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## Mentoring Prospective Engineering Students Through the After School Program "Girls in Engineering" Focused on Building an Underwater Remotely Operated Vehicle

Vukica M. Jovanović  
*Old Dominion University, v2jovano@odu.edu*

Deborah Marshall  
*Norfolk Public Schools*

Jeff Warren Larson Jr.

Abdul Rahman Badawi  
*Old Dominion University, abada002@odu.edu*

Neil R. StClair  
*Old Dominion University*

*See next page for additional authors*

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**Authors**

Vukica M. Jovanović, Deborah Marshall, Jeff Warren Larson Jr., Abdul Rahman Badawi, Neil R. StClair, Otilia Popescu, Murat Kuzlu, Petros J. Katsioloudis, Linda Vahala, and Michael Anthony Crespo

## **Mentoring Prospective Engineering Students Through the After School Program "Girls in Engineering" Focused on Building an Underwater Remotely Operated Vehicle**

**Dr. Vukica M. Jovanovic, Old Dominion University**

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 Industrial 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 electro-mechanical 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.

**Ms. Deborah Marshall, Norfolk Public Schools Career & Technical Education Dept.**

**Mr. Jeff Warren Larson Jr.**

**Mr. Abdul Rahman Badawi, Old Dominion University**

Abdul, Granby Girls in Engineering's mentor, is currently pursuing a Master of Science degree in Mechanical Engineering and expected to graduate in December 2020. Abdul is also a Research Assistant with the department in addition to the National Institute of Aerospace. His focus is on Piezoelectric Energy Harvesters. Abdul is very interested in robotics, control systems, and mechatronics.

**Mr. Neil R. StClair, Old Dominion University**

Neil St. Clair is a recent graduate of Old Dominion University where he received a degree in Mechanical Engineering Technology, with a concentration in Nuclear Systems, and a minor in Engineering Management. While at ODU he helped to reestablish the university's chapter of ASNE (American Society of Naval Engineers). He also served as the founding president of the chapter.

**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, served 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.

**Dr. Murat Kuzlu, Old Dominion University**

Murat Kuzlu (Senior Member – IEEE) joined the Department of Engineering Technology, Old Dominion University (ODU) in 2018 as an Assistant Professor. 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 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.

**Dr. Petros J. Katsioloudis, Old Dominion University**

Petros J. Katsioloudis is a Professor, Department Chair and the Industrial Technology Program Leader, Department of STEM Education and Professional Studies, Old Dominion University, Norfolk, VA. His research focuses on improving teacher and student performance in STEM education, and enhancing the development of a national STEM-educated workforce.

**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.

**Mr. Michael Anthony Crespo, Granby High School, Norfolk Public Schools, Norfolk, VA**

Department Chair, Career and Technical Education Granby High School, Norfolk, VA I teach AP Computer Science Principles, Cyber Security Fundamentals and Cyber Security Software Operations Code.org & codevirginia.org Computer Science Discoveries Facilitator

## **Mentoring Prospective Engineering Students Through the After School Program “Girls in Engineering” Focused on Building an Underwater Remotely Operated Vehicle**

A number of studies by engineering education researchers have pointed out that all-female teams, rather than mixed teams, result in better forms of participation and interaction in engineering related after-school programs and clubs. In particular, for after-school programs or clubs that form in response to a STEM competition, all-female teams have better chances of developing. One such competition, which will be discussed in this paper, is a regional Marine Advanced Technology Education (MATE) competition in which students from Granby High School, Norfolk, Virginia have been participating for many years. For each year’s competition, an all-female team of students enrolled in the Career and Technical Education program at Granby High School, Norfolk, Virginia build an underwater autonomous robotic vehicle, for which the robot specifications and competition rules are formulated each year by the MATE regional competition. Any team participating in the competition must have a mentor, and the students must be enrolled in courses within the engineering studies program. This paper will discuss the collaboration developed between the high school and college students, how the mentorship program was delivered, and how the program successfully helped future engineering students to establish their engineering and future STEM identities.

### **Introduction**

Various sources indicate that women have earned only 18% of the engineering degrees awarded in the United States and Canada [1], although girls do not lag behind boys in grades or test scores in either math or science [2]. Consistently low populations of women in engineering are often attributed to discrimination, the perception that engineering is a masculine domain, and the lack of understanding about the roles and responsibilities of an engineer [3]. More positive perceptions of engineering careers were noted among participants of the programs that integrated the use of role models and a teamwork component [4]. Some researchers pointed out that a successful outreach program, with the goal to attract more girls to engineering, has to focus on the multidisciplinary nature of engineering, and the activities developed must be interactive in nature and should include problem-based learning [1]. Other researchers noted that some of the successful strategies for the targeted outreach include after-school sessions, industry visits, university visits, family nights, summer camps, professional development activities and focus groups [5]. Some other studies suggest that young women are drawn to engineering when they see its potential for improving peoples’ lives and by integration of the social values that young women care about with the emphasis on important and unique contributions to individuals and to the overall society [6, 7]. Although many researchers point out that outreach as early as middle school is important in embedding the idea that anyone can be an engineer, many universities do not offer many outreach programs to this age group because of the inexperience with age-appropriate pedagogy, risk management issues, and unknown benefits to the institution in relation to the limited resources available [8]. Longitudinal studies suggest that special focus has to be placed on generational aspects of Generation Y, and designing activities that would

improve participants' math scores and confidence are important [9]. Various researchers, who compared the effects of single-gender enrichment programs to comparable mixed-gender programs, found female-only programs to be effective in positively influencing their perceptions of engineers and attitudes toward engineering as a career [10]. Some researchers pointed out that STEM female student focused after-school programs, in schools that have a high percentage of underrepresented students, have to design activities that would address issues rooted in deficit thinking and critical race theory [11]. Such programs also need to have activities that counteract negative gender stereotypes and peer pressure, which may lead to the increased perception of the student's self-efficacy and confidence in their ability to excel in engineering [12]. After-school programs add value in the exposure to this generation's knowledge through discourse, chatting online, drawing, and presenting in ways not normally accomplished in the school-day classroom [13].

**Setting:** The Hampton Roads metropolitan area is unique in terms of a high presence of students from low socioeconomic backgrounds and a high percentage of students usually underrepresented in engineering. Of its 30,087 students, 67.8% students qualify for the free or reduced lunch [14]. Granby High School is an urban high school in Norfolk, Virginia, with an enrollment of nearly 2,010 students. The high school is part of the Norfolk Public Schools system. Granby High school has 67% minority students: 52% are African American; 28% are White; 10% are Hispanic, with a number of minority students significantly higher than the state average [15], and 56% of the student population are from low socioeconomic status [1]. Only 3% of low-income and underserved minority students are college ready, compared to the 14% college ready students among all other students in the school.

### **Girls in Engineering Program in Granby High School**

The "Girls In Engineering" Program was initiated in the fall of 2012 with the goal of inspiring more high school girls to enroll in engineering programs post-graduation [1]. The program initially started as an after-school program intended to introduce the girls to various aspects of engineering and have them work on robotics projects. The event which marked the starting point of the project was an IEEE Women In Engineering presentation, presented by chapter representatives and the student branch president. Female high school students, who showed interest in an engineering school club, were invited to attend, and the women presenting in the event introduced the fifteen high school attendees to information about STEM Careers and how to select the right courses in high school to prepare for college in support of a STEM Career. Only one month after this introductory event, the after-school program was launched with a group of six high school girls in attendance. The program introduced the girls to basic engineering aspects by having them design, build, and troubleshoot an underwater Remote Operated Vehicle (ROV). This activity allowed the girls to enter their first robot in the Marine Advanced Technology Education (MATE) ROV competition in April 2013 [17]. Through the MATE ROV competition, the girls were challenged with a real-world situation. The MATE

Center uses underwater robots – also known as remotely operated vehicles or ROVs – to teach science, technology, engineering, and math (STEM) and prepare students for technical careers.



Figure 1: Girls in Engineering participated in various hands-on activities while designing, building, testing and programming underwater autonomous robots


The “Girls In Engineering ” program was designed to: 1) Develop their self-confidence in engineering; 2) Demonstrate creativity and innovation abilities; and 3) Think critically, solve problems, and make decisions.



Figure 2: The main goals of Girls in Engineering program

With their first competition participation, the team established the first all-girls team participation in the MATE ROV competition. They had a very good start placing 6th out of 14 teams participating in the 2013 Mid-Atlantic MATE ROV Regional Competition. From this very first competition participation, the team grew in confidence and experience and the girls became highly motivated in continuing their competition participation. For the second year, the all-girls team placed 2nd out of 14 teams overall and qualified for the MATE ROV International Competition in Alpena, MI on June 26-28, 2014. At the international competition, the team placed 27th out of 550 Ranger teams worldwide. Back at their school, the girls team competition success opened the door to starting the first “Girls Only” course in engineering, which got started with 22 young ladies enrolled, and even had a registration waiting list. The goal of this course was to introduce girls to the world of engineering, to expose them to science and technology careers, and to encourage students to develop and apply technical knowledge, teamwork, and problem-solving skills. For the first time the course was offered in 2013-2014, 63.6% of the students completed the class with a grade of a C or better, and 27.3% earned an A.

Table 1: Different generations of Girls in Engineering teams [15]

			
2012-13	2013-14	2014-15	2015-16
			
2016-17	2017-18	2018-19	2019-20

Some of the main activities pursued by the school in order to increase the engagement of high school students in engineering were:

1. *Engages students in STEM and exposes them to science and technology careers* (by exposing them to the role models, industry trips, visiting speakers, making them present in the front of the audience of engineering and STEM professionals);
2. *Encourages students to develop and apply technical, teamwork, and problem-solving skills* (by participating in the MATE ROV competition that is focused on building an underwater autonomous robot);
3. *Provides funds, materials, and technical expertise to support student learning and provides industry with skilled individuals who can fill workforce needs* (by school funding, fundraising and collaboration on federally funded projects).

One of the examples of engagement events is the “Meet and Greet” annual events held during the instruction session. These events included interaction with STEM and engineering role models through formal and informal discussions. In this way, high school girls who would not necessarily have a lot of previous interaction with female engineers or engineering students could learn about some opportunities and possible engineering pathways that are available to them. As a result of one such interaction, one of the girls decided to pursue a flight academy [18], which was a selection-based program provided free of charge to high school students. The completion of this program later led to her future career choice. The close collaboration between Old Dominion University faculty and high school students, and the regular meetings related to the robotics club activities, facilitated formal and informal discussion, and created the possibility for the high school student to learn about this specific opportunity, get details about it from faculty,



and receive advice from the school instructors about the applicability and outcomes of this opportunity, as well as the support and encouragement to apply.



Figure 3: Meet and greet annual event in which girls presented their ROV designs to women mentors (engineering professors and Society of Women Engineers (SWE) student members)

“Lunch and Learn” is another event that was held annually in the high school library. CTE students from the culinary department of the same high school would provide catering. The high school students would present their team and their robot design to the audience of engineering faculty, engineering professionals, and other STEM related professionals. Thereby, girls practiced public speaking and their networking skills.



Figure 4: Lunch and Learn annual event in which students from Girls in Engineering program presented their ROV designs to STEM women mentors and invited audience

Throughout the years the “Girls in Engineering” program was very successful, and the teams have won multiple awards such as the international “Martin Klein MATE Mariner Award” in 2019 [19]; 1st Place: MATE ROV Mid-Atlantic Regional Competition; Best Design Award in 2019 and 2016, Best Marketing Presentation in 2019, Best in Engineering Evaluation Award in 2014; Armed Forces Communications and Electronics Association of Hampton Roads. STEM Teaching Tools in multiple years; Virginia Mathematics and Science Coalition “Programs That Work” in 2018; and others.

### **Mentorship Program and Collaboration with Blind Review University**

Collaboration between Granby High School and Old Dominion University started with high school CTE teachers participating in the “Mechatronics Teacher Camp: Foundations of Mechatronics Professional Development Workshop for Career and Technical Education Teachers” organized by faculty from the Old Dominion University in 2014. This project was funded by the Opportunity Inc. of Hampton Roads, a Workforce Development board of Hampton Roads, and started in 2013 by the request of local industry and local CTE programs in all

different cities of this metropolitan area. Educational modules and Arduino Sparkfun Inventor kits were distributed to CTE teachers and collaboration among Engineering Studies courses and Girls and Engineering Courses continued. The second grant obtained funding from the Office of Naval Research, for a STEM program named “Higher Education Pathways for Maritime Mechatronics Technicians (MechTech)” which started in 2015 [20]. As a part of this grant, various equipment was purchased for the CTE classroom: Arduino kits, VEX robots, Sumo robots, and various controls and electronics equipment to support Girls in Engineering programs - \$6,000 annually for three years.



Figure 5: Various equipment was purchased through grant funding to support CTE instruction

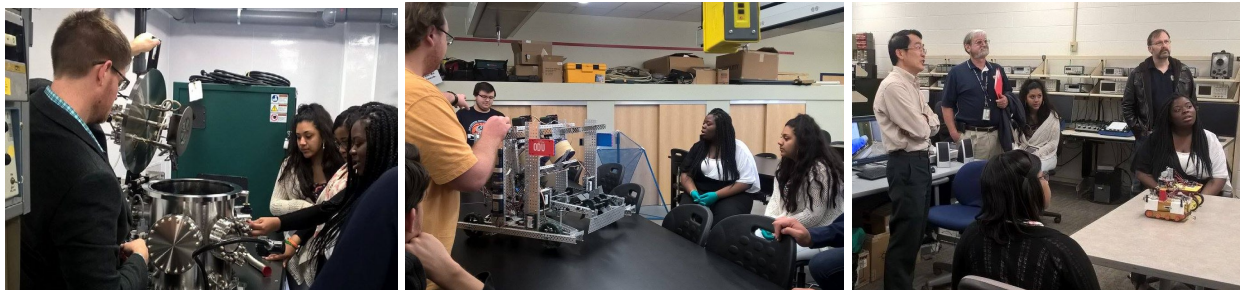


Figure 6: Girls in Engineering visiting Blind Review University campus and interacting with engineering professors

In addition, undergraduate and graduate students served as mentors in CTE classes and during the Girls in Engineering meetings. They provided assistance with programming, electronics equipment setup, such as voltage regulators and voltage drop problems, sealing of wires, housing design, additive manufacturing knowledge, and support with the Computer Aided Design process.

High school students, undergraduate and graduate students are shown in Figure 8 a as examples of successful mentorship, and the impact of the mentorship on different participants. One of the students served as a mentor to Girls in Engineering, Jeffrey Larson, at that time an undergraduate student at Mechanical Engineering Technology program. Figure 7 shows the design of the robot and the girls’ team in the regional competition.



Figure 7: a) ROV robot Girls in Engineering Granby HS built – funded by ONR MechTech project; b) team competing at MATE ROV competition with Larson paid from ONR MechTech project; c) Jeffery Larson giving industry tour to Unilever Lipton plant in Suffolk to Granby High School Girls in Engineering and our U.S. Department of Labor project with Norfolk Public Schools

The same student led his own veteran undergraduate students in the mechanical engineering technology program. They designed, built, programmed, and tested their own underwater autonomous robot with camera and light, which can be used to detect problems on the hulls of the ships. The project was selected to be a representative project in the mechanical engineering technology program at the engineering student project expo. Additionally, the undergraduate students wrote a peer review conference paper that won an award as a best undergraduate student paper and was selected to be published in a journal.



Figure 8: a) Jeffery Larson presenting the award; b) ROV team (Larson, Summs and Travis presenting their senior project (ROV) at the ODU Senior Design Expo

A few years later that same student was now a Reliability Supervisor in a Unilever, Suffolk plant. He hosted a field trip to this company for 10 students, five of which were from the Girls in Engineering program. Subsequent advisor, Abdul Badawi, who was funded by a U.S Department of Education project led by the same Principal Investigator from the Old Dominion University, attended the field trip. Thereafter, he was hired as an intern in the same plant, and currently he works as a full-time employee for Unilever. These are examples of how the strong collaborations developed during the mentorship program for high school students bring together students at different levels in their career, and how the bonds established help them all in the long run and guide their choices for future careers. It is often said that one better understands a subject not as a student but by teaching someone else, trying to explain that subject to another student. It is the same with mentorship. The community created among mentors and mentees, the special framework for collaborating and communicating, which follows a completely different model than a lecture class, creates the grounds for mentors also to grow and to develop new skills through this process, including public speaking and mentoring, in addition to improving their technical skills and knowledge.



Figure 9: a) Granby High Schools students watching the presentation about different products at Unilever Lipton plant in Suffolk, VA; b) Granby High School students (5 Girls in Engineering and 5 male students) learning from female engineers about their job

Ninety percent of the girls who went through the Girls in Engineering program have continued after high school graduation to either a military program or a four-year institution in pursuit of a degree in engineering. One of the girls that was part of the early “Girls in Engineering” program is graduating with a bachelor’s degree in Biomedical Engineering this year. Another student, who is graduating from the HS program this year, will start the U.S. Air Force Academy in the Fall 2021. The “Girls in Engineering ” program has grown in demand and popularity very much based on all their success stories, and as a result of this success the program has also expanded to initiate other after-school programs, such as the rocketry program, within the NORSTAR program. Following the same model of college students mentoring high school students, the rocketry program is currently advised by an undergraduate student Neil St Clair, a senior in Mechanical Engineering Technology at Old Dominion University, now paid as an undergrad student researcher on a project funded by the U.S. Department of Education named “Computer Science Principles and Cybersecurity Pathway for Career and Technical Education”.

## Conclusion

This paper presents the successful experience of a girls only after school program in engineering, their experience and successes, the way the students were mentored, and the strong implications for future career choices for all the participants, the mentees and mentors alike. The students in the Granby HS’s team, while officially mentored by one of their high school instructors, have also been mentored by university faculty and students, and by industry members. Two of these mentors for the “Girls in Engineering” team were students from the Old Dominion University’s Batten College of Engineering and Technology, Norfolk, Virginia one undergraduate and one graduate student, and the paper talks about how participating in the HS program as mentors also affected them and their future choices. Therefore, the particular cases presented in this paper are to show how creating these collaboration communities of high school and college students along with their instructors and faculty, in such an informal environment as an afterschool program, out of the rigid structures of a course, facilitates the type of interactions that led to strong bonds between the participants, and are more powerful in shaping the choices that each of the participants make for their own future.

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