needs for the classes, as well as for the competition groups, and the first laptops were given right before the winter break. They are given to the high school students participating in the Cyber Patriots team.

Figure 4. First laptops arrived at Cyber Patriots student team in Granby High School

Students from Granby High School went on a field trip to one of Unilever's Lipton factories in November 2019. There, they had to go through a safety procedure given by the Safety Officer on site where they learned about the importance of safety and how strict the safety policy is at Unilever. Then they were given steel toe shoes, safety glasses, and visitor vests. After that, a full factory tour was given by one of the engineers. Students learned how tea was processed, all the way from the tea leaves to the final product getting wrapped in a box. They learned about different machines such as the robotic arms, wrapping machines, and the sorting machines. They saw the

real application of various enterprise management systems that handle data from the manufacturing system, which is used to control this high paced manufacturing facility. Finally, they got to enjoy a small taste test for different types of tea and understood how this taste test is essential for quality control purposes.

Figure 5: Granby High School field trip to Unilever, Suffolk, VA in 2019

Mentorship Program with the Girls in Engineering ROV Team

The MATE ROV competition aims to enhance students' technical and entrepreneurial skills, which are in high demand nowadays for job opportunities. These skills include but are not limited to the ability to understand the scope of business operations (such as research and development, finances, and marketing), working as a team, critical thinking, and applying technical knowledge in a creative and innovative way. Granby Girls in Engineering have been participating in this competition for the past several years. Last year, they were able to achieve first place in the Regionals for the Ranger class and they also won the Mart Klein MATE MARINER Award in the internationals. This year, the project team aims to help them achieve a top position in the internationals. When the faculty members of the team first started working with the high school robotics team, they tried to understand the main issues girls' team faced last year so that together they could start the new competition round by analyzing and fixing previous years' problems.

Figure 6: Old Dominion University graduate students and faculty advising Girls in Engineering team

From these discussions, it was found out that there were some fundamental issues in the core concepts of ROV design that the high school students did not fully understand. The main issues were with electrical power management, waterproofing the electronics enclosure, and buoyancy. College students and faculty started by showing them how to perform their power calculations to include the ROV not exceeding the permissible power rating of 300W. One of the conclusions the high school students made was that they were using too many thrusters. As a result, the number of thrusters was reduced from six to four. Moreover, this led to the design of a new frame to position the thrusters properly. Using Autodesk Inventor, and with the help of college students' mentoring, high school students were able to come up with a frame design on their own. Finally, the project members explained to them how buoyancy works and how to choose a material that is neutrally buoyant in order to reduce weight and enhance the performance of the ROV. They found a sponsor that was willing to donate HDPE (High Density PolyEthylene) sheets, which has a density of (0.97) instead of the Polyurethane they were using the past years with a density of 1.2. Using the CAD model, the sheet was sent to a CNC Router to accurately cut out the frame and proceed to assembly. This year, the project team is aiming to make a fundamental change in the way the high school students think and approach a project. The main goal is for the high school students to have a better understanding on how to analyze their design and think outside the box for solving the issues. The teaching approach is to get them out of their comfort zone and encourage them to try a whole new design for the ROV, which will hopefully perform better than the previous years. Most importantly, this approach will teach the students that trying completely new solutions is not always bad and may have a better outcome than modifying older designs.

Conclusion

This paper summarized the start of the "Computer Science and Cybersecurity Pathway for Career and Technical Education" funded by the United States Department of Education Innovation and Modernization Program funded by the Perkins V statute, Congress. The project started in November 2019 and this paper presents its initial quarter. This project is a continuation of collaboration that was established between Old Dominion University and Granby High School that was funded by the Office of Naval Research and that was focused on mechatronics pathways for Career and Technical Education. The impact of the project will be accessed with in depth data collection and analysis after the first set of modules and activities is completed in June 2020 and will be then presented and published in various outlets. This paper presents the first sets of activities hoping that this work can help other academic institutions to get some ideas how they could establish similar program with local public-school districts.

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