Evaluation of Student Learning Outcomes and Motivation in an Innovative Engineering Course

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Abstract

This paper reports on the positive learning outcomes observed in an innovative undergraduate engineering class that incorporated veteran and non-veteran students' interest and prior experiences in military technology and experiential learning approaches. This study is a part of a larger project that evaluates a veteran and non-veteran recruitment and retention program at a large public urban university located in the Southeast region of the United States. The project targeted military veterans in an attempt to increase science, technology, engineering, and mathematics (STEM) enrollment and the number of degree recipients while facilitating non-veteran students' interest and comprehension of military technology and related career opportunities. Results indicated participating students, both veteran and non-veterans, demonstrated increased knowledge across multiple learning objectives set by the instructor. Engineering students also exhibited higher interest and awareness about science and technology careers within military and defense technology sectors.

Keywords

Veterans, mechanical engineering, STEM, military technology

Introduction

Military veterans' civilian transition has traditionally operated in conjunction with post-secondary education enrollment. The Post- 9/11 Veterans Educational Assistance Act passed in 2008 provides higher education benefits to the two million service members who enlisted in the military after 2001 and supports their civilian transition into post-secondary education enrollment[1]. A substantial number of veterans are transitioning from military into higher education institutions to increase their knowledge and skills sets, maximize employment opportunities, and achieve career goals[2,3]. Due to the growing number of veterans on higher education campuses, further research is necessary to identify proper academic supports to engage this new group of non-traditional students. One possible way to support student veterans is providing them with an opportunity to link their prior military experience and knowledge base to what they learn in academic courses. However, current literature rarely discusses the role of students' previous experiences, such as prior knowledge, expectations, dispositions, and how they influence student learning and knowledge acqusiiton[4,5].

Literature Review

Relevant literature on student learning outcomes primarily emphasizes the critical role that instructors play in student learning. Research on instructors' effectiveness is centered around four main themes: 1) personal characteristics, 2) content knowledge, 3) pedagogical knowledge, and 4) instructional designs and strategies[5,6]. Personal characteristics taken into account for instructors' effectiveness include personality traits, teaching style, and the ability to relate and form connections with students[6]. Pedagogical knowledge, outlined by Schulman, assesses an instructor's ability to teach based upon the course content knowledge, also known as the instructor's ability to transform content matter to facilitate attainment of student learning outcomes[7]. To increase instructor effectiveness and student learning outcomes, Okpala and Ellis recommend that instructors implement student-centered approaches rather than lecture-based to increase student engagement and achievement[6].

While the majority of research emphasizes the vital role of the instructor in the learning process, there is an increasing amount of literature focusing on students. Just as instructor effectiveness is centered around four themes summarized above, literature on student learning outcomes also centers around three main themes: 1) construction of knowledge, 2) constant feedback, and 3) application of knowledge[8,9]. To increase students' ability to retain information and construct knowledge adequately, students should be empowered to actively engage with material rather than passively receive information[9]. Constant feedback, the notion that learning is maintained through frequent feedback, aids students in becoming constructors of knowledge. Lastly, the application of knowledge, or the opportunity to apply the knowledge that has been learned in an engaging environment increases effective learning for students through multi-faceted processes[8]. Course designs that significantly rely on cooperative learning through group reflections and team assignments demonstrate increased levels of students' self-efficacy and individual learning outcomes[10,11]. Student-centered, hands-on projects are constructive, favorable activities for helping engineering students build problem-solving competency and quantitative reasoning skills[12.] The combination of these learning strategies and course activities is beneficial for addressing the eclectic backgrounds of students entering the engineering field[12].

With the vast majority of literature on student learning outcomes focuses on the influence instructors hold in student learning, the increase in research on students aids in development of effective course material to promote student learning outcomes. Specifically, when developing a course targeting the unique population of a collaborative veteran and non-veteran student class, the components of instructor effectiveness are important to consider. Although all four themes are crucial to quality course development and student learning outcomes, pedagogical knowledge and teaching strategies are key elements in course design. Student learning outcome themes emphasize the importance of reciprocity and empowering students to engage with academic material to increase information retention and critical application. Therefore, the development of innovative engineering courses should target student learning outcomes through active, experiential learning with multi-faceted teaching strategies and assessment tools.

Research Purpose

The purpose of this study was to determine the effectiveness of a new engineering undergraduate course, ENGR 3999 (a pseudonym) on student learning outcomes and two psychological/ affective measures. The psychological/affective measures evaluated by researchers encompass motivation and attitudes toward military science and technology careers. Through the analysis of quantitative survey data, researchers examined student's knowledge and competency to conduct experiments with varying military technology and equipment upon completion of the ENGR 3999 course.

Method

The quantitative portion of this study employed a non-experimental survey design. Members of the research team developed and administered pre- and post- surveys in order to assess the quality of student learning experiences in the ENGR 3999 course. Pre- and post- surveys also assessed the effectiveness in teaching engineering students about military engineering technology and the transferability of skills into the respective professional field.

Participants

Participants in this study consisted of 20 engineering students actively enrolled in the ENGR 3999 course in fall of 2018. Engineering students studied were all upperclassmen (i.e. juniors and seniors). The sample size encompassed both male (n=15) and female (n=5) engineering students. In the sample 15% (n=3) were student veterans, 10% (n=2) were minority students of differing race and ethnic backgrounds, while 90% (n=18) were Caucasian. Due to the survey being distributed anonymously and on a volunteer basis, it is not feasible to provide accurate demographics of all 18 survey respondents. The instructor, a Caucasian male, was accompanied by two teaching assistants to help throughout the course. One teaching assistant was an African American male and the other was a Caucasian male. Both of the teaching assistants were student veterans.

Course Development and Objectives

ENGR 3999, an innovative engineering course, was developed to engage undergraduate students in experiential learning through varied instructional strategies including lecture, research, and experimental labs. Course objectives emphasize gaining knowledge on instrumentation and data acquisition while targeting application skills in undergraduate engineering students. Students are introduced to topics such as wireless communication, wind and water tunnels, composite airframes, and unmanned aerial vehicles (UAVs).

Through enrollment in the course, students had the opportunity to engage in a lecture session followed by a corresponding lab experience in the following areas: wireless transmission, parachutes, rocket nozzles, carbon fibers, quadcopter tracking, particle image velocimetry (PIV), and wind and water tunnels. Specific learning outcomes included: 1) determine wind velocity and pressure data, 2) identify basic types of structural damage and most probable causes, 3) identify and describe three types of wireless networks, 4) calculate coefficient of drags of parachutes, 5) list advantages of composite materials and defense applications, and 6) demonstrate operation of wind tunnels, water tunnels, and PIVs. Student projects and hands-on experiments were conducted individually and within teams resulting in collaborative groupings of veterans and non-veteran students.

While the course materials covered a broad spectrum of experimental engineering methods, key learning contents and related lab experience were grounded in integration of engineering and military technology experiences. For example, one aspect of the course that worked directly with military technology was the subject of rocket nozzles. Through involvement in lecture, lab, homework, and the writing of a lab report, students had the opportunity to gain knowledge on the use of rocket nozzles in the military setting as a propellant. Another aspect of the course directly related to military technology was the quadcopter tracking lab. Through engagement in the lab experience, students had the opportunity to gain further understanding of the use of quadcopters as a surveillance tactic in the military. Students not only had the opportunity to engage in experiential learning through lecture, research, and experimental labs, but also attend guest lectures on related course material. Guest lectures as related to military technology include: NAVAIR, a group intended to support naval aviation aircraft, as well as navy nuclear. Through active engagement and participation in the ENGR 3999 course, both veteran and non-veteran students received the opportunity to increase their knowledge and awareness of military-related technology and tools.

Quantitative Data Collection and Analysis

Pre- and post- surveys were implemented as a formative measure for the evaluation of student learning outcomes and motivational constructs. Formative measures for the study were developed by a team of faculty members consisting of two engineering faculty members and one external evaluator. One of the two engineering faculty members was the ENGR 3999 course instructor. Survey questions were created based upon ENGR 3999 course objectives and learning outcomes. The last two questions (survey questions 10 and 11) measured two key motivational constructs of interest. The survey was designed to answer the following research question: (1) Upon successful completion of this course will engineering students have the ability and knowledge to design and conduct experiments with a variety of military technology and equipment?

Pre- and post-survey questions measured five major constructs: 1) students' knowledge of water and wind tunnels (survey questions 1, 2, and 3), 2) students' knowledge of military technology applications (survey questions 4, 5, 6, and 7), 3) students' knowledge of mechanical system damage (survey questions 8 and 9), 4) students' interests in science and technology career opportunities in the military (survey question 10), and 5) students' intent to pursue science and technology career opportunities in the military (survey question 11).

Given the purpose of the quantitative study was to asses students' ability and knowledge to design and conduct experiments with military technology, both survey constructs two and three consisted of sub-constructs to more accurately assess the course learning outcomes. Student's knowledge of military technology application (construct two) consisted of sub-constructs related to unmanned aerial vehicles, composite airframes, and wireless networks. Students' knowledge of mechanical system damage (construct 3) consisted of sub-constructs related to the ability to identify and determine root cases of mechanical system damage. These sub-constructs were created to align with and correctly measure the student learning outcomes within the MEGR 3999 course (i.e. identify basic types of structural damage and most probable causes and identify and describe three types of wireless networks).

Surveys were distributed to engineering students (n=20) at the beginning of the semester and upon course completion. Both pre- and post- surveys were completed by 18 students. Answer choices were converted to a 5-point Likert scale: 1= totally disagree; 2= disagree; 3= neither agree nor disagree; 4= agree; and 5= totally agree. To evaluate the issue of comparable learning outcomes, the following hypothesis was evaluated across all five constructs:

> H_0: There is no statistically significant difference in mean scores of all 5 constructs between pre- and post-surveys for ENGR 3999.
>
> H_a: There is a statistically significant difference in the mean scores of all 5 constructs between pre- and post- surveys for ENGR 3999.

Data collection and analysis were conducted by a faculty member and their evaluation team consisting of three research assistants. Research assistants completed data entry and statistical analysis using SPSS. A paired t-test was conducted to compare the mean scores and standard variations on five target constructs between the pre-and post- surveys. Although the course consisted of 20 students, only 18 students participated in the pre- and post- test data collection procedures.

Results

This result section engages the reader in quantitative results examining whether ENGR 3999 lead to significant increases in engineering students' knowledge of military technology. A paired t-test was administered between pre- and post- survey means to determine whether ENGR 3999 course implementation was positively associated with three student learning outcomes and two motivational constructs. Pre- and post- survey means, standard deviations, and differences for each construct are shown in Table 1.

Table 1: Pre-Post Survey Means, Standard Deviations, and p-value

Concept	Survey	Mean	SD	p-value*
Student knowledge of water and wind tunnels	Pre Post	1.54 3.60	0.69 0.62	0.00
Student knowledge of military technology application	Pre Post	2.35 4.33	1.01 0.48	0.00
Student knowledge of mechanical system damage	Pre Post	2.72 3.86	1.05 0.73	0.00
Student interests in science and technology career opportunities in the military	Pre Post	2.72 4.67	1.10 0.58	0.00
Students' intent to pursue science and technology career opportunities in the military	Pre Post	2.50 3.06	1.31 1.32	0.004

*Note: *p<.01 (two-tailed test)*

Table 1 presents the means, standard deviations, and p-value for each construct measured between the pre- and post- surveys. The null hypothesis is rejected and the alternative hypothesis is accepted due to the p-value equaling less than $\alpha = 0.01$. Overall, the pre- and post- survey scores were statistically significant, with additional analysis determining that all five constructs were also statistically significant suggesting that cognitive outcomes increased as learning effectiveness increased. The first four learning outcomes were found to be statistically significant at ($p<0.001$). The last construct, students' intent to pursue career opportunities in the military, was also statistically significant ($p<0.005$). The results indicate that students in the ENGR 3999 course gained knowledge on water and wind tunnels, military technology applications, mechanical system damage, as well as opportunities and interests for pursuing science and technology careers in the military.

Discussion

The results of this evaluation research provide strong evidence that the ENGR 3999 course had a positive impact on engineering students' learning of military technology and increased their motivation and interest in related professional careers. Students in the course showed a statistically significant increase across all five measures including three learning outcomes: water and wind tunnels, military technology applications, mechanical system damage, as well as two psychological/affective domains, interests in and motivation for pursuing science and technology careers in the military. While surveys, as a self-reported measure, may have a limitation in assessing student learning outcomes, the participating students' clear sense of effective learning in the course is still noteworthy. Because this quantitative study was part of a larger mixed-methods study, students' focus group interview data provided further evidence that the application of student-centered approaches in the course resulted in an increase in student engagement and positive learning outcomes[6]. The qualitative data also suggest that students' positive cognitive learning outcomes was due to the multi-faceted learning strategies implemented by course instructors through his lecture and active lab engagement[8]. For example, one student, a non-veteran Mechanical Engineering major, stated,

> Yeah, I would say that as far as teaching method. It's kind of what I said earlier which would be just getting like on lecture talking about applications in the real world. And then the next lecture switches to seeing it actually happening in front of you, to being involved, to making it happen. Cause I felt like once the hands-on sessions happen I was able to get a better grasp of what we talked about in the lecture.

Students consistently discussed the value of experiential and hands-on learning in the class and mentioned it as a factor positively affecting their learning outcomes. One student, an Air Traffic Control Officer in the Navy for eight years, summarized it,

> What I found most helpful was the labs, of course because it's hands-on. You can see it and apply what you learned in the lecture. That's what helps me the most, the hands-on. Not just talking about the experiment but doing the experiment in the lab. Seeing with my eyes and touching with my hands and seeing the data, seeing the results- that's what

> helped me the most. That's what I enjoyed the most, as opposed to just a head in the books, So, it definitely is more applicable to see it applied.

Additional data collection by the evaluation of the team through end-of-course focus group interviews and classroom observations suggest that student veterans enrolled in the course had the opportunity to develop a connection with their program of study through a sense of familiarity in utilization of military experiences and trainings. One veteran stated,

> Just because I had worked with some of these systems, and some of these, uhm, air craft and stuff like that. I just wanted to find out more about it with a deeper interest. And plus as an engineering major now, it's been my interest since I was in the military, and I'm still pursuing air craft positions now in an air craft field as an engineer. A lot of things relate to the same thing.

Through enrollment in the ENGR 3999 course, student veterans have the opportunity to develop a connection with their program of study through a sense of familiarity in utilization of military experiences and trainings. Furthermore, interview data revealed that non-veteran students also developed a sense of empathy and connection with their student veteran counterparts through authentic interactions and shared training experiences with various forms of military technology throughout the course. The experiential learning component of the course led to collaboration between veteran and non-veteran students, affording them to have a unique, synergetic experience in group discussion. One Marine veteran stated,

> Yeah, I liked the idea that in every lecture a lot of people had input on it. Rather it was veteran students or non-veteran students, our professor, or TA… like everyone had a different point of view. A lot of people in the class had hands-on experience with something. One of the guys had hands-on experience with carbon fiber with Boeing, I think. Everybody had a little bit of something else to throw into the group and chime in on different subjects, and again not just the veteran students.

In particular, observed learning effectiveness can be linked to the two concepts, students' ability to actively construct knowledge and application of knowledge highlighted in existing literature[7,8]. Students ability to actively construct knowledge in the ENGR 3999 course and opportunity to apply knowledge through lab experiences created a positive learning environment with student-centered approaches at the forefront[6,7,8].

Conclusion

Upon completion of the course, results from the pre- and post- survey data demonstrated that the ENGR 3999 course had a positive impact on both veteran and non-veteran students' learning of military technology, resulting in increased motivation and interest in military technology careers. Instructors' utilization of diverse teaching strategies facilitated engineering students' engagement, productive learning experience, and cognitive learning outcomes, which all validated the effectiveness of experiential and hands-on learning in engineering courses[12]. While all ENGR 3999 students self-reported increased knowledge and skill development in military technology and career interest in related STEM fields, non-veteran students learned important professional skills from the interactive and inclusive classroom environment that fostered professional collaboration and empathetic dispositions toward veteran students. This unique relational connection formed by student veterans and non-veteran students was conducive to their positive course experience and overall learning outcomes. Results presented in this study indicated that the ENGR 3999 course provided a positive learning environment for both veteran and non-veteran students in which the significant relational and cultural gap commonly found between traditional engineering students and student veterans seemed to diminish. When given the opportunity to participate collaboratively in their educational experiences, traditional non-veteran students gained a deeper appreciation for the knowledge and skills required by veteran, and both group of students were engaged in shared learning and growth.

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Dr. Peter Tkacik is a professor in the William States Lee College of Engineering. Throughout his time at UNC-Charlotte, Dr. Tkacik has taught sixteen different courses, ten of which are new to the university. He was the recipient of the Bonnie E. Cone Early-Career Professorship in Teaching from 2016 to 2019 and served as a UG mentor for 239 students in senior design. Dr. Tkacik has received thirty-four research grant awards and three equipment donations totaling over $5.4 million. His major initiatives center around tire cornering force research and veterans in engineering. Dr. Tkacik received his Ph.D. in Mechanical Engineering from the University of South Carolina in 1991.

Dr. Jerry Dahlberg

Dr. Jerry Dahlberg is an assistant teaching professor in the William States Lee College of Engineering. He currently teaches Manufacturing Systems (MEGR 2180) and serves as the Senior Design Committee Chair. Prior to becoming a faculty member at UNC-Charlotte, Jerry retired from the U.S. Army after 20 years of service. Jerry works on numerous veteran programs inside the College of Engineering and the Mechanical Engineering and Engineering Science Department. Upon his retirement from the Army in 2010, Dr. Dahlberg enrolled at UNC-Charlotte in the B.S. Mechanical Engineering program, and then went on to complete his M.E. degree in 2016, and Ph.D. in 2018.

Dr. Jae Hoon Lim

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Appendix A

Military Instrumentation and Technology: Pre-Survey*

I. Rate your agreement with each of the following statements using the scale below.

1	**2**	**3**	**4**	**5**
Totally Disagree	Disagree	Neither Agree Nor Disagree	Agree	Totally Agree

1.	I can operate a wind tunnel.	1 2 3 4 5
2.	I can operate a water tunnel.	1 2 3 4 5
3.	I can use Particle Image Velocimetry (PIV) to evaluate fluid flow in a wind or water tunnel.	1 2 3 4 5
4.	I can describe the process for repairing composite air frames.	1 2 3 4 5
5.	I can identify different types of wireless networks.	1 2 3 4 5
6.	I can describe various wireless network applications.	1 2 3 4 5
7.	I can describe how GPS is used to control unmanned aerial vehicles (UAV).	1 2 3 4 5
8.	I can identify different types of mechanical system damage.	1 2 3 4 5
9.	I can determine the root cause(s) of mechanical system damage.	1 2 3 4 5
10.	I am aware of Navy science and technology career opportunities.	1 2 3 4 5
11.	I am interested in pursuing Navy science and technology career opportunities after graduation.	1 2 3 4 5

II. Answer the following questions as best as possible based on your current knowledge and experience

12. List and briefly describe 3 types of parachutes.
13. List and briefly describe 3 types of wireless networks.
14. List 3 factors that impact rocket nozzle exit Mach numbers.

III. What was your primary reason for enrolling in this course?

- o Defense industry career interest
- o Prior veteran experiences
- o Interested in topic/research
- o Technical/Motorsport elective credit
- o Faculty recommendation
- o Peer recommendation
- o Other: ________________________________

IV. What do you hope to learn or do in this course?

*The Post-survey consists of the 14 questions listed in Section I and II in this Pre-survey.