



Support for Interdisciplinary Engineering Education Through Application of Industry-Focused Case Studies

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INTRODUCTION:

Nuclear engineering students have many expectations of them upon graduation; primary among those expectations is to be technically proficient—it is hard to be successful without this trait. Understanding that success for engineers comes in many forms, it often follows those that are able to apply their technical skills in concert with a strong foundation in other skills that are fundamental to practicing their profession. “The practice of engineering involves significant interaction with subjects that fall outside those traditionally associated with engineering.”¹ For this reason it is appropriate that educators afford students the means to gain “the knowledge and skills that are fundamental to the practice of their profession.”² For the nuclear engineer, this might mean finance, politics, law, communications, and marketing to name but a few.

For graduating nuclear engineers of the United States Military Academy, this holds particularly true even though seldom does one get the opportunity to directly apply the context of their engineering degree in their first job. Graduates from the U.S. Military Academy commission as lieutenants into the U.S. Army, regardless of their academic major. Cadets receive a broad, liberal arts education whereby even the engineers receive classes in history, international relations, law, and English. Those majoring in the humanities, too, must take extensive courses in math and sciences to round-off their education. The precept of this degree is that graduates are diverse leaders with an educational background that enables them in a wide array of situations to think critically and take action accordingly.

Like any institution, U.S.M.A. bases its practices on preparing its students to be successful graduates, or, more specifically, successful Army officers. In this vein, a case study entitled *Operation Persian Gold* held in the nuclear weapons effects classroom aimed to broaden the students’ way of thinking by forcing them into a situation unlike any engineer would expect in a typical engineering curriculum. Cadets were to apply their technical knowledge of nuclear weapons design and weapons effects to influence national and strategic policy decisions relating to foreign affairs.

The purpose of the *Operation Persian Gold* case study in the curriculum was to contribute to ABET EAC student outcome (h): “attain the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.”³ The case study was a group exercise. The participating population was a diverse makeup of college seniors across all academic disciplines, including the humanities and social sciences. The multi-discipline composition of the group

¹ Aldridge, M.D., “Professional Practice: A Topic for Engineering Research and Instruction,” *Journal of Engineering Education*, vol. 83, no. 3, July 1994, p.232.

² Raju, P.K., and C.S. Sankar, “Teaching Real-World Issues Through Case Studies,” *Journal of Engineering Education*, vol. 88, no. 4, October 1999, p. 501.

³ ABET Engineering Accreditation Commission. 2005. *Criteria for accrediting engineering programs*, Baltimore, MD: ABET, Inc. <http://www.abet.org/eac-criteria-2014-2015/>

was nothing more than a cross section of the students enrolled in the Nuclear Weapons Effects class. No special effort was made to generate diversity. The class is offered to nuclear engineering majors and non-majors who take the class as a part of a nuclear engineering sequence. Nuclear Weapons Effects teaches students nuclear weapon design at an unclassified level. Additionally, the course teaches the mechanical effects of weapons as well as discusses the non-mechanical effects of the weapon which include the pervasive social, political, economic, and environmental considerations.

This paper analyzes this Persian Gold case study experience based on student responses and faculty feedback. The conclusion of this paper seeks to answer whether or not an industry partnership for case studies supports ABET EAC student outcome (*h*). This paper argues that engineers can broaden their perspective and attain some fundamental professional knowledge and skill by working on interdisciplinary teams in industry-led case studies. This, in turn, will augment the understanding of how engineering solutions impact a multitude of non-technical contexts.

THEORETICAL FRAMEWORK & CONSTRUCT:

Some authors suggest that the ideal means of teaching real world issues is through the application of case studies in the classroom. Case studies offer facts, opinions, and prejudices of real world situations/issues to students for “considered analysis, open discussion, and final discussion as to the type of action that should be taken.”⁴ Industry-led case studies, those administered by members from a representative industry, arguably have an advantage, then, at elevating the reality of particular issues graduates may face in their job because their scenarios theoretically come from experience. Business schools often use case studies and have found great success with their implementation. Inherently case studies move students away from the traditional lecture method of teaching and more towards the complex problem solving needed in the real world. Real-world case studies “allow the students to vicariously experience situations in the classroom that they may face in the future and thus help bridge the gap between theory and practice.” It is for this reason that educators are inspired to adopt them in the engineering curriculum.⁵

Operation Persian Gold was a hypothetical, situation-based case study that was developed by the Center for the Study of Weapons of Mass Destruction (WMD) located at the National Defense University in Washington, D.C. The Persian Gold case study was used in the Nuclear Weapons Effects course to expose students to a means of collaborative problem solving across disciplines related to the nuclear industry. Students were faced with a well developed international issue where WMDs became an imminent threat. The situation escalated, forcing players to be aware of and consider the multiple facets that impact the direction of the scenario. These facets included, but were not limited to, the social, political, economic, and environmental aspects of numerous countries and peoples. A key objective was for students to demonstrate that good decisions (i.e. a good outcome) require that members of the collaborative team become involved in the understanding of unfamiliar vocabulary and strike a balance between technical and non-technical (e.g. social, political, economic, and environmental) issues. Ultimately, this meant that no single discipline could arrive at a viable solution independent of the others represented in the team. The majority of the group (60 percent) had backgrounds in the humanities; the group dynamic was predisposed for interdisciplinary, versus multidisciplinary, collaboration as defined below. The academic demographics put the nuclear engineers (25 percent of the group) as a minority, but they did maintain the largest contingent of a single discipline.

According to Borrego & Newswander, participants on a multidisciplinary team “leave [a] project without having learned much about the other disciplines” with whom they were involved. For multidisciplinary

⁴ Raju & Sankar, 502.

⁵ *Ibid.*, 501.

collaborations, team members bring their expertise to bear on a problem and execute their work independently. Information is not so much exchanged as it is combined to create the collaborative solution. Participants in these teams remain “unchanged by the experience” because there is “limited exchange of information” in this method of cross-disciplinary problem solving.⁶ On the other hand, however, there is what’s called interdisciplinary collaboration. Interdisciplinary team members must “understand and appreciate the contributions presented by the various disciplinary frameworks.”⁷ In so doing, each member learns from the collaborative experience. In addition to these definitions, Borrego & Newswander posit that “low consensus disciplines like the humanities and social sciences” tend to benefit and thrive on interdisciplinary teams while high consensus disciplines like traditional engineering favor a multidisciplinary approach.⁸

Data collection for this paper was done through student surveys conducted before and after the exercise. In preparation for the exercise the students were provided a primer, background information on the industry (NDU’s Center for Study of WMD) leading the case study and scholarly papers related to scenario. The pre-event survey served to this author a purpose of gaining a basis for how the students perceive their understanding and comfort of case-specific knowledge prior to the exercise. The post-event survey was conducted one week after the exercise and focused on providing data relative to their understanding and knowledge before the event.

RESULTS AND DISCUSSION:

Pre-event survey results indicate that the students believe they have, in general, a moderate to above average understanding of background information and knowledge necessary to deal with the issue presented in the case study. On average, 71 percent reported they have the understanding necessary to deal with the issue and, remarkably 92 percent stated they are at least moderately familiar with ways to approach and deal with the problem. These results can be attributed to two potential causes: (1) 100 percent of the student population is enrolled in a liberal arts curriculum where they are required to take both technical and non-technical (e.g. humanities) courses, and (2) the students were provided primers and articles to prepare them for the event. Regardless of the cause for the high confidence, one may expect good cross-discipline participation from students with high confidence in their abilities and knowledge.

Results of the post-event survey show that on average 59 percent of the students claim to have improved their knowledge and understanding of case-related topics as a direct result of the case study; the remaining 39 percent claimed no gain or loss of their understanding—this datum reinforces the application of case studies in the curriculum. Of the nuclear engineers, two-thirds reported that their learning of non-technical matters was attributed to by individuals of disciplines other than their own. This is a result of peer education and not from the traditional, lecture model of instruction. Forty-five percent of the students had high levels of confidence in the group’s solution because of the academic diversity of the group. Students felt contributions stemming from those of other disciplines provided for a more complete, well rounded solution. An equal percentage of the nuclear engineers were also sympathetic to this belief.

On the other hand, more than one-third of the engineering population claimed that students outside their discipline negatively affected the outcome by degrading the technical aspects of the collaborations. This is one of several indicators discovered in this research that suggests the engineering students are not fully

⁶ Borrego, M. and Newswander, L.K., “Characteristics of Successful Cross-Disciplinary Engineering Education Collaborations,” *Journal of Engineering Education*, vol. 97, no. 2, April 2008, p. 124.

⁷ Ibid.

⁸ Ibid.

adept at communicating how and where their technical expertise fits into low consensus discussions (such as those found in interdisciplinary collaborations). Additionally, this result suggests they are reluctant to consider non-technical solutions as viable ones because they do not hinge on concrete truths as they are accustomed to in their field. When compared with the non-engineering majors, the consensus was quite the opposite. In fact, only the nuclear engineers felt the case outcome was unfairly weighted on non-technical considerations. As one student wrote in a free response on the survey, “the exercise failed to force decision makers to consult technical experts.” The student continued that the “proposals lacked engineering solutions.”

Richter & Paretto posit engineers’ difficulty and/or reluctance integrating themselves into an interdisciplinary teams is due to “disciplinary egocentrism.” Disciplinary egocentrism describes the “cognitive barriers engineering students [face] when moving into interdisciplinary contexts.”⁹ There are two learning barriers within the disciplinary egocentrism framework as cited below:¹⁰

1. Students fail to recognize the relationship between their own discipline and an interdisciplinary subject.
2. Students fail to recognize and value the contributions of multiple technical and non-technical fields to a given interdisciplinary problem.

In dialog with students after the event, faculty learned that the first learning barrier was certainly at play with the nuclear engineers in particular. Because this case study was hinged on developing strategic policy with respect to WMD, the engineers felt, as one student stated, that “the technical [aspects were] always secondary and out of place” within the discussion. This student didn’t realize the value of their contribution to the interdisciplinary subject. With respect to the second barrier listed above, faculty agreed that engineering students had difficulty accepting that they were but one piece of many in the interdisciplinary subject and failed to find the value of other, non-technical contributions.

Of the 60 participants, 84 percent claimed on the preliminary survey to have at least an average level of exposure to complex problem solving as part of their undergraduate education. 48 students stated that at least part of their prior complex problem solving occurred as part of an interdisciplinary team. This suggests that the students may have already had an appreciation for different ways of thinking, problem solving, and approaches to problem solving before this collaborative group exercise. The post-event survey revealed that despite their previously working on diverse teams, there is still much room for growth. This case study helped 64 percent improve their ability to think beyond the scope of their academic discipline and gain better perspective on how to approach complex problem solving. This again is positive traction for the use of interdisciplinary case studies because as educators we want to see students “incorporate new ideas and practices in their own work [and develop] their ability to contribute to larger interdisciplinary problems, believing that their work has [something] to do with those problems.”¹¹ Survey data show that an industry-led case study is a step in this direction.

A final bit of survey data that stood out in the post-event survey was related to nuclear engineers finding a voice within a team partly comprised of non-technical collaborators. A majority (58 percent) agree that it is more difficult to communicate technical issues and convey the importance of these matters in an interdisciplinary setting. Sixty-seven percent conceded to having to come out of their comfort zone in order to be an effective, contributing member of the team. Students need practice in articulating with confidence their knowledge to groups with different backgrounds. It is clear that an interdisciplinary case study can do this based on the number of engineering students that confessed to this shortfall. A recent

⁹ Richter, D.M. and M.C. Paretto, “Identifying Barriers to and Outcomes of Interdisciplinarity in the Engineering Classroom,” *European Journal of Engineering Education*, vol. 34, no. 1, March 2009, p. 38.

¹⁰ *Ibid.*, 39.

¹¹ *Ibid.*, 38.

article in *PRISM* magazine even addressed this concern amongst engineers. Engineers need to train to interact with the public in order to “communicate the details of an idea or one’s profession.”¹²

The nuclear engineers in the group were faced with a difference in understanding from their peers in the interdisciplinary collaborative group. A young engineer might argue that they were disadvantaged for not having a facilitator or moderator give more gravity to their contributions. A sage engineer who has experienced industry might offer a different perspective. What we can be certain of is that participants of this interdisciplinary case study were exposed to new ways of thinking and had an excellent opportunity to learn and practice a skill that will be useful in the years to come.

CONCLUSION:

In my short time as an educator I have seen that students, especially in introductory courses, compartmentalize the information they learn in different courses. Students mature throughout their degree program and eventually smear the boundaries of their engineering courses. They apply fundamentals to all courses and see that classes are linked and information is not to be fitted into mental silos. The goal for any engineering student should of course be to become technically proficient, but, also, to graduate with the skill of practicing their profession amongst a world of non-technical professionals. This means smearing the lines between the technical engineering knowledge and the non-technical knowledge and skill relevant to the practice of their engineering.

Industry partnerships for the development and execution of case studies are a viable method to achieve this balance of technical application with the non-technical understanding. ABET EAC student outcome (*h*) is therefore well suited for assessment by industry-led case studies. Many discover with higher education the following maxim, “the more you know, the more you know what you don’t know.” This was certainly true with the students in the Persian Gold case study. Students identified the real-world need for engineers to “transcend their own disciplinary boundaries, appreciate different frameworks, and eventually broaden their perspectives to include those of other disciplines.”¹³ When it comes to strategic and national policy, many eyes were opened to the fact that typically engineers and scientists serve as advisors to policy and decision makers. It is a duty incumbent on them as technocrats to communicate their messages clearly. Though students may not have mastered student outcome (*h*) during this case study, many at least realized the need to practice it further.

In the end, interdisciplinary engineering education does not require engineering classrooms be filled with a mix of engineer and humanities majors, but that we at least bring them together for an exercise where they form an interdisciplinary team for complex problem solving. This unification will help educators and students discover if disciplinary egocentrism is at play and allow for the concern to be addressed.

FUTURE RESEARCH:

The *Operation Persian Gold* case study will return to the Nuclear Weapons Effects classroom in the spring semester. It is the intent of this author to attain more data by conducting a similar survey of the students before and after the event. Lessons learned from this exercise will be implemented to encourage greater participation of discussion amongst all students. The primary lesson learned will be to break

¹² Wesson, R.D. “Develop an Elevator Speech,” *PRISM*, American Society for Engineering Education, vol. 23, no. 4, Dec 2013., p.21.

¹³ Schaffer, S.P., X. Chen, et al., “Self-Efficacy for Cross-Disciplinary Learning in Project-Based Teams,” *Journal of Engineering Education*, vol. 101, no. 1, Jan 2012, pp. 82-3.

students into smaller groups. The results of this future study will be provided in the ASEE 2014 summer conference in Indianapolis, IN.

Acknowledgements:

Thanks to U.S. Military Academy and U.S. Army for time and resources to conduct and accomplish this task. The opinions, findings, and conclusions expressed herein are that of the author and do not necessarily reflect the views of the U.S. Military Academy or U.S. Army.

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