Authentic Knowledge, Learning Outcomes, and Professional Identity: A Mixed-Methods Study of a Successful Engineering Course

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***Abstract*—This research full paper reports results from a sequential mixed-methods study that included quantitative (pre- and post-survey) and qualitative (focus group interviews, class observations, and student journals) data from 60 undergraduate engineering students. Subject matter authenticity is an important topic in engineering education research. The study investigated how students evaluated and accepted the relevance/authenticity of knowledge delivered by the instructors in an engineering course focusing on military technology. Quantitative data analysis with students' pre- and post-surveys showed a statistically different difference indicating that students' learning in the class was highly effective. Qualitative findings provided a further and detailed account of how the students organized, evaluated, and accepted the new course contents. Overall results indicate that successful learning involves students' holistic development, affirming their current personal and professional identities and facilitating new professional identities which create a meaningful connection to the new piece of knowledge presented to them.**

Keywords—authentic knowledge, mixed methods, professional identity

I. Introduction

Effective teaching and learning have historically been a topic of scholarly interest among educational researchers including engineering educators. The process of teaching, however, is not a one-dimensional phenomenon but shaped by multiple factors [1]. The current body of research on student learning focuses primarily on the aspect of instructors, examining instructors' personal characteristics [2], their content and pedagogical knowledge [3], and their instructional designs/strategies [4]. Less is known about how students' prior knowledge, expectations, and dispositions facilitate or hinder their construction of meaning over the delivered content knowledge, and how/why they accept its relevance and authenticity. Students, conceptualized as the main agent of learning and understanding in this study, are capable of accepting or repudiating the relevance and legitimacy of the subject matter presented in a classroom context. Furthermore, learning is not a simple psychological or cognitive process, but a multifaceted, complex process that involves the instructors' and students' past, current, and emergent identities [5].

In an effort to understand the nature of student learning and its pedagogical implications, we focused on an engineering course and how its specific subject matter on military technology and instrumentation was perceived, adopted, and adapted to the core interests and dispositions of the learners. To understand the nature of student learning and its pedagogical implications, the purpose of this paper was to explore how students made sense of the subject matter and accepted it as authentic, relevant, and legitimate knowledge.

II. Theoretical Framework

In the research literature on education, there is a shared interest in teachers' professional knowledge [6, 7, 8]. Traditional perspectives of pedagogy support a dualistic nature of teacher expertise composed of content knowledge—the scholar's understanding and specialty of the subject taught—and pedagogical knowledge—the instructor's organization and preparation of the classroom for instruction. We also know that teaching requires much more than simply knowledge of the subject matter being taught [8]. Lee Schulman [9] recognized a large base of knowledge for teaching that includes: content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge; knowledge of learners; knowledge of educational contexts; and knowledge of educational ends, purposes, and values. He also believed in an important and separate category known as knowledge of learners—a specific understanding of the learners' characteristics and how these characteristics can either support or hinder student's learning [9].

Jean Lave and Etienne Wenger [5] introduced the theory of situated learning as an alternative perspective to explain the nature of learning in society. Whereas traditional theories conceptualized learning as a psychological, cognitive process of certain forms of knowledge acquisition, Lave and Wenger explained that learning in nature is a social process--a process of engagement in a "community of practice" [5]. From this perspective, learning takes place when an individual develops a set of relationships with others (co-participants) in the community [5]. She/he initially engages in "peripheral participation" developing competency and comfort, and gradually progresses to larger and more complex activities

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through enriched collaboration. In other words, the process of learning itself involves a fundamental change in his or her identity by internalizing a set of values and norms in the community and embodying behavioral patterns that characterize the members of the particular community.

In engineering education, the concept of authenticity was introduced with a strong call for student-centered learning and is seen as a hallmark of best-practice development for different learning environments [10]. Major theories and design models were developed to increase authenticity including the use of simulations, cognitive apprenticeship, and problem-based learning frameworks [11]. These theoretical frameworks remind us that the learning process is an intricate relationship between knowledge of learners, situated learning, and context authenticity.

III. Methods

A sequential mixed-methods approach combining a qualitative discourse analysis method and a pre- and post-survey was employed [12]. This research design "employs the methods that will best advocate for participants and better understand a phenomenon or process that is changing as a result of being studied" [12].

A. Participants and Classroom Context

This two-year study was conducted at a large urban public research institution located in the southeastern United States. The course was offered at an engineering program each fall semester in the southeastern United States and was designed for veteran and nonveteran students to learn about military technology applications and job opportunities. The course was taught twice a week; one day dedicated to lecture and the other focused on the application of the acquired knowledge in experimental labs. For example, students would first learn about the structure and applications of different technology and equipment such as parachutes and carbon fiber. In the following class, students would engage in different laboratory activities that allowed them to apply the material, such as constructing a coaster out of carbon fiber.

The sample included 60 junior or senior engineering students, mostly Caucasian males (68%), with eight (13%) Caucasian female students, five (8%) racial/ethnic minority students, and six (10%) Caucasian male students with a military background. The instructor and teaching assistants (TAs), were Caucasian males. Both TAs were graduate student veterans.

B. Data Collection Procedures

Four types of data were collected each year: pre- and post- survey, class observations, student journals, and focus group interviews.

Pre- and post-surveys are widely accepted as a viable method to quantify the knowledge attained by the students with diverse learning styles and educational backgrounds in a course [12]. By comparing the results from pre- and post-surveys, the success of a course in increasing participant knowledge and understanding of the course content can be measured [12]. The research team created a 12-item survey to evaluate five objectives that were aligned with the curriculum. Ten of them were intended to measure students' knowledge of water and wind tunnels, military technology applications, and mechanical system damage. One question was intended to measure students' interests in science and technology career opportunities in the military, while the final question aimed to measure students' intent to pursue science and technology careers opportunities in the military. The pre- and post- survey were administered at the beginning and end of the semester, following the same format, and under the same conditions to minimize any instrumentation or reporting threats.All questions were based on a 5-point Likert scale (1=totally disagree to 5=totally agree). In order to address other threats of validity, the authors also collected and analyzed supplemental data (i.e. participants' journal entries, focus grousp interviews, and observations) that supported the increase of students' knowledge of the course content.

Three types of qualitative data were utilized in this study. Four reflective journal entries were collected from each student throughout four different periods of the semester. Students were asked to reflect on their expectations of the course, the most helpful and challenging aspects of the course, what they learned after successful completion, students' prior experiences or knowledge of military technology and applications, and how lectures provided by TAs and guest speakers with first-hand knowledge of the course content impacted their learning. In addition, three observations were conducted by a research assistant each year. Each observation lasted the entire class period and therefore took about one hour and 45 minutes. The observing researcher created an observation log for each class documenting several key academic, social, and educational aspects of the lecture or experimental labs. Finally, by the end of each semester, the research team also conducted focus group interviews. Each focus group interview had 4 or 5 engineering students enrolled in the course and lasted about 20-30 minutes. Focus groups were based on a semi-structured interview protocol and were audio-recorded for verbatim transcription later.

C. Data Analysis

To determine whether the course implementation was associated with students' learning of military technology applications, a paired sample t-test was conducted for all five constructs measured by the surveys.

Using thematic analysis, an initial set of open codes was created reflecting key points made by the students. Atlas.ti, a qualitative analysis software, was used to ensure consistency and thoroughness in the coding process. The occurrence of each code was marked to estimate consistency of the initial observations and determine thematic categories. To ensure the confidentiality of all participants and minimize possible psychological pressure, all quantitative and qualitative data were managed by the research team. After reviewing the entire qualitative data set, the team examined the linkage between frequent thematic categories observed across multiple sets of data (i.e., journal entries, observations, and interview transcripts) and across many participants, identifying major patterns and relationships in the data and drawing three thematic categories.

The research team employed strategies throughout the entire research process to ensure the quality and trustworthiness of final outcomes including peer review and researcher triangulation. Data were analyzed collaboratively by the entire research team. This researcher triangulation is one of the key quality-ensuring strategies adopted in the study. The research team included four researchers, each with a distinct cultural, ethnic, and professional background including some with first-hand military experience which facilitated open discussion that maximized trustworthiness throughout the data collection and analysis.

IV. RESULTS

A. Pre-and Post-Surveys

To evaluate positive outcomes in student learning, a paired t-test was conducted for each objective (see Table 1). There is a statistically significant difference between the mean scores of pre-surveys (M=2.23, SD=1.2) and post-surveys (M=4.32, SD=0.45) for all five objectives; t(59)=2.66, $p<0.01$ with an effect size of .65. The results suggest that the objectives of the course curriculum were obtained. Engineering students in the course increased their knowledge on military technology applications, as well as their interests in pursuing science and technology careers in the military.

TABLE I. PRE-POST SURVEY

Course Objective	*Pre*		*Post*		*P-Value*
	Mean	*SD*	*Mean*	*SD*	
Student knowledge of water and wind tunnels	1.45	0.91	3.96	0.40	0.00
Student knowledge of military technology application	2.03	1.11	4.55	0.37	0.00
Student knowledge of mechanical systems damage	2.68	1.24	4.49	0.32	0.00
Student interests in science and technology career opportunities in the military	2.26	1.27	4.71	0.21	0.00
Students intent to pursue science and technology careers opportunities in the military	2.74	1.47	3.90	0.96	.002

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

B. Qualitative Findings

Qualitative data analysis generated twelve key codes that helped illuminate how students approached, evaluated, and accepted incoming information and how they developed interest in military technology applications. The codes were later classified into in four thematic categories: (1) Prior dispositions, (2) Interpersonal relationships, (3) Authentic knowledge, and (4) Coalescing professional identity. Each of these four themes are further explained below with students' direct quotes as supporting evidence.

TABLE II. CODE FREQUENCIES FOR STUDENTS (N=60)

Major Codes	*n*	*Frequency*
Interest in military knowledge	56	84
Interest in engineering jobs in the military	48	90
Students' connections with the military	12	65
Positive interpersonal relationships	36	55
Instructors' passion for the course content	20	68
Instructor and TA's teaching style	26	76
Professional speakers with authentic knowledge	58	90
Instructor's willingness to share the role of expert	40	71
TA's military background	43	96
Instructor and TAs' pedagogical content knowledge	54	74
Students' experience-based knowledge	60	96
Connecting theory to application	60	103
Self-competency as professional engineers	44	73
Students veterans' military-civilian connection	6	29

1) Prior Dispositions

Upon enrollment, students showed a keen interest in the content of the course, military technology, and a desire to explore the content in relation to their professional career. Students expressed a professional curiosity about military technology and engineering jobs in the military, as well as intent to build a professional relationship with the military engineering community. Through positive interpersonal relationships with the instructor and TAs, students became more proficient in the course contents and constructed identities aligned to the topics of the course [2, 4]. The students' journal entries displayed their willingness to accept materials presented to them throughout the course. Many students recollected their childhood fascination with technological innovations in the history of military engineering, as explained by one student,

> *As a kid, my interest has always been science. I was the kid who eager to know how stuff works. I was also the kid who disassemble and break/fix stuff. Through history, military had huge impact over technology. Military technology has always been the most advanced technology in the world so I am so curious to know more about military technology.*

The second most common reason for enrollment was previous connections with the military that sparked an interest in military technology applications. Students either had family members who were in the military or had been service members themselves as one student veteran explained,

> *I enrolled in this course for many reasons. I had heard good stuff about the course and the subject material appeared to interest me. With my prior military background, I thought the course would benefit me as an engineer, and maybe even help me get a job in the federal sector.*

As evidenced by their journals, their openness to newly introduced learning materials and their willingness to accept the given content knowledge made them advance in the field of military technology.

2) Interpersonal Relationships

Many engineering students mentioned that the interpersonal relationships formed within the classroom were conducive to their learning. A good number of students had taken courses with the professor and enjoyed his teaching style and passion for the course content. Students felt that he was approachable and someone who showed interest in their own success. Students felt the instructor and TA's "rapport with the students" encouraged them to discuss, ask questions in class and feel more engaged, as explained by one student,

> *I think Dr. T is a great teacher, very knowledgeable about what he's talking about, very fun guy and great personality. The way he interacts with the class makes it fun. Definitely one of my favorite teachers I've had.*

Many students also mentioned that the professor and TAs were the most helpful resources when they faced challenges with the course content. Students enjoyed having the TAs' support and would seek them when they faced any challenge in the classroom or with homework. One female student recounted how both the professor and TAs were willing and responsive to provide help in person or via email,

> *Probably the teaching method of the teacher, Dr. T, is really helpful. The environment is really good, the working environment, and sometimes it's just the way he talks, just the way he acts. It's just really good. Whenever you have question to ask for him, you go for it and he'll answer it. The TAs, they're also really good and helpful and sometimes when you email them, they take their time to respond, but they definitely respond.*

3) Authentic Knowledge

Of particular importance for the engineering students was the conviction that the class instructor and TAs had superb pedagogical content knowledge [9]. This included the ability to select appropriate topics and hands-on instructional strategies as well as facilitation of real-world connections that provided "a perfect opportunity to gain an aptitude in both theory and application," stated one student. Another recurring subtheme was the instructors' willingness to create a learning space for authentic knowledge experiences. That is, the professor would acknowledge his scope of military engineering applications and invite guest speakers or TAs with military background that had more expertise on the subject at hand. Students respected the instructor's openness to share the "role of the expert" by establishing a space for the TAs and guest speakers with significant military backgrounds, as explained by one student.

> *The lecture then lab rotation of the course works well to educate students about the various topics in the class. By having the professor invite guest speakers to present the lab topic prior to the experiment, students have a good foundation of knowledge prior to analyzing the data. For example, having the paratrooper lecture the class prior to the parachute lab introduced me to many things I was able to look for during the experiment. I liked how he's brought in people with personal experience about what he's talking about.*

By doing so, all students mentioned that experience-based knowledge presented by those with military background attested its authenticity with personal credibility. "Dr. T. lectures in areas and topics that he has expertise in; however, if anyone (expert or classmate) has a greater knowledge of the subject, Dr. T. gladly lets them discuss the topic," explained another student.

Students enjoyed listening to first-hand experiences from the TAs and the guest speakers who work with military technologies and instrumentation. "They've got testimony because they have gone through it," stated by students who interpreted TAs and guest speakers' military experiences as primary and legitimate sources of knowledge. Class observations were also able to capture students' first-hand experience with authentic knowledge. One Teaching Assistant, a former infantry paratrooper in the Army, provided a lecture on the aerodynamic functions of military parachutes. Throughout the lecture, the students inquired about the TA's personal military experiences of parachute functions, as well as engineering elements that prevent parachute malfunctioning. In order to answer these questions, the TA had to recall painful memories of combat, adding a sense for all that the lecture's content was a serious matter. This was a critical moment for students' learning experience. As one student stated,

> *"TAs with actual military experience can give in-depth examples on how our engineering decisions will affect the soldiers; it gives us a perspective that most of us don't have."*

4) Coalescing Professional Identity

Students' professional identity developed in relation to the course content and the instructors [5]. As students progressed throughout the course, they expressed a connection to the content presented. Not only were the activities and lectures enjoyable for students, but students recalled that laboratory activities provided a window into life after academia in their desired role as professional engineers. Many students stated that this class prepared them to be a "well-rounded engineers." Some students even felt compelled to pursue a similar or related professional career as their instructors or guest speakers. One student explained,

> *The parachute lab was probably the best one in my experience because they had multiple videos explaining how it worked, and then we could go outside and do it ourselves. It was kind of like a real-life implementation as if though we were all an engineering team. I didn't know there are so many different types of parachutes out there and how their functions can change based off their shape and dimensions and how they can be controlled.*

The engineering students also felt that hands-on activities connected theory to application in real-world situations with technology design, problem-solving strategies, and applications of military technology. Their ability to successfully apply the material and solve problems individually or in groups increase their self-competency as professional engineers. Three students discussed their experiences during a focus group interview,

> *P1: I think the class gave me more confidence. All the other classes have labs where there's a lecture portion and a lab portion but they're separated. So what you learn one day is not what you're gonna be doing in the lab because it's off schedule, but then here because you're learning it, then you're applying it and you can get it to work, it definitely helped a lot.*

> *P2: I was actually gonna say a similar thing. It did make me more confident in my abilities and skills because there was very little inconsistency between other labs and lectures. Here the material was consistent at all times.*

> *P3: Yeah, same thing, you can watch someone do a math problem but unless you do it yourself, you really don't know what you're doing. So just being able to apply it, made me feel more competent.*

For student veterans, this class presented an opportunity to share their life experiences and connect their prior military experience with engineering material. Nonveteran engineering students also felt connected to the material as they accepted and valued the knowledge delivered to them. Students enjoyed having professional engineers who work in the field of military technology and instrumentation as guest speakers. Their presentations showed students an accurate representation of the major performance skills, knowledge, and dispositions required of professionals in the field. One student mentioned,

> *I especially liked the NavAir guest speakers. It was a good experience to meet other professionals that are in the field. I learned about difficulties and problems they faced in the workplace and how they overcame these obstacles to succeed in their career. It is great to know what to expect when I become an engineer.*

V. Discussion

This study explored how students, as co-creators of the classroom, negotiated incoming information and interest on military technology applications. This study investigated how students evaluated and accepted the relevance/authenticity of knowledge delivered by the instructors in an engineering course that subsequently impacted their professional identity development. Quantitative data analysis indicated that students' pre-and post-surveys were statistically different, suggesting that students' ability and knowledge to design and conduct experiments with a variety of military technology and equipment (i.e. jet propulsion, rockets, underwater propulsion, high-speed vehicles, and mechanical system damages) increased after the class. Results from pre-post surveys also support that students in the course shared more interest in engineering jobs in the military. Qualitative findings provided an in-depth exploration of how students organized, evaluated, negotiated with, and accepted the new course contents.

Understanding student's prior dispositions before enrollment was important to understand how they accepted or rejected the course content. Even before the course had been underway, many students showed a keen interest in the content of the course, military technology, and a desire to explore the content in relation to their professional career. Like Coleman (1990), Stryker (1980, 2002), and others, it is our view that the social structure is created by the actions of individuals, though it is recognized that these actions are produced in the context of the social structure they create and are influenced by this context. Therefore, there could have been an elaborate system of mutual influences between students' prior dispositions and attitudes towards the military, and the course context—military engineering applications—that potentially affirmed and verified students already established professional identity and interest within military engineering applications.

Several engineering students mentioned that the interpersonal relationships formed within the classroom were conducive to their learning. These findings remind us that learning is largely the function of its social context [5], which is affected by interpersonal relationships between co-creators of knowledge, in this instance students, professor, and TAs. As such, their learning was situated within these relationships that allowed students to feel more comfortable to ask questions, discuss, problem solve, and engage as active learners. These findings stress the importance of social relationships and broadens the concept of learning beyond the focus on cognitive processes.

Finally, the authenticity of knowledge provided by the instructors, TAs, and the guest speakers who work with military technologies and instrumentation attested the knowledge that students were learning in the class. Students not only enjoyed listening to first-hand experiences, but felt that this made the information more credible and important. Hands-on activities also provided direct experience with the material by integrating both theory and application. Students enjoyed the dual nature of the course that allowed them to apply the information learned through lectures. During their laboratory activities they were able to apply the knowledge, skills, and competencies required by professional engineers. By engaging in these exercises that required them to problem solve, experiment, work in teams, lead, and report their findings, students' application of theory increased their self-competency and proficiency with technology design, trouble-shoot strategies, and real-world applications of military technology. Finally, their ability to connect theory with application in real-life situations—made important by guest lecturers and TAs with first-hand knowledge of military engineering—encouraged students to feel connected to the material and value the knowledge delivered to them. As a whole, the students' overall learning experiences in the class reflected the very concept of "peripheral participation" [5] in which learning was inexorably aligned to their emerging professional identity and collaborative social networks.

VI. SIGNIFICANCE OF THE STUDY

Findings from this study provided important insight into how and why students find certain content knowledge meaningful and authentic, which ultimately translates to significant student learning outcomes. Practical implications could be drawn about how content knowledge should be organized, presented, and adapted to the interest and dispositions of learners to maximize student learning outcomes. First considering that individuals make sense of new incoming information based on their current knowledge, it is important to assess knowledge of learners—a specific understanding of the learners' characteristics and how these characteristics can either support or hinder student's learning [9].

Second, findings support the providing space for authentic and experience-based knowledge impact content authenticity and students' openness and connection to the material. It is important to consider different sources of authentic knowledge outside of the instructors' knowledge or the textbook, such as guest lecturers, media sources, or students' first-hand experiences with the course content. Third, although students may accept incoming information as accurate, they must have their own connection with the material as co-creators of knowledge. Research has shown that there are several critical factors that motivate students to connect a particular activity and to their professional career, one of them being that the experience is authentic, meaningful, and connected to their own real-world understanding [3, 5, 10]. Therefore, hands-on or experiential activities allow students to personally connect their professional identity with the course content. Most important, this study suggests that successful learning inevitably involves students' holistic development, enacting and constructing new professional identities that create a meaningful connection to the new piece of knowledge presented to them.

VII. LIMITATIONS AND FUTURE RESEARCH

Like all other research studies, our study is not without limitations. There are some threats to the validity of this research: (1) the limited number of participants, (2) other factors not considered in the study may have impacted on the results, (3) the student self-report measure allows bias in responses. Therefore, it is important to conduct further research to better assess the impact of these factors on student learning outcomes through an experimental study and/or more sophisticated measures. As future work, we intend to improve the quality of measures and accurately evaluate the correlation amongst student's learning outcomes, authentic knowledge, and professional identity.

In addition to the implications for educational practice, the analysis has also introduced several opportunities for future study. As discussed, this course was chosen primarily because of its dual structure that included a complimentary lecture and laboratory activity. However, the analysis did not focus on students' diversity in terms of race and gender and how these factors influenced their learning as co-creators of knowledge. Examining these characteristics could provide a better understanding of how gender and race could either support or hinder student's learning about a subject that is predominantly presented in a Caucasian-male dominant social context, such as military engineering applications.

This paper focused on how students evaluated and accepted the relevance/authenticity of knowledge delivered by the instructors in an engineering course. Future research could benefit from a deeper description of what "authentic" knowledge means and how can different pedagogical approaches can reflect an authentic intent. Moreover, although most students in this course were traditional students, there were some non-traditional students with previous work experience in the military or civilian context. All students expressed how hands-on activities and instructors with first-hand knowledge helped integrate incoming information and interest in military technology applications with their professional identity development. However, we cannot make the assumption that each student shared a similar level of professional identity development. This process could be very different between traditional and non-traditional students. Future studies can benefit from comparing individual students' professional identity development with their ways of meaning making. An analysis such as this may shed additional light on the intersections of college student learning and professional identity development.

VIII. Conclusion

Overall, this study was able to explore how students accepted incoming information in a course about military engineering applications. Quantitative data analysis with students' pre-and post-surveys showed a statistically significant difference, indicating that students' understanding of the course contents and related technical competency improved. Qualitative findings confirmed that prior dispositions, interpersonal relationship, and authentic knowledge facilitated students' disposition towards the course content and allowed them to connect the material to their professional development as future engineers in the military science and technology community. The students benefited from practical, concrete lab activities that supported the information they learned through class lectures. Both veteran and non-veteran students expressed an interest in pursuing engineering jobs in the military and felt this course would enrich their curriculum as engineers.

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