6-2019

Impact of Bioinspired Robots on Veterans Pursuing STEM Degrees

Otilia Popescu

Vukica M. Jovanovic

Krishnanand Kaipa

Karina Arcaute

Anthony W. Dean

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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 Assistant 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.

Dr. Vukica M. Jovanovic, Old Dominion University

Dr. Vukica Jovanovic is an Associate Professor of Engineering Technology in Mechanical Engineering Technology Program. She holds a Ph.D. from Purdue University in Mechanical Engineering Technology, focus on Digital Manufacturing. Her research is focused on mechatronics, digital manufacturing, digital thread, cyber physical systems, 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 Office of Naval Research, focusing on mechatronic pathways. She is part of the ONR project related to the additive manufacturing training of active military. She is also part of the research team that leads the summer camp to nine graders that focus on broadening participation of underrepresented students into STEM (ODU BLAST).

Dr. Krishnanand Kaipa, Old Dominion University
Dr. Karina Arcaute, Old Dominion University

Dr. Karina Arcaute received her BS in Chemical Engineering from the Instituto Tecnologico de Chihuahua, and her MS (Mechanical Engineering) and PhD (Materials Science and Engineering) from the University of Texas at El Paso. Dr. Arcaute is an Assistant Professor in the Department of STEM Education and Professional Studies at Old Dominion University in Norfolk, VA.

Dr. Anthony W. Dean, Old Dominion University

Dr. Anthony W. Dean has had several roles in academia. He is currently Assistant Dean for Research, Batten College of Engineering and Technology (BCET) at ODU. His previous appointments include Associate Professor of Engineering Technology and as Associate Director of the Institute for Ship Repair, Maintenance, and Operations at Old Dominion University (ODU).His research has focused mostly on control systems (integration and testing) and the reliability and maintainability of complex systems. He has been selected as both a NASA and an ONR Faculty Fellow. He regularly teaches courses in Marine Engineering and in Maintained Systems. Most recently Dr. Dean was on the Headquarters Staff the American Society of Naval Engineers. He received his Ph.D. from the Department of Engineering Management and Systems Engineering, and a B.S. in Nuclear Engineering Technology, from the Batten College of Engineering and Technology at Old Dominion University. Additionally, Dr. Dean received an MBA from the College of William and Mary. Prior to is academic career Dr. Dean was Director of Operations and Business Development for Clark-Smith Associates, P.C., and served as an Electrician in the US Navy aboard the USS South Carolina and the USS Enterprise.

Impact of Bioinspired Robots on Veterans Pursuing STEM Degrees

Abstract

The gap in the area of advanced manufacturing skilled workforce and the efforts in guiding veterans towards STEM careers are merged in the NSF funded project presented in this paper. While most of the products and STEM educational programs focused on a maker concept that are currently available are specifically designed for young population, at various K-12 grade levels, to increase their interest in STEM and engineering careers in particular, there is a limited availability of such programs to address adult population. The study presented in this paper focuses on developing and implementing a series of workshops for veterans, using bio-inspired robots as a learning platform. The design, making and controlling of bio-inspired robots require knowledge of mechanical, electrical, computer, and material science engineering, and have the potential to spark interest in a wide variety of engineering pathways. The paper discusses the topics covered by the workshops, the scaffolding of the activities, and the assessment conducted on how the bio-inspired robotics activities may influence veterans' attitude towards advanced manufacturing careers.

Introduction

For the last few decades, some technical fields, especially the area of advanced manufacturing, experienced a gap related to the hiring of highly skilled technical personnel, in particular engineers who have high technical skills as well as hands on practical experiences. As a result, various efforts across the country are focusing on guiding veterans towards STEM careers, since they have practical technical skills developed during their military careers.

Old Dominion University is highly committed to serve military students and assist them with their needs for fulfilling a college degree. This is satisfied through a variety of programs, from detailed consideration of the transfer credit, to specialized advising, to programs designed to help the military student get fast on track for taking courses in their selected majors, and more recently even with financial assistance. The university decided starting with fall 2018 to reduce undergraduate tuition by 28% for active-duty military, for both campus and online courses. There is a permanent call from industry for the most current and emerging skill sets, in particular those related to the concepts of making, computer-aided design, and additive manufacturing technologies. As a result, a variety of makerspaces were developed by various institutions, but in most cases they are focused only on participation of white, male, middle-class, able-bodied hobbyists who have the time and funds to access these spaces [1]. Due to its strategic location in the Hampton Roads area of the Southeastern Virginia, Old Dominion University already serves a wide population of women, underrepresented minorities, and military veterans entering the engineering and technology workforce. It is this university commitment to helping the workforce in the community to learn the necessary skills to adapt to the changing economy [2]. Old Dominion University is supporting veterans and service members for over 70 years and was a pioneer in introducing distance learning for military members stationed abroad.

Most of the efforts targeting military veterans are usually focused on counseling [3], assisting with the transition [4,5] or the re-integration process [6], and less often they are technical related, or focused on strengthening the necessary background for a successful college experience. National Science Foundation (NSF) had lately signaled that military veterans may be a group to address the shortage in engineering skilled workforce, and had funded specially designed projects to address the transition of the veterans to successful college pathways [7].

There is a strong commitment from the engineering faculty members at Old Dominion University to support and engage in programs and activities to help military members decide for an engineering career and to be successful during their academic studies. Faculty members of the college of engineering developed several funded projects specifically designed for veterans and active military. The project presented in this paper, the NSF funded project "*Understanding the Impact of Making on Veterans in Pursuing STEM Degrees"* [8], grant #1749566 [9], continues the efforts along this line, with the focus on veterans and activities developed to recruit them for engineering careers. Part of the research team members participated previously in developing the project *Creating a Fleet Maker Project*, sponsored by the Office of Naval Research, grant # 12118989, which focused on training active duty military to use additive manufacturing technologies (3D printing), solid modeling, and reverse engineering [10, 11], and the current project builds on this previous one, continuing the *Maker* approach to broaden participation of veterans in the Hampton Roads (HR). One major change in the current project was to use manufacturing techniques such as 3D printing in a more applied context, specifically of building bio-inspired robots, since it is expected that more specific project based activities would be received with more enthusiasm and would better stimulate the interest in various engineering branches. A second major change was to recruit the participants among veterans and not active duty military. The reason for focusing on this group was a combination of the fact that the area of advanced manufacturing was identified as a gap in the workforce necessary to enable consistent U. S. economic growth [12-15] in this globally critical area, and of the interest in guiding veterans towards STEM careers. The current project was conducted by a research team of faculty members from the colleges of engineering and education at Old Dominion University with broader areas of expertise: mechanical engineering with focus on robotics and bio-inspired robots in particular, digital thread, additive manufacturing, electrical engineering, microprocessor based design, material and technology engineering, as well as engineering education. The team has also broad expertise in working with military students, in large part through previous projects specifically developed for military students, as well as from experience in advising military students when joining an engineering education path and throughout the program. For this project the research team used the already established *Digital Manufacturing and Collaborative Robotics Laboratory* at Old Dominion University. A secondary outreach component of the project addresses the K-12 student population in the community, since the bio-inspired robots built by the veterans during the workshops will be used by individual faculty of the research team for outreach activities conducted in the local public schools.

Participants' Recruitment and Demographics

Recent years saw an explosion in STEM outreach activities and projects led by both industry and academia, for diverse groups of prospective students, mostly K-12 students. There is however a very limited offering of outreach programs targeting adult populations, one of the reasons being

the fact that it is not an easy task to convince adults to volunteer for workshop activities. Scheduling issues, conflicting with work or personal schedule, are most of the time the main reasons to turn adults away from programs that would otherwise interest and benefit them. A lot of times various incentives may help in convincing potential participants to rearrange their schedule and participate in educational programs. The project presented in this paper encountered in part this problem in recruiting participants for the robotics workshops. While for active military participation in education workshops and the design of such programs can be directly negotiated with the leaders of the military units, veterans are no longer following the same model, and they face the same hardships as any other adult in committing to a program that lasts for a few days.

For the bio-inspired robotics project presented here, the faculty team organized two workshops, one during the summer of 2018 and one in the fall of 2018. The summer workshop was scheduled for 4 consecutive workdays, 4 hours a day in the mornings. It was expected to be easier for the participants to commit for shorter times per day than for full days. For the fall workshop the schedule was changed to two full days, during a weekend, a Saturday-Sunday set-up. The workshops were free, all the materials for the workshops were provided, and booklets with workshop presentations were provided for free for the participants to keep, but no other material or monetary incentives for participation were offered. Even though the two days' weekend schedule seemed to be preferred, recruitment was not easy in neither of the settings. It is the faculty team conclusion that in the future, finding various incentives for participation is very important for bringing larger groups of adult participants and helping this way to form a larger research study group.

Each of the workshops organized for this project had 10 participants, for a total of 20 military veterans in this study. The summer workshop started with a little larger group, but still 10 participants completed the workshop. In some of the answers in the surveys (especially in the pre-workshop survey) the overall number of participants may be a little over 20 due to this reason.

Demographics related questions were asked in the pre-workshop set of surveys. The specifics related to the participating group in the research study based on these surveys are presented next, see Figures 1-4. *Age groups:* The research group was very distributed in terms of age. Even though the most participants were under 30 years old, there were participants in all age groups from under 25 to over 46, 58 being the oldest age mentioned. *Gender:* 18 of the participants were male and 2 of them were female. *Marital status:* 10 married, 8 single and 2 divorced. *Ethnicity:* mostly white participants 12, 5 Hispanics, 1 black, 1 Asian, 1 other.

Highest education degree earned: High School Diploma (8), Associate Degree (junior college) (6), Bachelor's Degree (5), General Equivalency Diploma (GED) (1).

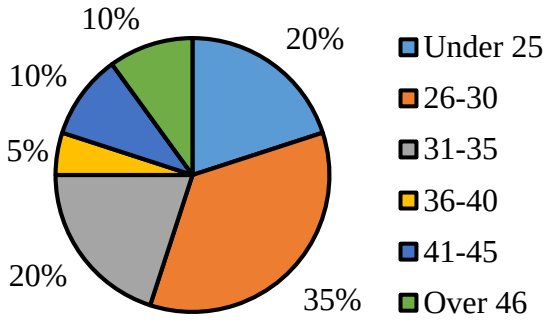

Figure 1: Age group distribution

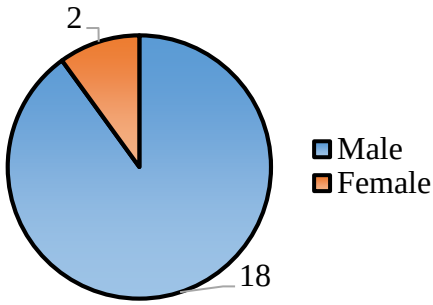

Figure 2: Gender distribution

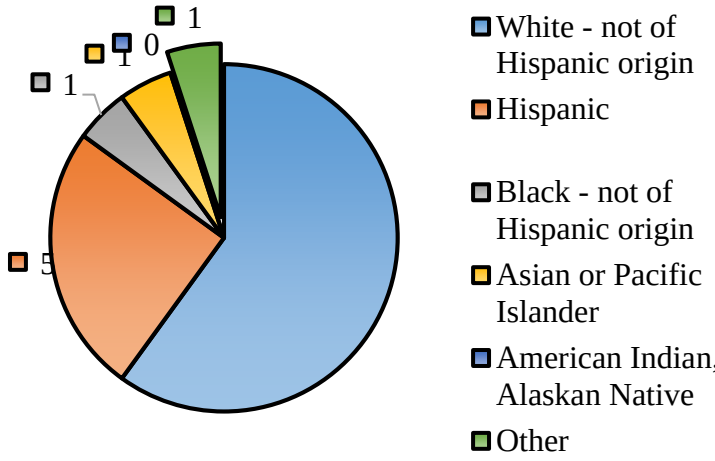

Figure 3: Number of participants per their ethnicity

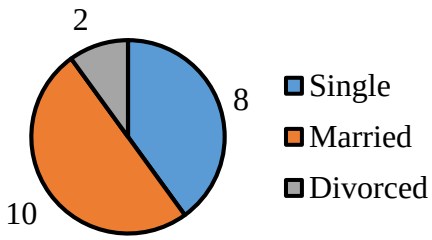

Figure 4: Marital status

The surveys included a whole set of questions related to the current or previous work areas of the participants, as well as their military training, see Figures 5-10:

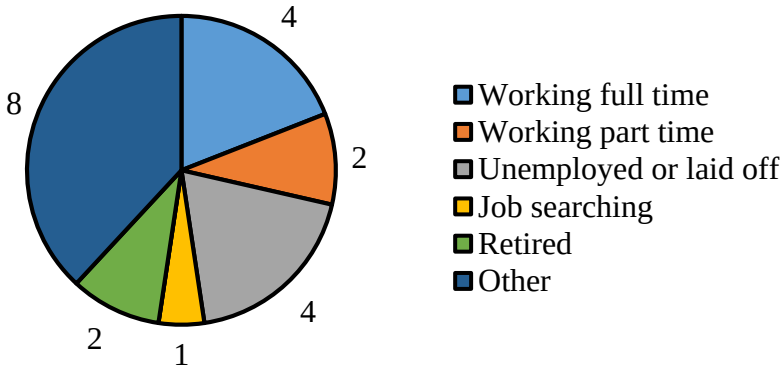

Figure 5: Number of participants per their current working status

Most recent job activities: aerospace industry (2), telecommunications (2), electrical power (2), energy – petroleum (1), manufacturing – ship building (1), defense (3), constructions (2), financial services (2), other (6)

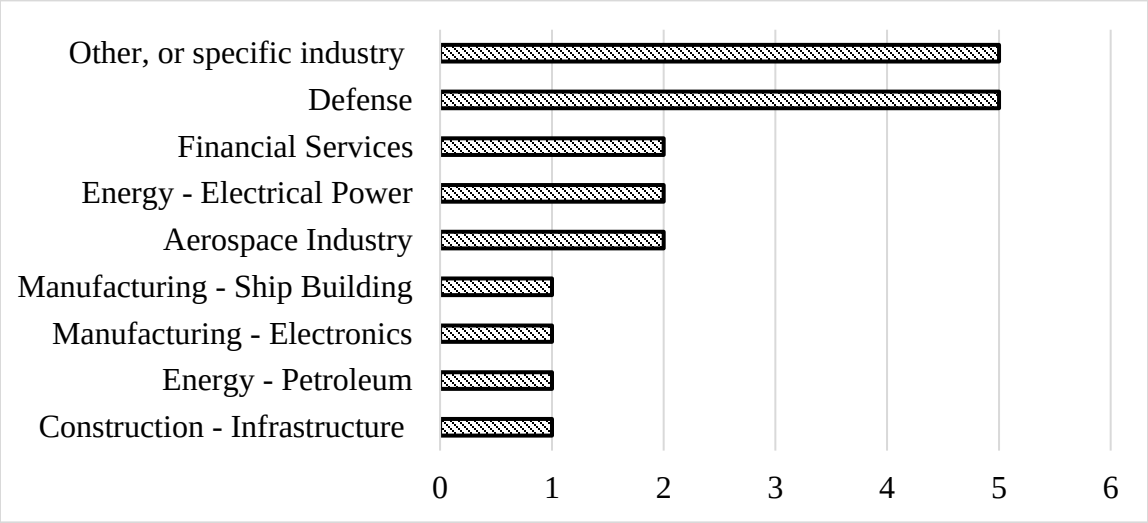

Figure 6: Most recent job activities

Branch of Armed Forces: Navy (13), Marine Corps (4), Army (1), Air Force (1), Other (1)

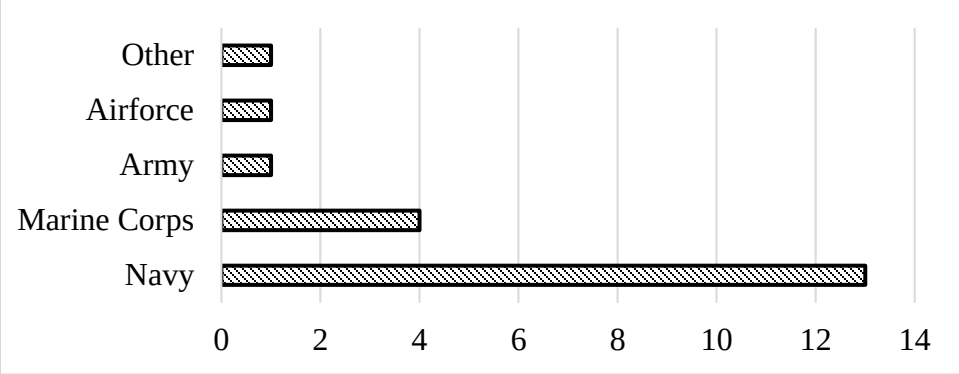

Figure 7: Branch of armed forces

Rating Specialty: Nuclear Electricians Mate, Aviation Electrician's Mate, Data Network Specialist, Avionics Electrical Technician, EMN, Builder, Navy Diver, Fire Control mate, Machinist Mate, Logistics, Sonar Technician, Hospital mate, Quality Assurance.

Serving as active reserve: 3 –Yes, 18 –No

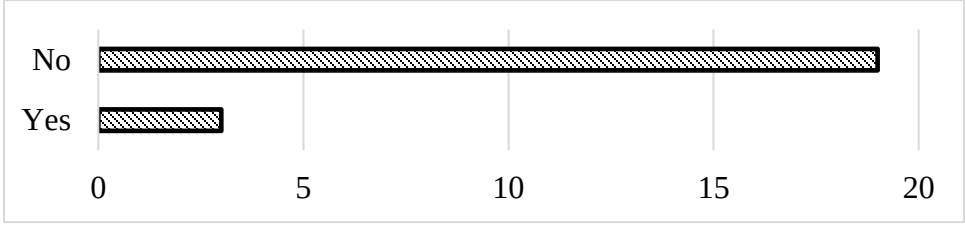

Figure 8: Serving as active reserve

Number of years served in Armed Forces:

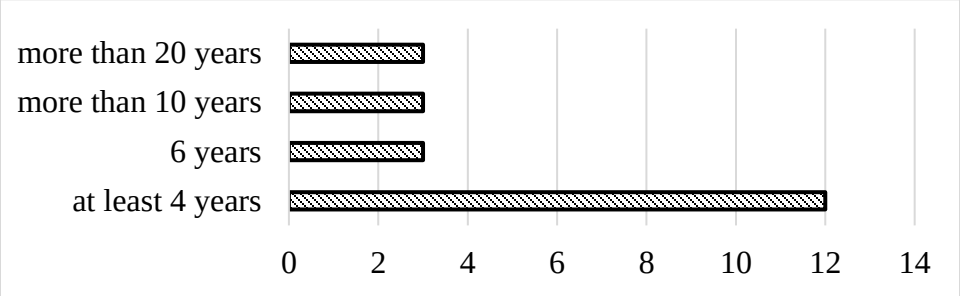

Figure 9: Number of participants per their time of service in Armed Forces

Number of year since leaving the military

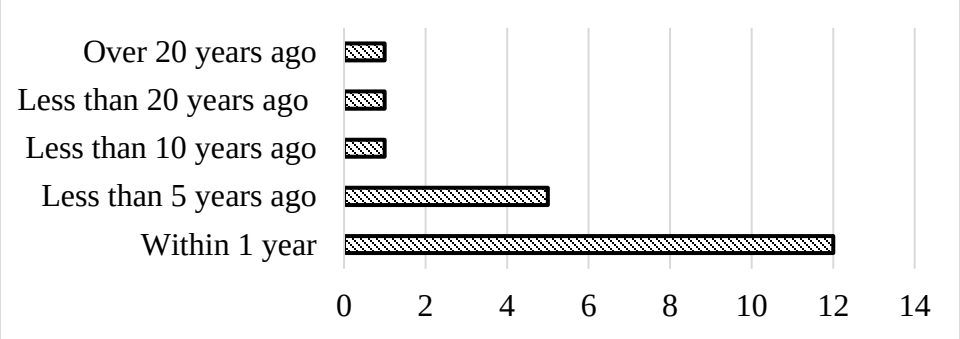

Figure 10: Number of participants per their time since left the Armed Forces

The survey results presented above in conjunction with the fact that the participation to the workshop was not enforced or incentivized in any way, may lead to the conclusion that within the military veteran group, the interest for further careers in engineering is stronger for younger people, shortly after leaving the military, and is motivated by an engineering related background gained while in the military. While our research group was relatively small and recruitment was conducted within the local community, more similar studies may confirm the conclusion implied by our data. Since all of the participants had jobs in the military involving hands-on engineering related skills, it seems natural for them, once leaving the military, to pursue an engineering diploma that would step up their background and put them on a successful engineering career pathway.

Methodology and Workshop Content

The project presented in this paper used as a learning platform the making of bio-inspired robots during short (2-4 days) workshops. The design and fabrication of small bio-inspired robots is a great example of a maker application centered on a microcontroller based mechanism. However, from the engineering point of view, such mechanism needs a wide spectrum of engineering knowledge, and the workshops' purpose was not only to lead the participants on a step-by step building process of the final robots, but to also introduce them along the way to some basic theoretical knowledge needed to understand the complexity of the final product. The research

team's expectation was that exposing the participants to an introductory level of knowledge from various fields will stimulate their interest and will help them identify engineering areas that are of specific interest to each of them. The workshops activities were split between hands-on, Q&A and presentations, with the latest starting with a brief introduction to the theory of bio-inspired robot mechanisms, 3D modeling, animation, STL generation, slicing, G code generation, printing of the robot segments, and concluding with the prototype. The workshops focus was on the connection between 3D computer-aided-design and 3D printing through the use of a bio-inspired robot as an example, as well as on introducing the participants to microcontroller based design, and programming of microcontrollers to control servomotors. Computer Aided Design (CAD) was used directly to design parts for the robots, which were next 3D printed to be used in building the robots, the final workshop product. Another teaching component of the workshop introduced the participants to the area of electrical engineering, through some basic concepts of electrical circuits, electrical wiring and the use of servo-motors in electromechanical mechanisms, the use of signals to control such mechanisms, as well as an introduction to microprocessor based design and basic programming of microcontrollers. Arduino Uno microcontroller was chosen in this project to teach the basics of microcontrollers as well as to build the bio-inspired robots. Sparkfun Inventor kit was used during the workshops to introduce the participants to circuitry, and to the addition of control to the design by programming the Arduino Uno microcontroller [16]. The participants worked on various circuit designs from very simple circuits with LEDs, to circuits with DC motors and servo-motors, to learn the basic skills. Separate Arduino Uno microcontrollers were provided to be used for the actual building of the robots. Table 1 presents the schedule of the two-day workshop offered in the fall 2018. For the four-day workshop offered in the summer 2018 the same structure was followed, just divided on more days, with the overall length of the workshops being the same.

The lecture parts of the workshop were opened to Q&A, were very interactive, and were alternated with hands-on activities. They were designed for an audience that would have been completely new to each of the area presented. The workshops were structured around four major modules: Robotic Design Principles, 3D Design, 3D Printing and Programming of Microcontrollers. While the 3D printing and CAD modules for example are more self-contained, more specific, to develop basic understanding of the programming, microprocessor controlled servomotors and the signals used to accomplish this task is not easy to do in a very short time. The compact presentation of the electrical part of the lectures exposed the participants to the following: the basics of electrical circuits, types of devices, breadboard design and wiring, adding control to the design, using the Arduino's Integrated Development Environment (IDE) to develop code on a desk computer or laptop and download it on the microprocessor board, the basics of the analog and digital type of signals and their use for controlling servo-motors, and even to the notion of pulse modulation, in particular Pulse Width Modulated (PWM) signals, which were used to control the servo-motors for the bio-inspired robots.

For the actual building part of the workshop, the participants studied various types of walking, specific to different types of animals (such as lizard, horse, crab, or bear) and they applied their learning to program the servo-motors that were controlling the legs of their robots. This part of the workshop raised the most enthusiasm, as the participants got really excited to watch their robots walk, and to change their walking style by modifying the programming code. Simple

changes of parameters or different sequences of delays were translated in new walking styles, and the participants were really engaged in trying all sorts of patterns.

Table 1. Monarch Maker Workshop Schedule

Day 1	**Activities**	**Duration**
8:00– 9:00 am	Pre-workshop Assessment Surveys	1 hr.
9:00 – 9:45 am	Bio-Inspired Robotics: Introduction to principles of bio-inspired robotics, legged robots, and walking gaits.	45 min.
9:45– 10:00 am	Break	15 min.
10:00–12:00 pm	Arduino: Introduction to microcontrollers, Arduino, and programming. Hands-on activity with LEDs, single motors, and multiple motors	2 hrs.
12:00 – 1:00 pm	Lunch break	
1:00 – 2: 00 pm	Making: Intro to 3D Printing and Additive Manufacturing Technologies.	1 hr.
2:00 – 3:00 pm	Computer Aided Design (CAD): Introduction to CAD. Keychain Activity	1 hr.
3:00 – 3:15 pm	Break	15 min.
3:15 – 4:05 pm	Hands-On Making: Slicing - creating G code from STL designs and preparing them to be 3D printed.	50 min.
4:05– 5:00 pm	Design: Parametric Modeling Fundamentals	55 min.
Day 2	**Activities**	**Duration**
8:00– 10:00 am	Assembly: Assembly of bio-inspired robots with pre-printed parts and servo motors	2 hrs.
10:00-10:15 am	Break	15 min.
10:15–12:00 pm	Electrical wiring: Electrical wiring between servo motors, batteries, and switch	1 hr. 45 min.
12:00 – 1:00 pm	Lunch break	
1:00 – 2:45 pm	Programming: Programming code for: a) testing each leg and b) walking gait	1 hr. 45 min.
2:45 – 3:00 pm	Break	15 min.
3:00– 3:45 pm	Testing: Testing of robot walking and readjustment by analyzing possible failures and making improvements.	45 min.
3:45– 4:15 pm	Race to Finish	30 min
4:15– 5:00 pm	Workshop Assessment Survey	45 min.

Most of the veterans participating in the workshops were not completely new to engineering, and most of them had already made the decision to pursue engineering careers, even though not all were very sure about which specific engineering area. Therefore, their previous background affected their perception of the presentations, as some of them were more or less familiar with parts of the content of the presentations. Since not all of them had the same background, it turned out to be beneficial to everybody to go through the whole material, providing a perspective of the complexity of the engineering field, and the broad area of knowledge necessary to build even a small robot, which for so many people these days would be no more than a toy. Nevertheless, adults or children alike, veterans or faculty, men or women, we all appreciate a smart toy when it

becomes a vehicle of learning, and the bio-inspired robots used in these workshops were excellent choices to bring up the enthusiasm of the participants and to stimulate their interest in further learning. As one of the participants said:

> "*It was very fun. I built a robot that did not walk very well to be honest, but I learned that engineering is more than just one discipline – it's a combination of multiple skills from different fields that you need to utilize to complete a job.*" [17].

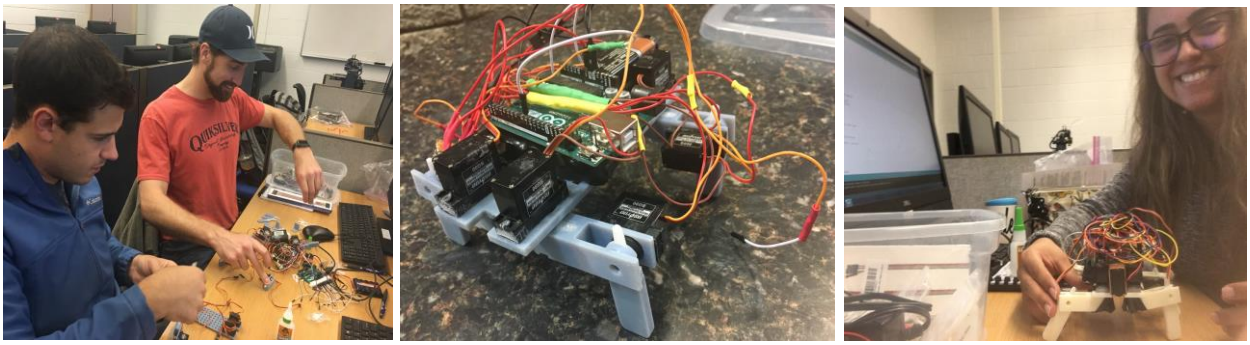

Figure 11. Workshop Participants Building the Bio-Inspired Robots

Teaching Experiences

As mentioned, the faculty team that developed and implemented the bio-inspired robotics workshops presented in this paper included members from the College of Engineering as well as from the College of Education, specifically from STEM education. Most of the faculty have multidisciplinary background and together they cumulate degrees from five engineering disciplines. This diversity in the team background was reflected in the development of the workshops, throughout the materials presented, and through the complexity of the final product of the workshops. The faculty team collaborating on this project decided to approach the teaching of the making process from a multidisciplinary perspective, using this very specialized project based theme, of the bio-inspired robots. Some specific topics included in the workshops are currently included in the courses they teach regularly, such as the "Bioinspired Robotics" course which is offered to undergraduate students in the Mechanical Engineering program, the "Introduction to Mechatronics" course which is offered to undergraduate students in Mechanical and Electrical Engineering Technology programs, the "Computer Solid Modelling" offered in the Mechanical Engineering Technology program, and "Additive Manufacturing Methods" course that is currently under development as an elective course in STEM and Professional Studies program. The research team shared their expertise and the experience from their classes in working with undergraduate students, and developed the curriculum of the workshops to present the design and making of electro-mechanical devices inspired by nature in a unified way. The main goal of the curriculum design was to incorporate as many engineering areas as possible in a single final product, and to be able this way to expose the participants to the wide spectrum of engineering and to help them identify areas of individual interest. Some take home lessons that were learned during the workshop, other than the recruiting issues, were that the durations originally scheduled for the activities may have been rearranged, to allocate more time to the actual assembly, programming and troubleshooting of the robots. Also, with a larger pool of participants they may be grouped on their common background and the schedule may be

modified accordingly, to reduce the portions were the participants have strengths, and allocate more time to those parts were they are completely new. The main impression of the faculty team, as well as from the participants' feedback, is that the workshop could have been longer, especially if some parts of the workshop were to be more detailed developed.

Participants' Feedback to the Workshops

The workshops were very well received by all the participants, as they were engaged and enthusiastic about the activities. The strong positive feedback received about the workshops is reflected by the post-workshop survey results presented in Figures 12-17 and Tables 2-4:

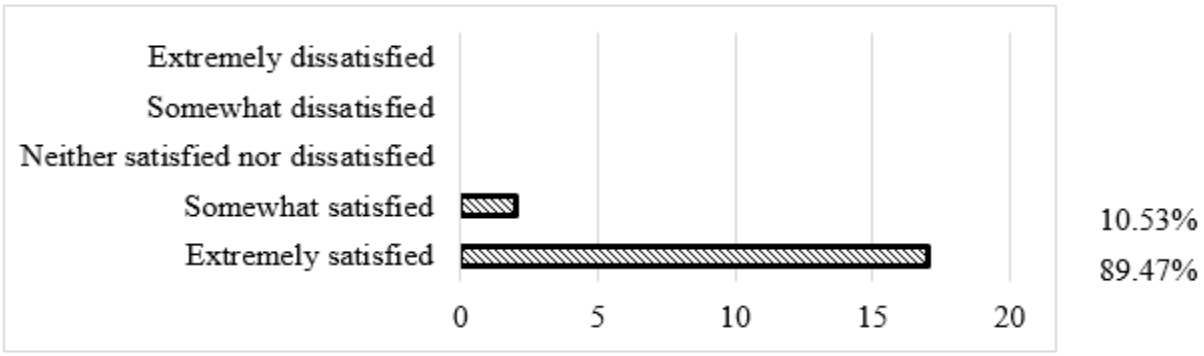

Figure 12: Percentage of students that selected one of the options on a Likert scale for question "*How will you rate the workshop overall?*"

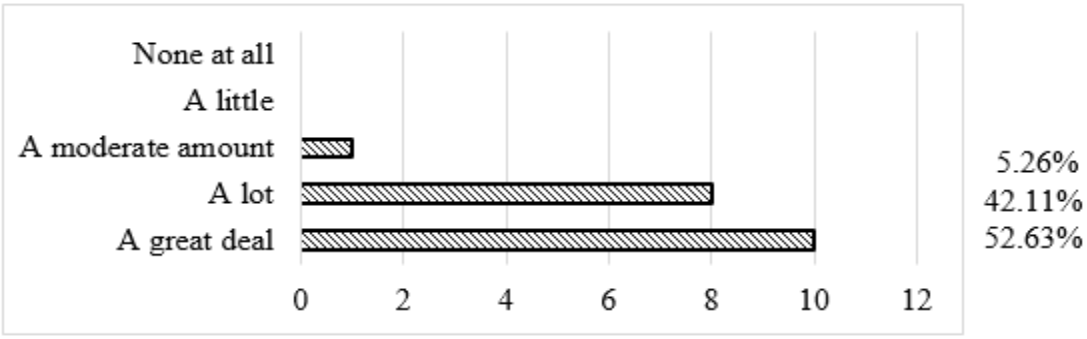

Figure 13: Percentage of students that selected one of the options on a Likert scale for question "*To what extend was attending this workshop worth your time?"*

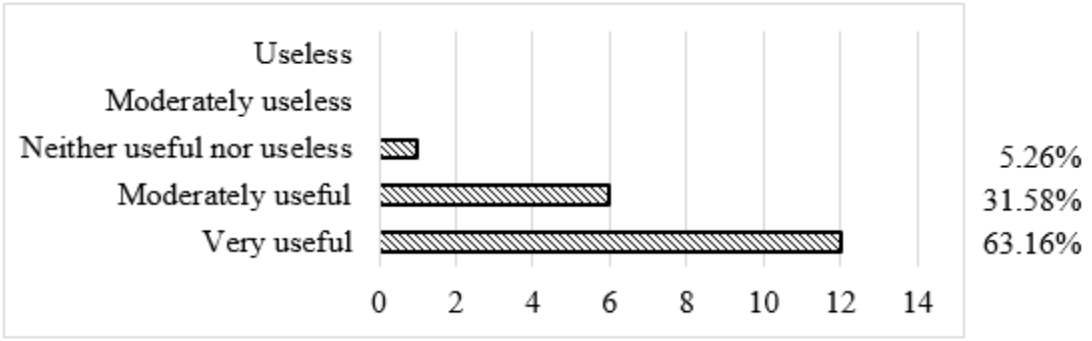

Figure 14: Percentage of students that selected one of the options on a Likert scale for question "*Overall, to what extend was this workshop useful to you?*"

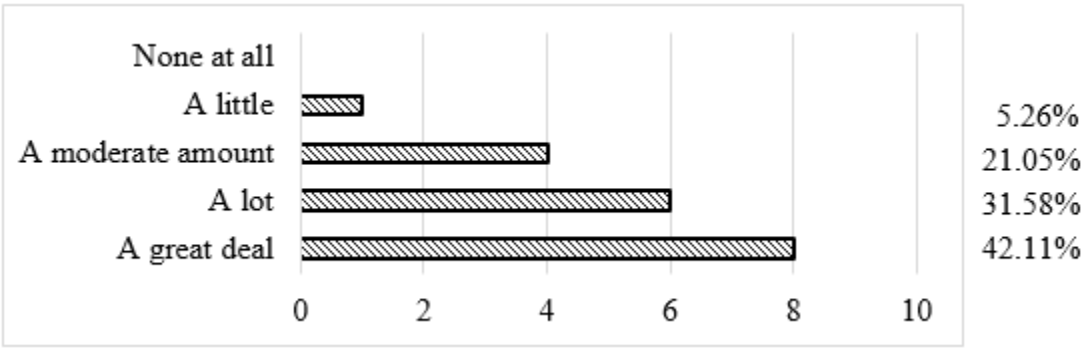

Figure 15: Percentage of students that selected one of the options on a Likert scale for question "*To what extend do you think you can apply the "Maker" topics presented in this workshop to your work?*"

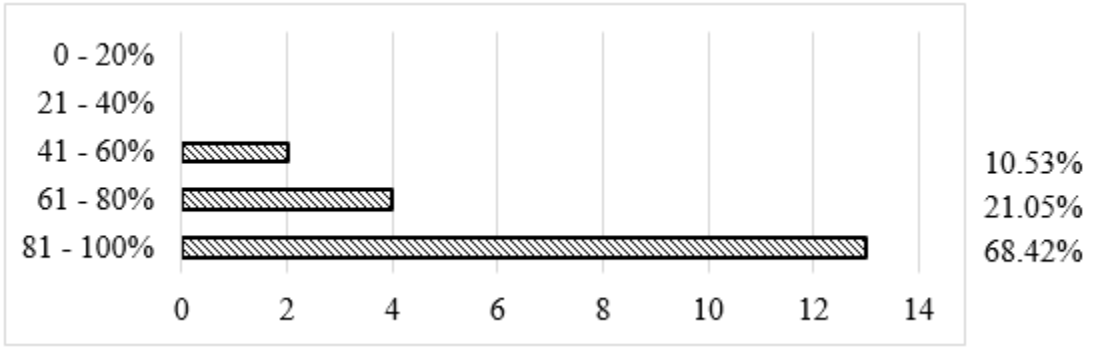

Figure 16: Percentage of students that selected one of the options on a Likert scale for question: "*Of the topics covered in the workshop, how much is usable to you?"*

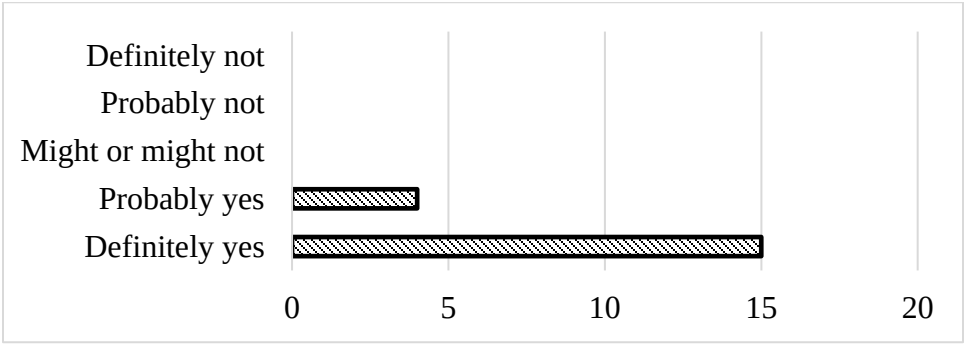

Figure 17: Percentage of students that selected one of the options on a Likert scale for question: *"Would you recommend this workshop to others?*"

Table 2: Percentage responses to the question *"Please rate the workshop on the following items on a 1 to 5 scale:"*

	N/A	1	2	3	4	5	Total
Content (1 = of little use, 5 = very useful)	0 0%	0 0%	0 0%	0 0%	7 36.84%	12 63.16%	19
Organization (1 = poor, 5 = excellent)	1 5.26%	0 0%	0 0%	3 15.79%	4 21.05%	11 57.89%	19
Use of Instructional aids (1 = appropriate, 5 = inappropriate)	0 0%	2 10.53%	1 5.25%	1 5.26%	7 36.84%	8 42.11%	19
Pace of delivery (1 = appropriate, 5 = inappropriate)	0 0%	3 15.79%	0 0%	4 21.05%	3 15.79%	9 47.37%	19
Booklet materials (1 = helpful, 5 = of little help)	0 0%	1 5.26%	2 10.53%	5 26.32%	4 21.05%	7 36.84%	19
Hands-on sessions (1 = appropriate, 5 = inappropriate)	0 0%	2 10.53%	0 0%	0 0%	2 10.53%	15 78.95%	19

Table 3: Percentage responses to the question: *"The workshop was designed to build different "Maker" skills. To what extend did the workshop helped you to build:"*

	Not at all	Very Little	Some	Very Much	I had these skills already	Total
Skills to use 3D printer	1 5.26%	1 5.26%	5 26.32%	10 52.63%	2 10.53%	19
Skills to build bioinspired robot	1 5.26%	0 0%	5 26.32%	13 68.42%	0 0%	19
Skills to design a part on a computer	0 0%	0 0%	5 26.32%	13 68.42%	1 5.26%	19
Skills to use the layered software Slic3r	1 5.26%	1 5.26%	4 21.05%	12 63.16%	1 5.26%	19
Skills to use a microcontroller (Arduino)	1 5.26%	0 0%	3 15.79%	14 73.68%	1 5.26%	19
Skills to program with Arduino	1 5.26%	1 5.26%	5 26.32%	12 63.16%	0 0%	19

Table 4: Percentage responses to the question*: "Would you like more information or an additional workshop on any of the topics covered in this workshop? (check all that apply)"*

Bioinspired robots	CAD – computer aided design	Arduino – electronics prototyping	3D Printing
12 22.64%	14 26.42%	14 26.42%	13 24.53%

The survey results presented above show a strong positive response from the participants. They liked the workshops overall, found them very useful and well organized. The topics included were all well received, and even though each of them can be individual topics in other settings, the fact that they were all merged in building of the final robots assured the unity of the workshops. The results also show that the topics covered stimulated the interest of the

participants, as each of them showed interest in learning more in few of the areas presented. Even though most of the participants had already made the choice to pursue studies towards an engineering degree before attending the workshops, the responses provided in these surveys show that the workshops was still very beneficial, and they helped all the participants learn new skills or reinforce some background knowledge. The most gain from the workshops seem to be the better understanding of the engineering complexity, the wide variety of career options, and the help each participant came to have in understanding their own preferences among these options. Even if some of them already made the choice for an electrical or mechanical engineering path for example, they were able to learn throughout the workshops the variety of choices available to them within each of the major fields. The choice for the bio-inspired robots as a learning platform to introduce the participants to the engineering complexity was definitively an excellent one to make. Not only that a variety of topics were introduced in order to build the robots, but they were also a great choice for making the workshops engaging, fun and exciting. This positive atmosphere throughout the duration of the workshops contributed to the receptiveness towards the topics presented and to the learning environment. The survey results also motivated the research team to conclude that the content and organization of the workshops would have led to similar results if all the participants would have been still in their prospective stage of choosing a further educational pathway, and would have definitely helped them decide on their future career choice. In future workshops for veterans will be offered by this research team most efforts would be focused on investigating various recruitment methods, including the use financial or academic incentives.

Conclusions

This paper presented the details of a series of bio-inspired robots workshops designed to stimulate the veterans' interest in pursuing engineering degrees. The paper includes the rationales for these workshops, the organizational and content details, as well as the lessons learned from the recruitment and demographic characteristics of the study group, and the feedback that the group provided. The workshops overall were successful, as the participants found the bio-inspired robots to be an excellent learning platform for introducing them to the variety of engineering specializations, and giving them the starting point for seeking further learning. Adult recruitment for educational programs is challenging in general, and bringing military veterans to the workshops was not an easy job. However, due to their previous exposure in the military to various hands on engineering trainings, veterans are excellent candidates for pursuing engineering degrees and to expand their opportunities for successful engineering careers. Moreover, there is a potential for these types of workshops to be offered to a wider adult population that is transitioning to a technical or engineering career, which opens the door for future studies.

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