Integrating Army Doctrine and Engineering Design: Preparing Millennials to Become Future Officers

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Abstract
The United States Military Academy (USMA) mission is to "educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character." Anecdotally, some cadets believe the "educate" aspect occurs within the academic setting and the "train" aspect occurs within the military program. However, the interconnectedness of these two seemingly disparate goals within the mission are able to be achieved simultaneously and can enhance the future officer's development. We have designed a senior capstone engineering design course that purposefully blends the "body of knowledge" from the American Academy of Environmental Engineers and Scientists (AAEES) and Army doctrine. The interaction of these two professional aspects, and how they are integrated into the engineering design project, will be presented. The deliberate blending of these critical components from each perspective to meet both the needs of the engineering profession and the needs of active duty military service will be discussed. Although meaningful assessment of the impact of this educational approach is not borne out until students have graduated, the faculty at our institution have assessment data that demonstrate the value of this approach for future personal and professional growth.

Introduction

One of the common attributes of a profession is that it defines and maintains a professional body of knowledge (BOK) [1]. A clear goal of any undergraduate education program is to familiarize graduates to the knowledge, skills, and attitudes that serve as the foundation for entry into a given field. Within engineering curriculum, each undergraduate program has an associated professional organization such as the American Academy of Environmental Engineers and Scientists (AAEES) that maintains and widely publishes "The Environmental Engineering Body of Knowledge (2009)[2]. For any given profession, the BOK serves as a focal point where students, educators, employers, and professional practitioners can gain an understanding of the breadth and depth of knowledge expected of its members. The BOK is not to be viewed as a prescriptive checklist nor does it eliminate multi- or interdisciplinary approaches. The BOK can serve to enhance communication when seemingly disparate approaches exist and find a common framework to discuss, design, and communicate solutions to engineering problems.

The United States Military Academy's (USMA) mission is to "educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character [3]." With respect to the "educate" part of the mission, the Dean of the Academic Board publishes a strategic document outlining the specific aspects of the educational domain. The recently published document, *Educating Army Leaders: Developing Intellect and Character to Navigate a Diverse and Dynamic World*, states that, "West Point educates and inspires leaders of character who think critically, internalize their professional identity, and employ their education to help build the Army and the nation's future [3]." The United States Army, as a profession, also publishes and maintains their BOK in the form of doctrinal publications intended to meet the wide range of professional needs; some apply to the entire profession while others are more focused upon the scope of the knowledge being discussed.

In an effort to simultaneously achieve the "educate" and the "train" aspects of the USMA mission [3] within an academic setting, we designed a senior capstone environmental engineering design course to blend the American Academy of Environmental Engineers and Scientists (AAEES) Body of Knowledge and Army doctrine. One of the unique educational challenges at West Point is for instructors to integrate both the professional disciplinary knowledge associated with each student's academic field with the requirement to develop students to be Army officers. On the surface, especially from a student-centric perspective, this underscores the educational goal of "relevance to the profession [3]." The ability to acquire and apply knowledge within a military context of current operations is at the forefront of each student's interests. Most students will focus on short-term academic coursework that will support their immediate and perceived tasks that they will encounter as a junior officer. However, the Environmental Engineering Sequence approaches officership from a long-term perspective by blending disciplinary and doctrinal knowledge as mutually supportive instead of mutually exclusive standpoint. So, the faculty challenge is to intentionally plan, resource, and integrate course curricula that will meet both the short and long-term goals of our students, faculty, Army stakeholders, and the profession itself to better equip millennials for their future roles as officers in the Army.

The Students of Today; Officers of Tomorrow

"In the learning paradigm, the mission and purpose of education is to produce learning, not to deliver instruction." [4] A critical task for faculty is to design learning activities that (1) nest within a discipline's body of knowledge, (2) support the Institution's academic charter, and (3) create opportunities for each individual student's growth. "The goals are the same for all our students—to foster academic success…One of these factors is knowing the cultural context of our students' life experiences so we can maximize their particular strengths [5]."

The undergraduate students currently in our classrooms have been referred to as ""Generation C"—students who are connected, content-centric, computerized, community-oriented, and, most importantly, continually clicking [6]," "Millennials", or "Digital Natives." The labels are applied because the students were "born between 1982 and 2004 [7]" and they have the distinct privilege to have always been "immersed in digital world." [6]. There is little public debate that today's students—widely referred to as "millennials"— bring different attitudes, expectations, preparation, strengths, and shortcomings into the college classroom than previous students. [6] But, this can be a simplistic view if limited to the focus upon their ability to use technology. The interaction with "content" is a topic that needs more attention. After all, "learners don't know what they don't know [8]." Professors across the country are finding that millennial students are less interested in classical STEM studies, group-work, "and in anything that involves non-virtual media [9]." This study begins with a baseline understanding of the students we desire to engage in our classrooms and inspire in our disciplinary communities. As a generalization, Millennials are often characterized by the following sentiments:

- "They can easily, and quickly switch their attention between tasks and technology, like laptops, smartphones, and television, an average of 27 times per hour compared to only 17 times per hour for previous generations [10]"
- "Millennials have a mindset of continuous learning [10]"
- "Despite millennials' ability to multi-task, they still crave structure. Project instructions, assignment guidelines, and training courses should be clearly communicated and delivered [10]."
- "Alongside with their special skills of naturally interfacing with software... there are justified concerns in educating this generation due to their general lack of interest in a physical, conceptual grasping of the real world [9]."

Since 2013, the Deloitte Group [8] has released the results of its annual "Millennial Survey" to gauge the attitudes of millennials towards a broad range of topics. The survey "reinforces the connection made between purpose and retention… Businesses frequently provide opportunities for millennials to engage with "good causes," helping young professionals to feel empowered while reinforcing positive associations between businesses' activities and social impact [11]." Interestingly, the responses to several questions shows a change from 2015 to 2017. This includes responses that indicate millennials' attitudes are changing [11]:

- "focus on their own agenda" Agree 75% (2015) to 59% (2017) [11].

- “behave in ethical manner” Agree 52% (2015) to 65% (2017) [11].

- “leaders are committed to helping society” Agree 53% (2015) to 62% (2017) [11].

These trends indicate a decrease in self-centric attitudes and emerging “social optimism [11].” “The latest survey indicate that millennials feel accountable, to at least a fair degree, for many issues in both the workplace and the wider world [8].” This is supported by responses that indicate that millennials feel more accountable than influential to protect the environment (59% feeling accountable to 38% influence) and social equity (53% feeling accountable to 33% influence) [11].

Like any cohort of students, there are strengths and opportunities for growth. We intended to build upon the ability of millennials to interact with information from a wide range of sources that is available digitally and introduce them to the professional dogma of both the Army and environmental engineering. The intent of our course is to leverage their strengths to further develop cadets’ “higher-order” thinking through the correct application of “mind models”, within the engineering process [9]. This higher level thinking is both doctrinal [12] and pedagogical [9] in nature. Using the doctrinal framework as a critical thinking tool combined with creative thinking and engineering design principles, we teach students to apply “practical thinking” skills on a complex design problem with no readily available “book answer” [12]. The benefits of this approach is the production of officers who can balance creative and critical thinking techniques who are “prepared to think about issues instead of ignoring or dismissing them, and asking insightful questions.” [12].

Knowledge Content and Course Design

The overarching purpose of this course is to serve as the stand-alone capstone event for the three-course environmental engineering sequence blending the Environmental Engineering Body of Knowledge (2009) [2] within the context of specific knowledge of Army Civil-Military Operations Doctrine, see Figure 1. Prior to the capstone, students get two baseline courses of Environmental Science and Environmental Engineering Technologies. As such, the capstone course, is designed to be robust and challenges students to link concepts from the first two courses focusing on environmental science and environmental engineering technologies, to solve problems that are open-ended and contextually-based in the developing world. Students are expected to integrate concepts from core curriculum courses, their life experiences, and the experiences and training from the military program. A large portion of the course is dedicated to the students developing concrete answers to problems by applying science, technology, engineering, and mathematics (STEM) skills. However, the semester long design project is a realistic, open-ended problem representative of a humanitarian assistance or disaster response (HA/DR) mission. It is through this design problem that the students are challenged to synthesize potential solutions, assess their feasibility, and make a final recommendation based on the students’ analysis and judgment. The engineering design process threaded throughout the course and is shown in Figure 1 as it pertains to the significant blocks of instruction.

In order to engage and inspire students with a relevant assignment, a semester-long design project was developed that focused on environmental engineering problems in the developing world. As Aktan [9] concluded in his critique of current undergraduate civil engineering curriculum “we believe that a critical missing element is to be able to transform any case or project into a "Creative Design Problem," and address these in the realm of "Design". He goes on to suggest incorporating "Project-Based-Learning", defined as open-ended design projects, into engineering curriculum [9]. We fill this critical thinking gap through a engineering design project that implements Project-Based-Learning. Context for the course was deliberately selected in order to challenge student mindsets and perspectives since most of the Army operational environments are located in these parts of the world. The desired end state is for each student to design technologically and culturally appropriate solutions and then to communicate these solutions as part of a deliberate decision-making exercise in a realistic civil-military scenario. In other words, replicate the activities and actions that young company grade (Captains and below) staff officers are often tasked through scenario based projects. Thus, the overarching scenario is that of a team of staff officers (student design groups) who are interacting with the Advanced Echelon (ADVON) personnel (instructors) during the design activities. The staff officers (students) will then prepare a decision brief for approval by the Forward Engineering Support Team (FEST) Commander (instructors). Blending the Environmental Engineering BOK with the EV450 Scenario Projects were deliberate to ensure students incorporated knowledge and skills throughout all four blocks of instruction as seen in Figure 2. Block 1 focuses specifically on community and engineering assessments, specifically framing the problem, identifying key stakeholders, conceptual analysis and conceptual overlays. Block 2 and 3 focuses on General Engineering solutions within the context of water, sanitation and energy. While block 4 emphasizes decision-making, value-based trade-off analysis, cost analysis, and Mission Command requirements.

Within the Army of today, we expect our leaders to possess the ability to analyze and solve complex, nonlinear, and dynamic problems. The *Army Leadership,* Army Doctrine Reference Publication (ADRP) 6-22, states that Army Leaders must "understand the importance of conceptual skills…Conceptual Skills being the basis for making sense of complex situations, understanding cause and effect, critical thinking, solving problems, developing plans, and leading others [12]." However, as shown by Aktan [9] "[millennial] students have difficulty in appreciating and accounting for uncertainty." In the manual *The Operations Process*, ADRP 5-0, leaders must "use design to help them understand complex, ill-structured problems and to develop a broad operational approach to manage or solve them…Based on this understanding and operational approach, Army leaders continue more detailed planning using the [Military Decision Making Process] MDMP to develop a fully synchronized plan or order that serves as the practical scheme for solving the problem [13]." The approach used throughout the Army is to apply interactive doctrinal frameworks of understanding in a deliberate manner while determining or acknowledging underlying facts and assumptions. Likewise, the overall engineering design process is iterative throughout planning since information clarity typically improves over time as intelligence is refined and analysis is performed. Throughout the process, leaders and staff officers are expected to operate within high performance teams that approach problems from various perspectives. Through these various frames of references, leaders are expected use critical thinking skills to solve highly complex problems often with incomplete, contradictory information, with subsequent both positive and adverse consequences for various actions [12]. The integration of doctrinal and environmental engineering knowledge forms the full body of knowledge that students are able to demonstrate at the end of the course as shown in Figure 3.

This course uses the Environmental Engineering Design Process (Figure 3) to address complex problems and develop solutions. The process throughout the course involves analyzing the social, economic, and political considerations of the stakeholders (with the stakeholders) in order to determine feasible solutions that are also viable and sustainable. The unique aspect of this process is that once an individual understands design, he or she can apply it to a wide spectrum of complex problems unrelated to environmental engineering.

As Army Officers, these students may deploy to the developing regions of the world, and mission success is often contingent upon successful interactions with communities to solve complex problems. This course uses common environmental engineering problems including energy, water, and sanitation issues. The far-reaching impact and ubiquitous nature of these projects make them superb case studies in environmental engineering for community development.

During the semester-long design project, students must specifically address the aforementioned problems affecting developing communities. Students analyze potential actions and systematically recommend a course of action to best meet the needs and wants of the community studied. At the end of the course, the design teams present their findings and results in a decision briefing. Throughout the course, we emphasize critical thinking combined with analogical reasoning by the use of design projects which give students engineering license to develop their projects according to engineering design principles applied in the context of Army Doctrinal frameworks. Within the Army, we describe the Strategic and Operational Environment through Operational Variables in terms of eight interrelated operational variables: political, military, economic, social, information, infrastructure, physical environment, and time known as PMESII-PT [14]. Students are expected to use these operational lenses to evaluate the operational environment where their project area resides. "Army forces use operational variables to understand and analyze the broad environment in which they are conducting operations. They use mission variables to focus analysis on specific elements of the environment that apply to their mission [14]." Without this critical analysis, students would fail to include key stakeholders who could apply tremendous influence over the project area and ultimately affect what we are trying to accomplish. In addition, we have students apply the mission variables using elements of ASCOPE (areas, structures, capabilities, organizations, people, and events) by analyzing the key points of each operational variable as they apply to the project. Throughout the course we teach the essential PMESII-PT/ASCOPE framework principles and the application thereof. The goal is to have the students able to "integrate people and processes, using multiple information sources and collaborative analysis to build a common, shared, holistic knowledge base of the operational environment [14]."

Once students have an understanding of the operational environment, the next focus is to develop possible solutions by conducting a design charrette, data collection of the area of focus, applying engineering judgement based on lessons learned in class, and identifying feasible solutions given the constraints within the community. Technology, like Google Earth, is integrated throughout the course within the engineering process to assist visualization of the overall layout of the community and identify key terrain features. For simplicity, students are provided with water usage data from the community to generate possible solutions. The possible solutions are distributed into three different assignments with the focus on water supply and distribution, sanitation services, and energy demand. The cost for these projects is not taken into account at this stage, rather, the feasibility of the engineering solutions are the main focus. As the course progresses, we also expect our students to analyze different courses of action available within the context of the design project. We do this through Functional Hierarchy analysis of the overall "Functional Objective" of the design problem. Functional Hierarchy analysis is essentially breaking down the functional objectives into functions, objectives and corresponding value measures. Value Measures will typically correspond directly to specific outcomes. Within Army doctrine, leaders "must measure progress toward mission accomplishment." Likewise, we assess progress within the operational environment (an assigned community) through specific standards called Measures of Performance (MOP) and Measures of Effectiveness (MOE). An MOP is tied to the performance of a task whereas an MOE is tied to the accomplishment of an "endstate" or objective. Within our curriculum, we have incorporated MOP and MOE assessments within our learning objectives and ultimately within a functional hierarchy framework [15]. Throughout the course, we expect students to apply functional frameworks along with corresponding MOPs and MOEs to baseline a situation within an Operational Environment and measure progress, trends and the effectiveness of their design solutions [15]. This is especially important when outcomes are contradictory, vague, or have secondary effects which must be considered. It can be difficult to place a "value" on how important a particular function or objective really is within mission priorities. Ultimately, with proper weighting within simplified tradeoff analysis, using value measures within a functional hierarchy helps leaders to make informed decisions, set priorities, and measure progress over time.

USMA Senior Stakeholder Feedback.

These data were gathered from a population of stakeholders who can assess if the graduates are demonstrating the expected level of intellectual competence and critical and creative thinking skills. Although this is not a longitudinal study of the development of each graduate, this feedback is an effective mechanism for the Institution to capture the value of the intellectual development of our graduates. In essence, these data help to ascertain if "a pound of West Point education is worth it." These surveys focus on the relative performance of West Point graduates (WPGs) compared to those from other commissioning sources (i.e., ROTC and OCS) as well as shows areas of both strength and concern. The stakeholders in the survey are defined as the supervisors of recent graduates at both the rater and senior rater levels in company grade officer development [16], [17]. These stakeholder assessments were focus group surveys conducted with returning USMA faculty to represent the population of raters (i.e., former and successful Company Commanders) and senior officers in residence at the Army War College to represent the population of senior raters (i.e., former and successful Battalion Commanders) [16], [17].

The stakeholder data were not used to create a number of quantitative charts and metrics; rather it was used to focus on the statements made that inform the exact nature of preparing graduates to absorb the different bodies of knowledge that comprised their intellectual development experience at USMA. In general, the reports find that WPGs perform 3–4% points higher on quantitative metrics such as Basic Officer Leader Course (BOLC) GPA's and that WPGs tend to not be rated in the bottom 30% of any population of rated officers [16], [17]. The following comments from the 2016 surveys are included to describe the perspectives of intellectual competence and critical and creative thinking skills. The one finding that resonates with both the development of the student's intellectual competence and critical and creative thinking skills was to "provide continued opportunities for problem solving where there is no approved solution, seeking simple versus complex solutions [16]."

When stakeholders considered Intellectual Competence the comments generally described WPGs as: "well prepared for the duties assigned to them, having high technical ability, highly intelligent, self-starters, good critical thinkers and problem solvers, very adaptive (particularly once they have built up experience and mastered a task) and able to deal with complexity in tasks/assignments [17]." This is underscored by the fact that 94% of former Company Commanders characterized WPGs as "Intellectually competent for their duties and responsibilities [17]." This is to be expected as West Point has a very rigorous admissions process and admits candidates that demonstrate a high level of academic rigor and success in their preparation to attend the Academy. This also speaks to the academic reputation of West Point and all its associated academic programs as national rankings consistently rank USMA in the top tier of academic institutions.

One aspect that stakeholders identified as highly important was Critical and Creative Thinking. The ability to assess critical and creative thinking is often a great challenge during an undergraduate experience. It is during undergraduate education that students are learning the fundamental knowledge of the discipline and beginning to master the associated skills to apply that knowledge. Learning activities such as design projects assist in this aspect of student development. This is especially true when the design prompt is very "open-ended" with a wide range of potential candidate solutions that will involve some degree of "trade-off" analysis to make the best recommendation. It was hypothesized that it would be most valuable to students in the 3-4 year post-graduation period by developing broad design problems that mimic case study scenarios allowing maximum freedom to apply various solutions.

Longitudinal assessment data from the course demonstrates an increase performance in students' ability to apply the environmental engineering design process to develop solutions that are both effective and adaptable to community problems in the developing world. Using a Likert-type scale with responses consisting of 1 to 5, where 1 represents a low understanding and 5 represents a high understanding, in the previous four years students scored an average score above a 4.0, ranging between a 3.98 and 4.38, see Table 1. The focus on a "real-world" scenario in the developing world, changing from regions in Africa, Asia, and South America, provided students with the ability to engineer solutions based on the geographic location in question given resource constraints. The internal course assessment data also indicates an overall increase in the ability to identify and analyze the relevant dimensions (such as environmental, political, social, economic, and technological) of community problems in the developing world and their ability to use a value-based decision-making model to assess multiple engineered solutions to enhance community resilience.

Conclusion

In conclusion, these millennials ARE the Future Officers of our Army. Today's students have instant access to information and they know how to leverage it. Millennials are relentless consumers of information, just look at any student with a smartphone. But having access to information is not the same as knowing it or knowing what to do with it. Aktan [9] similarly concluded "a rigorous investigation of how to leverage the Project-Based-Learning...paradigms for enhancing the learning experiences of civil engineering [millennial] students." This course was specifically developed to leverage those strengths and apply doctrinal frameworks within an environmental engineering BOK. It is not the intent of this course to produce students on the cutting edge of environmental engineering, rather, we are producing dynamic critical thinkers who possess fundamental engineering skills. These future leaders will soon be charged with leading Soldiers in complex and dangerous environments, where they are often faced with difficult, ill-structured problems. These ill-structured problems are better solved through practical thinking and analogical reasoning especially when dealing with unfamiliar or unknown conditions and outcomes using doctrinal frameworks applied within the Engineering design process [12]. We will expect them to find solutions where there is no ready "book answer." We have best replicated this set of challenges through realistic problem sets where students are challenged to apply these frameworks along with fundamental Environmental Engineering Principles and the Engineering Design Process.

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Appendix A. Figures.

Figure 1. The USMA Environmental Engineering Design Process.

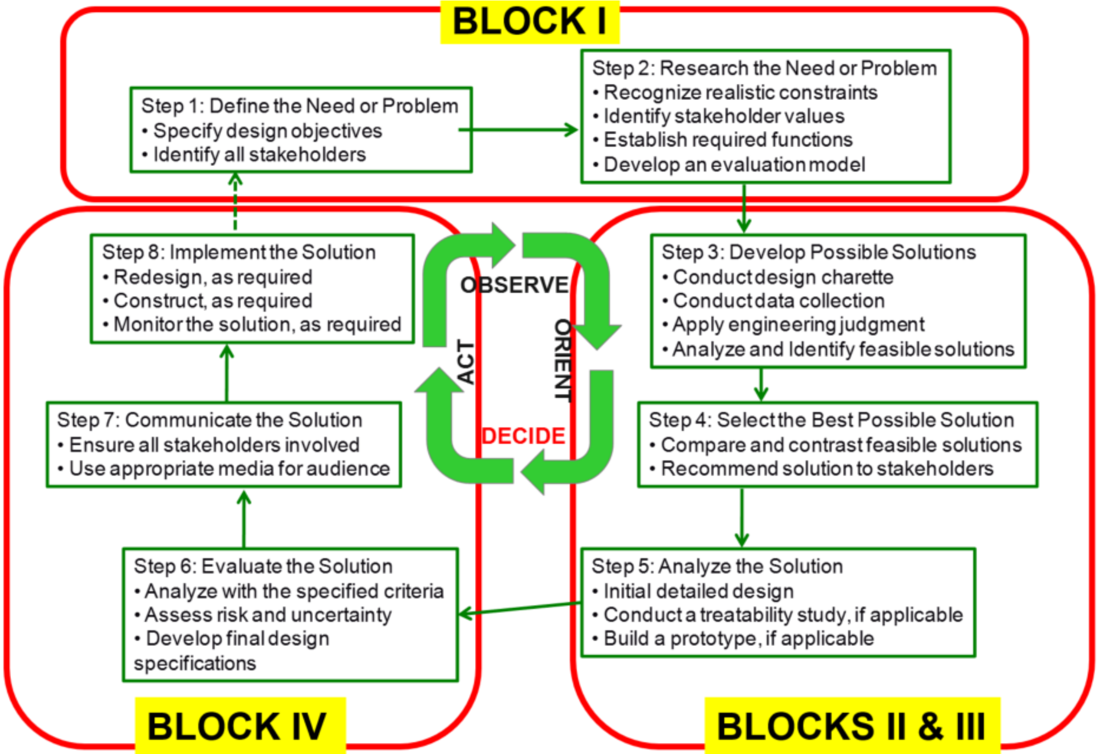
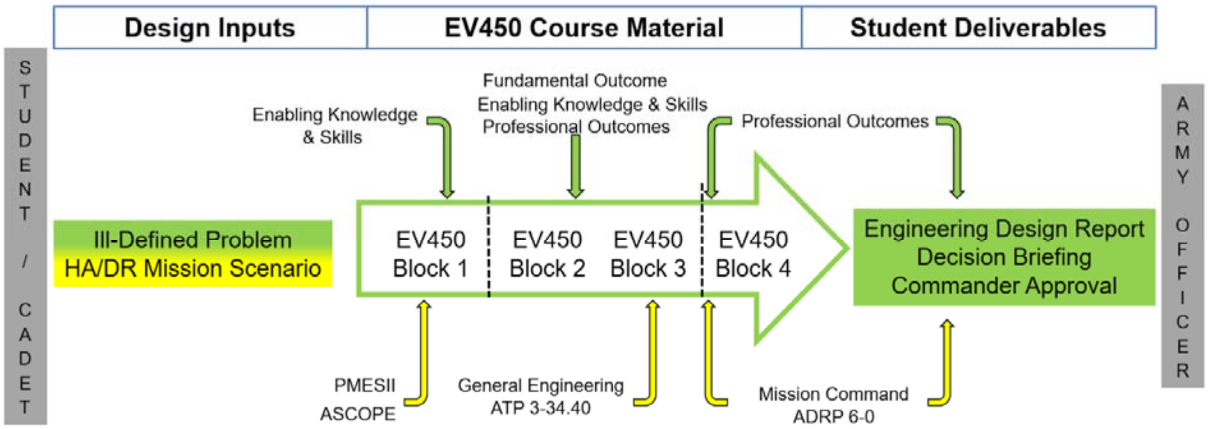


Figure 2. The Knowledge Cross walk between EV450 Capstone Course and the Environmental Engineering BOK.

Environmental Engineering Body Of Knowledge (BOK)		EV450 Thematic Organization			
Group	Outcome # and Title	Block 1	Block 2	Block 3	Block 4
Fundamental Outcome	1. Basic Engineering Math & Science (BEMS)		√	√	
Enabling Knowledge and Skills	2. Design and Conduct Experiments		√		
	3. Modern Engineering Tools		√	√	
	4. In-Depth Competence		√	√	
	5. Risk, Reliability, and Uncertainty		√	√	√
	6. Problem Formulation and Conceptual Analysis	√	√	√	
	7. Creative Design		√	√	√
	8. Sustainability	√	√	√	√
	10. Societal Impact	√			√
	11. Contemporary and Global Issues	√			
Professional Outcomes	12. Multi-Disciplinary Teamwork		√	√	√
	13. Professional and Ethical Responsibilities				√
	14. Effective Communication	√	√	√	√
	15. Lifelong Learning	√	√	√	√
	18. Leadership		√	√	√

Figure 3. Blending Army Doctrine and Environmental Engineering BOK throughout the EV450 Capstone Course.



Appendix B. Tables.

Table 1. Longitudinal data on two course outcomes over a 5-year period present in a 1 to 5, Likert-type scale, where 1 represents a low understanding and 5 represents a high understanding.

	Academic Year				
Course Outcome	**2014**	**2015**	**2016**	**2017**	**2018**
Identify and analyze the relevant dimensions of community problems in the developing world (such as environmental, political, social, economic, and technological).	3.97	3.98	4.13	4.17	4.19
Apply the environmental engineering design process to develop solutions that are both effective and adaptable to community problems in the developing world.	3.90	3.98	4.12	4.23	4.38