A Research-Focused, Collaborative Relationship for Environmental Engineering Education

Luke Plante, Matthew Baideme, Jeffrey Starke, Richard Rogers III, Gabrielle Young, Kristen McCarty, Michael Butkus

Abstract—Over 50% of the United States Military Academy’s (West Point’s) faculty is composed of professional Army officers hand-selected from the field Army and sent to the nation’s leading universities to earn a graduate degree. Upon completion of a three-year assignment at West Point, these officers rotate back to the field Army, endowing it with enhanced analytical and professional expertise. The primary responsibility of “rotating” faculty members is undergraduate teaching, as well as a wide range of faculty-student activities. We connected their graduate school experience with basic and applied research conducted by students and faculty members at West Point supporting the needs of the US Army. Within this model, a recent collaborative environmental engineering research project between West Point, Columbia University, the environmental division of the Armament Research, Development and Engineering Center, and the Holston Army Ammunition Plant aimed to capitalize on the educational value gained from the faculty-student-outside agency connection. This project connected two incoming rotating faculty members during their graduate studies at Columbia University with ten West Point students either preparing to or conducting independent study research on the biological removal of nitrogen from a waste stream generated by an ammunition manufacturing facility. In conjunction with mentorship and management provided by senior faculty members already at West Point, rotating faculty members were able to gain experience in directing research activities, and students gained significant laboratory and design experience. Utilizing student survey data and faculty feedback, this multi-pronged collaboration model proved to impact the education of all involved positively.

Index Terms—environmental engineering education, undergraduate research, collaborative education

I. INTRODUCTION

Student Learning Model

The main objective of the United States Military Academy (also known as USMA or West Point) is “to educate, train and inspire leaders of character who are committed to the values of Duty, Honor, Country and prepared for careers of professional excellence and service to our nation as Army officers” [1]. In support of this mission, the overarching goal of the academic program is “Graduates integrate knowledge and skills from a variety of disciplines to anticipate and respond appropriately to opportunities and challenges in a changing world” [2]. Our graduates must be able to define and then creatively design technological alternatives to complex problems — ultimately selecting a solution that is both effective and adaptable. Approaches to problem-solving and critical thinking cannot be fulfilled solely by lecture-style classes; rather, additional “significant experiences” are required to help students develop a holistic

The authors submitted this article for review on March 28, 2018. The U.S. Department of Defense funded the research this article describes. The authors present their own views here; the Department of Defense, the United States Army, and the United States Military Academy do not necessarily share these views.

L. Plante is with the Department of Geography and Environmental Engineering at the United States Military Academy, West Point, NY 10996 USA (luke.plante@usma.edu).

M. Baideme is with Columbia University, New York, NY 10027. He will teach at West Point, NY 10996 USA upon completion of his Ph.D. (mpb2177@columbia.edu).

J. Starke is a retired faculty member from the Department of Geography and Environmental Engineering at the United States Military Academy, West Point, NY 10996 USA (jeffreyastarke@gmail.com).

R. Rogers III was with the Department of Geography and Environmental Engineering at the United States Military Academy, West Point, NY 10996 USA. He is currently a student in the Command and General Staff College (richard.f.rogers18.mil@mail.mil).

G. Young is an undergraduate student in the Department of Geography and Environmental Engineering at the United States Military Academy, West Point, NY 10996 USA (gabrielle.young@usma.edu).

K. McCarty is an undergraduate student in the Department of Geography and Environmental Engineering at the United States Military Academy, West Point, NY 10996 USA (kristen.mcarty@usma.edu).

M. Butkus is with the Department of Geography and Environmental Engineering at the United States Military Academy, West Point, NY 10996 USA (michael.butkus@usma.edu).
appreciation for professional practice issues and to prepare them for the workplace [3]. Such experiences should relate course material to professional practice, be commensurate with students’ skill levels according to their progression through a curriculum, and be perceived by students as reinforcing rather than redundant [4]. Examples of such experiences include independent laboratory research projects, field trips, hands-on laboratory exercises, field sampling, modeling, technical designs, experimental designs, and research papers [4]. Students can learn an engineering thought process in an engineering program curriculum model, which features an iterative design opportunity because problem-solving is a process that students must experience iteratively [5]. This model includes a phase of research activity, a phase of development and reflection, and a follow-up phase of advanced research development activity [6]. These types of projects offer students a tangible reason to invest a significant portion of their academic time towards a common focus, the quality of their products, and innovative and creative solutions, and the ensuing satisfaction from their work confirms this assertion [6].

Students at West Point are all at the undergraduate level, and with few exceptions, they do not conduct research. Students can volunteer to complete 3.0 credit hour independent studies, also known as capstone projects, as electives. These projects give students the opportunity to research with faculty, and they have the potential to provide a more enriching experience than classroom instruction due to their applied nature.

**Faculty Model**

Fig. 1 depicts an anecdotal representation of the traditional university faculty composition. Most of the faculty in this model have a Ph.D. and are on a tenure track with some additional adjunct faculty or lecturers who may not have a Ph.D. In most cases, changes to faculty composition are minimal with many faculty members serving for long periods of time. Faculty gaps are identified to describe potential areas of development for engineering faculty members. The red border surrounding the gaps emphasizes that the gaps are weaknesses. Professional engineering (P.E.) licensure is necessary for program accreditation through ABET. Arrows point from faculty to gaps and back to faculty to depict that faculty members identify faculty gaps, that faculty members assess and reflect on their gaps, and faculty members act to address these gaps.

West Point’s faculty composition is significantly different from that of a traditional university. Faculty members at West Point are classified in Fig. 2 based on military or civilian status and expected length of the assignment. Subsequent paragraphs describe West Point’s faculty composition in more detail. Tenure-track faculty are similar between West Point and traditional universities, and adjunct faculty at conventional universities are comparable to rotating faculty at West Point. West Point also does not have teaching assistants or graduate students, and West Point is not an institution focused on research. Research can, however, help address faculty gaps and improve student learning. Research projects provide faculty members with management and design experience while connecting them with industry.
Fig. 2. West Point faculty composition is significantly different from traditional university composition. Rotating faculty at West Point, however, share some similar characteristics with adjunct faculty at traditional universities, and gaps are similar in both compositions.

West Point faculty members hold academic ranks as described below.

**Professor, U.S.M.A.** This academic title is held by 28 statutory professors at the Academy. These are Army officers permanently assigned to the Academy to provide senior leadership in academic positions who may serve until mandatory retirement at age 64.

**Academy Professors.** Academy professors are Army officers permanently assigned to the Academy for leadership, administration, mentoring of mid-grade faculty, teaching, and research. They hold a Ph.D. and the academic rank of assistant, associate, or full professor and may serve until mandatory retirement age based on rank.

**Civilian Faculty.** Title 10 of the U.S. Code authorizes civilian faculty members at West Point. The length of appointment depends on academic rank with full professors holding ten-year renewable appointments. West Point does not have a conventional academic tenure ladder. Civilian faculty members provide leadership, mentoring, continuity, breadth of experience, teaching, and research experience.

**Rotating Faculty.** Over 50% of West Point’s faculty is composed of young Army officers who are hand-picked from the field Army to attend the nation’s leading universities and earn an appropriate graduate degree before their assignment to West Point. Upon completion of their three-year tour at West Point, these officers return to the field Army, providing our Army with enhanced analytical and professional expertise. The primary responsibility of these “rotating” faculty members is undergraduate teaching. They also participate in a wide range of faculty-student activities, including research. The annual infusion of new rotating faculty members generates an atmosphere marked by vitality and enthusiasm and ensures a constant stream of fresh ideas and perspectives. Rotating faculty members fall into two groups:

- **Rotating Master’s Degree.** Most rotating faculty members are at the Masters level. Masters level rotating faculty members typically hold the rank of captain or major and enter the Academy with the academic title of instructor. They may advance to assistant professor upon achievement of appropriate academic qualifications, including scholarship.

- **Rotating Ph.D.** Rotating Ph.D. faculty typically hold the military rank of lieutenant colonel and the academic title of either assistant or associate professor. They have also typically been Rotating Master’s Degree faculty earlier in their careers and are currently competing for limited Academy Professor positions.

Academic promotion requires excellent performance in five domains: teaching, scholarship, service, student development, and faculty development. The Environmental Engineering Program uses these domains to establish yearly objectives for its faculty to enhance the quality of student education and for the professional development of each faculty member. Attainment of professional engineer licensure and promotion from instructor to assistant professor before completing a rotating assignment is a stated goal for eligible faculty members.

The purpose of this paper is to describe how a research-focused, collaborative relationship for education addresses environmental engineering faculty and student gaps. This project’s teaching model connects West Point faculty and students to industry, allows rotating faculty to develop management skills and a personal research portfolio, and provides undergraduate students with hands-on experience.

**II. RESEARCH-BASED, COLLABORATIVE EDUCATION MODEL**

We have recently developed a research program that links students, rotating faculty, and senior faculty with
a real-world research project addressing a solution to an Army environmental problem. The design of this program intentionally offers students and rotating faculty a period of reflection between research activities. This paper describes the educational value of the collaborative environmental engineering research project between West Point; Columbia University (C.U.); the environmental division of the Army’s Armament Research, Development and Engineering Center (A.R.D.E.C.); and the Holston Army Ammunition Plant (H.A.A.P.). Fig. 3 depicts the relationships between the different constituents in this project.

Fig. 3. This mutually-supported, faculty-student development model depicts the relationships among the various constituents involved in this project.

Academy professors and civilian faculty manage the project at the highest level. They mentor the rotating faculty members and the students, providing advanced understanding of the academic knowledge applied. They also have previous research experience with similar projects and share lessons learned. Also, these tenure-track faculty share best practices for management, manage much of the funding of the project, and maintain the relationships necessary for the project to occur and provide benefits to all parties. Tenure-track faculty contribute directly to their domains, including their scholarship, student development, and faculty development.

Rotating faculty manage the day to day research activities. They direct the student activities and ensure students gain an academic understanding of the systems they operate. They also work with the students to ensure they produce quality reports and posters at the end of each semester. Before teaching at West Point, two rotating faculty members have attended C.U. for graduate degrees, focusing specifically on this project for a dissertation or thesis. Research on this project is done in parallel at C.U. and includes collaboration with West Point faculty and students. These activities all help rotating faculty members develop management skills and specialized knowledge within the project’s field. Rotating faculty members contribute to their development in the teaching, scholarship, and student development domains through this research.

Undergraduate students conduct the daily research activities required for this project. They learn the academic material and apply it to help reinforce the material. Students participating in a semester-long research course help design and then execute a long-term research plan, and they analyze and communicate their results. Students in a summer internship gain exposure to laboratory work in industry or research university environments. These immersive, applied experiences help students learn concepts more deeply than they would in classes alone, and they provide students with opportunities to see and appreciate industrial practices.

A.R.D.E.C. and H.A.A.P., the outside agencies in this project, directly benefit from this project. A.R.D.E.C., through West Point, is ensuring relatively low-cost research is occurring for an environmental engineering problem that affects H.A.A.P. Consultant labor costs are eliminated through this relationship, as equipment and expendables are the only expenses that occur with this model.

Each constituent in Fig. 3 addresses a real-world problem for the Army; addresses West Point faculty gaps of limited research and project management experience; and provides an enriching, applied educational experience for undergraduate engineering students. This project also addresses the P.E. gap for rotating faculty to a degree. This project provides knowledge depth for rotating faculty that they would not otherwise acquire, and this knowledge gained is in the largest portion of the P.E. exam: wastewater engineering. The faculty gaps, which were outlined in red and located in the center of Fig. 1 and Fig. 2, are replaced by this project in Fig. 3. The red outline is changed to green to depict that the project directly addressed the previously identified gaps.

III. THE PROJECT

The focus of this project is a real-world, environmental engineering problem within the Department of Defense (D.o.D.). H.A.A.P.’s industrial wastewater composition is an ammonium nitrate solution (A.N.S.O.L.), and H.A.A.P. cannot discharge A.N.S.O.L. into its local river because doing so would exceed nitrogen discharge limits. Our project aims to remove the nitrogen in A.N.S.O.L. using denitrification (nitrate reduction to nitrite) followed by anammox (anaerobic ammonium oxidation, which converts...
ammonium nitrite to harmless nitrogen gas). Both denitrification and anammox processes occur without the energy-intensive, costly aeration requirements of traditional biological nutrient removal (B.N.R.) process used in traditional wastewater treatment. We are, therefore, developing a low-cost, environmentally friendly solution to a real-world problem through the reduction of energy costs and their associated greenhouse gas emissions.

Thus far, one rotating faculty member has managed students at West Point. Another faculty member has received a master’s degree at C.U. studying this project and has managed students at West Point. Also, a future rotating faculty member is halfway through his Ph.D. at C.U. studying this project, and he has managed students in a summer internship. Students conduct projects at West Point in parallel with and in support of projects at C.U. A total of 10 students conducted research on this project for their independent studies, and three of these students have completed a three-week summer internship before their capstone projects. Continuity of the project between the two future rotating faculty members completing degrees at C.U. allowed for additional research depth for all parties beyond what would have been otherwise possible.

Students’ independent studies consisted of 80 hours of work per semester, with time split between operating reactors, analyzing and predicting reactor performance, preparing and presenting a poster at West Point at the end of the academic year, and a written technical report. Summer internships consisted of three weeks of full-time work at C.U., including the same types of work as semester capstone projects except for the poster presentation.

Surveys helped the authors assess the educational value of the educational relationship, the capstone project, and the internship. Rotating faculty also provided feedback on the project with a focus on the value of the educational model.

IV. SURVEY RESULTS AND DISCUSSION

The authors administered a survey to eight students who had participated in this research in the past. Most students had graduated and been reassigned to different locations across the country to fulfill Army service obligations. Nonetheless, seven students had email access and responded within a few days, perhaps indicating the strong connections they made with this project. Survey questions focused mostly on students assessing the degree to which they believe the project helped them develop skills that support stated outcomes of the environmental program and the ABET accreditation criterion of the environmental engineering curriculum.

See Table 1 for survey questions and results. The survey employed a Likert-type scale in which a five indicated “strongly agree,” four indicated “agree,” three indicated “neutral,” two indicated “disagree,” and one indicated “strongly disagree.”

Nearly every response indicated a belief that the project helped students develop in areas on which our entire curriculum focuses. Only three answers were neutral of all of the responses. These results suggest that the project is an appropriate learning tool.

Given the applied nature of the project, perhaps it is not surprising that all students who took the survey strongly agreed that the project helped them learn to “[u]se the techniques, skills, and modern engineering tools necessary for engineering practice.” Students also all strongly agreed that they enjoyed briefing their posters at the informal session at West Point.

Other qualities critical for engineers and necessary for our ABET accreditation are the ability to communicate effectively and the desire to engage in lifelong learning. Students responded with an average score of 4.79 ± 0.49 for these questions. Developing a report and poster, and conducting independent learning led to these high scores.

Students believed that the project helped them better understand problems from a higher-level context. They scored the project at 4.57 ± 0.79 for how it helped them understand the “[r]oles and responsibilities of public and private organizations pertaining to policy and regulations.”

Students also believed the project helped them learn to “[d]esign and conduct experiments, as well as to analyze and interpret data” by scoring the project at 4.43 ± 0.53. They also believed the project helped them learn to “[i]dentify, formulate, and solve engineering problems” by scoring the project at 4.43 ± 0.79.

In response to the question asking how the project helped students “[f]unction on multidisciplinary teams,” scores were 4.00 ± 0.82. Students almost always operated in pairs of one environmental engineer and one environmental scientist, and, therefore, they mostly worked on multidisciplinary teams.

These scores indicate beliefs of agreement that the project helped students achieve environmental engineering curriculum goals. We will strive to sustain the project’s positive impacts on student development.

Beyond the questions listed in Table 1, students were also asked to comment in general on their experiences with the project. Students all wrote several sentences, mostly providing very positive feedback. The length of student responses was also appreciated and may also be indicative of how strongly students felt about the project.
Student comments indicated that they were excited to learn in this research-focused, collaborative model. One respondent stated that all students should “have the opportunity to do a research project similar to this.” Another commented that the project “helped in many ways, and the skills… gained working on the Holston Army Ammunition Plant continue to make [the student] a better problem-solver and professional” Another student stated that “this was a very educational experience for [the student]. Designing different experiments and solving different problems helped [the student] gain more in-depth knowledge and [a] better understanding of the concepts and topics [the team studied].”

There was one response that was critical about an aspect of this project. The student stated “[t]he project took a few weeks for [the student] to gain even a basic understanding of how the reactors were operating and the ‘why’ behind all of the checks and measurements that [the student] was doing weekly. It was a little overwhelming at first.” The authors appreciate this comment and will address it in the future with more-rigorous education and training before application. While the complexity of the biological reactors cannot decrease, preparing students to operate the reactors can improve.

There are two main drawbacks from this survey. The first is that the sample size is small: a total of seven students responded to the survey. The second is that students who participated in this research were of above-average caliber. These students were hand-picked for the project over their peers because they displayed increased aptitude and maturity. The three rotating faculty who participated in this research also provided comments on their experiences with the project. They indicated that the project did indeed address the faculty gaps that applied to them from Fig. 3. They each indicated that they gained particularly valuable planning and management experience with this project.

Project goals focused on how to best address H.A.A.P.’s nitrogen discharge limits. Planning long-term experiments for biological reactors took careful consideration. Faculty knowledge gaps also had to be addressed at times when topics and techniques unfamiliar to them were to be explored by students. Faculty members needed to select students, educate the students on the academic topics applicable to this project, train the students on laboratory techniques, validated students’ abilities to operate independently in the laboratory setting, and monitor students’ performance to ensure precise and accurate work. Budget, time, biological reactor performance, and stakeholder engagement needed to be planned, executed, monitored, and controlled while developing students. The management skills development was particularly useful for faculty members who felt more comfortable in the past operating individually. Independent learning was also a vital requirement for faculty members, as they had not learned the academic knowledge needed for understanding the intricacies of this project in classroom environments previously.

Previous work on a similar study involving graduate students conducting unstructured research in collaboration with community agencies indicated that many of these students maintained their community involvement after their research concluded [7]. This finding is interesting, and we might assess with future surveys if students maintain the relationships they developed in research after the completion of their independent studies.

Future work will focus on other biological processes. This work may develop significant wastewater treatment efficiencies compared to traditional B.N.R. Within the next year and a half, the future rotating faculty member currently at C.U. is expected to complete his doctoral degree and begin teaching at West Point. Also, four more students are expected to complete independent studies, and two of the four students are expected to complete summer internships at C.U. prior to their capstone projects.
Table 1. Survey results indicate positive feedback from students.

<table>
<thead>
<tr>
<th>Survey Question #</th>
<th>Survey Question</th>
<th>Criterion / Outcome</th>
<th>ABET Criterion / Program Educational Outcome [8]</th>
<th>Score Mean (n=7)</th>
<th>Score Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I can design and conduct experiments and analyze and interpret data that analyze innovative wastewater treatment strategies</td>
<td>b</td>
<td>Design and conduct experiments, as well as to analyze and interpret data</td>
<td>4.43</td>
<td>0.53</td>
</tr>
<tr>
<td>2</td>
<td>This research helped improve my ability to function on multidisciplinary teams</td>
<td>d</td>
<td>Function on multidisciplinary teams</td>
<td>4.00</td>
<td>0.82</td>
</tr>
<tr>
<td>3</td>
<td>I was able to calculate parameters needed for operating our research reactors</td>
<td>e</td>
<td>Identify, formulate, and solve engineering problems</td>
<td>4.43</td>
<td>0.79</td>
</tr>
<tr>
<td>4</td>
<td>Writing the final report and developing and briefing the poster for Projects Day help improve my communication skills</td>
<td>g</td>
<td>Communicate effectively</td>
<td>4.71</td>
<td>0.49</td>
</tr>
<tr>
<td>5</td>
<td>I enjoyed briefing my project on Projects Day</td>
<td>--</td>
<td>--</td>
<td>5.00</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>My motivation to learn and to continue learning has increased because of this independent study project</td>
<td>i</td>
<td>Recognition of the need for, and an ability to engage in lifelong learning</td>
<td>4.71</td>
<td>0.49</td>
</tr>
<tr>
<td>7</td>
<td>I gained an understanding and appreciation for the modern engineering tools used in this project (e.g. sequencing batch reactor w/ partial denitrification, DNRA, anammox treatment)</td>
<td>k</td>
<td>Use the techniques, skills, and modern engineering tools necessary for engineering practice</td>
<td>5.00</td>
<td>0.00</td>
</tr>
<tr>
<td>8</td>
<td>Based off of my interactions with various agencies in this project, I better understand the roles and responsibilities of public and private organizations (e.g. Columbia, Holston Army Ammunition Plant, Picatinny Arsenal) in developing new solutions for managing waste streams</td>
<td>*</td>
<td>Roles and responsibilities of public and private organizations pertaining to policy and regulations</td>
<td>4.57</td>
<td>0.79</td>
</tr>
<tr>
<td>9</td>
<td>I believe I will remember the concepts associated with this project more so in the long term than the concepts I learned in traditional classes</td>
<td>--</td>
<td>--</td>
<td>4.43</td>
<td>0.53</td>
</tr>
</tbody>
</table>

*ABET Environmental Engineering Program Criterion
REFERENCES


