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Engineering Management Student Study-Abroad Opportunities: Design Considerations for EM Programs and Faculty Mentors

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Abstract

Leading an undergraduate program in Engineering Management (EM) can be challenging due to the need to balance the requirements of accreditation engineering topics (ET) and the desire to inspire students through study-abroad opportunities. Often, foreign colleges do not offer the same level of ET rigor, putting students at risk of falling behind and not graduating on time. This paper proposes one approach to planning and creating student opportunity. It begins with understanding the problem in the global context using systems thinking and stays true to engineering design principles for addressing a complex problem in that host country. This approach provides students with a global perspective on technical engineering challenges, while also validating ET credits through applied research pursuits, using an online synchronous study-abroad learning model. The paper will present planning elements, a method of leading initial steps of a study-abroad effort, and case studies of EM students enrolled in the United States Military Academy at West Point who have participated in a semester abroad. This includes how the tools relate to the Engineering Management Body of Knowledge Domain 9 Systems Engineering and broader Engineering Design and constraint principles. The methodology and research approach presented in this paper could be used as a scalable model for other undergraduate EM program to help students meet graduation requirements in an accredited program while giving them the chance to experience global perspectives in EM applications early on in their academic careers.

Introduction

Pursuit an undergraduate degree in Engineering Management (EM) can be rigorous for any student under normal circumstances. It becomes even more complicated if the student aims to complete the program within four years and participate in an international study-abroad program. According to a 2016-17 study [1], only 5.3% of the 2% of US college undergraduate students who study abroad are engineering majors. It is difficult to determine the exact number of study-abroad opportunities available for accredited undergraduate EM programs within a four-year period based on a literature review. Most descriptions of study-abroad opportunities are offered in the context of integrated graduate school programs, and if undergraduate study-abroad offerings exist, it is not apparent as to how it affects the student's ability to graduate within four years. The small number of opportunities is attributed to fiscal resource and accreditation requirements constraints [2]. The global pandemic of 2020 also added travel constraints, further complicating prospects for studying abroad. Nevertheless, studying and conducting applied research on global engineering challenges with multicultural stakeholders is recognized as vital to the EM domain for effectively operating within the global economy.

The Accreditation Board for Engineering and Technology (ABET) program search engine yields fifteen current accredited EM undergraduate programs in the United States and its territories with another twelve international programs [3]. ABET requires forty-five semester credit hours in Engineering Topics (ET) and another 30 semester hours of Math and Basic Sciences [3] which can stress a student's ability to stay on the four-year graduation track. The study-abroad, broadening experience represents the additional layer of value for the student pursuing the EM degree yet must be carefully administered in the context of achieving the minimum ABET requirements.

Criterion 3: Student Outcomes of ABET reinforce the importance of a global perspective on engineering topics. The two outcomes which explicitly demonstrate the value to international experiences include [3]:

- Student Outcome 2: “an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.”

- Student Outcome 4: “An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which consider the impact of engineering solutions in global, economic, environmental, and societal contexts.”

Challenges with evaluating these two student outcomes should inspire innovation in designing educational experiences which help achieve these outcomes. Technical solutions increasingly require deep understanding of the challenges the global community faces, and those engineering solutions must work in an increasingly volatile, uncertain, complex, and ambiguous environment [4] [5]. That experience arms the EM student for achievement of outcomes ABET presents, and more importantly what society requires. Therefore, it is worthwhile to design overseas opportunities for an EM student who will require a global perspective for solving engineering and technical problems.

Setting Conditions for Distance-Learning Abroad

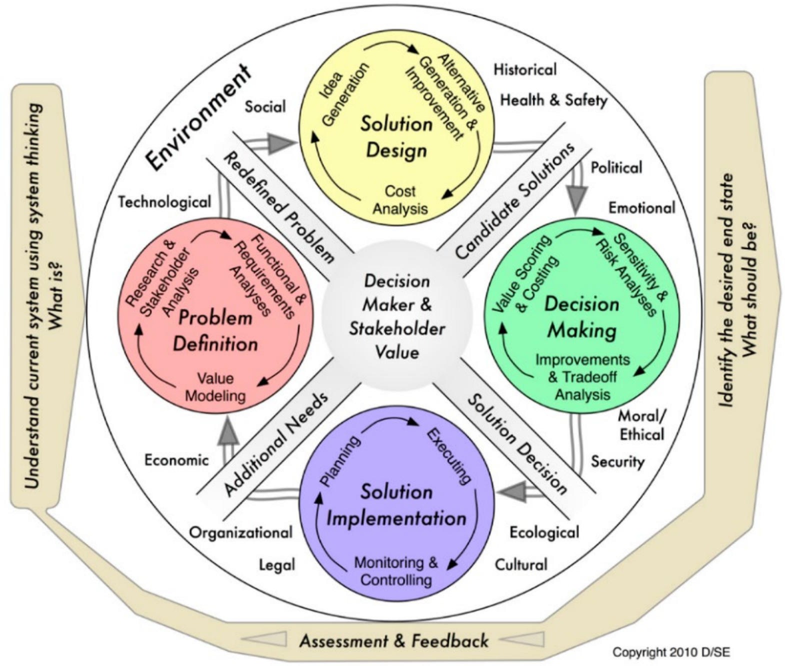
In the United States, there is certainly a need to develop human capital in STEM fields. A Bureau of Labor Statistics study in 2015 concluded that this market is heterogenous depending on which industry or market segment is studied [6]; some segments have shortages, and some enjoy surpluses. However, it concludes that the vitality of the workforce is a concern provided the increasing reliance on technology-based solutions to complex problems [6]. So, while the supply of the STEM workforces is an issue, that simply magnifies the importance of developing competent EM leaders who can work effectively in interdisciplinary teams and across international borders.

Experiential Learning creates conditions which allow for ‘creative synthesis and design’ [7] in engineering discoveries and development of useful technologies. Study-abroad provides experiential learning in the immersive global context for the student, and thus imbues deeper understanding of EM applications. This global experience is increasingly perceived as essential in career advancement [8] due to STEM field shortages and supply chain complexities which drive global interdependence to deliver technical projects.

The United States Military Academy at West Point's Engineering Management Program has witnessed a growth in semester abroad requests in recent years. Global network connectivity has certainly assisted student request increases due to accessible video-conferencing platforms whereas earlier efforts relied on email and phone calls. In the 2010/2011 academic year, the EM program supported one to two students per year in the study-abroad program. This has increased to four to five students per year in the 2022/23 academic year. With a fifty-five student EM cohort annually, this represents about 9% share of each junior year class.

The SE123, Research Project in Systems Engineering/Engineering Management course is the enabling course in the EM program of study which creates opportunity for study-abroad research when ET credit is assessed. Up to 3 ET hours can be approved by the program director based on a thorough review of complexity of engineering research problem, and application of appropriate engineering design given constraint considerations. This review and approval process is consistent with the Engineering Accreditation Commission (EAC) ABET requirements for evaluation of engineering coursework. The student and faculty mentor are responsible for development of well-defined research objectives and 'integrating the concepts and techniques learned in EM courses to solve a current problem' [8]. Research problems would be customized to regional topics of interest for the study-abroad to maximize understanding and application of EM methods in the context of the real world.

Since there are only 12 ABET EM undergraduate programs overseas, it is rare to find an exact ET match. While many international engineering or business schools might offer a course on project management, supply chain, or cost engineering, it remains a significant challenge to validate ET credits. West Point's EM program does have a pre-approved list of international schools where ET credits can be considered, but it is rare that the list leads to deep partnership since each student's situation in what culture they are studying, and where they are relative to the overall EM program of study is unique. SE123 creates a much-needed synchronous delivery of an engineering or technology-based applied research problem which results in appropriate ET hours earned, and thus alleviates the challenge of ET credit investigation. Three examples of project problems conducted in SE123 include a Systems Analysis and Functional Decomposition of an informal free marketplace, a Cost Modeling and decision analysis of for examination of a country's energy portfolio investment strategy, and a Decision Support Modeling and Analysis of Renewable Energy Partnerships. These projects rely on robust literature reviews and stakeholder analysis in country and follow an Engineering Design Process which employs the value-focused thinking, Systems Decision Process [8] as developed by Parnell, Driscoll and Henderson as shown in Figure 1. Unique to this process is an emphasis on thirteen environmental factors which impress upon the student the unique global considerations of how their analysis might be framed, and certainly influence a complex adaptive system.



(Figure 1: The Systems Decision Process)

Implementation of Semester Abroad Experience

The process of planning SE123, which allows EM students to shape and be part of the study-abroad, is conducted through the department's academic counselor, project faculty mentor, and EM program director. The location of the study-abroad is evaluated for engineering challenges unique to the country and considering the engineering or technical challenge's global context. The first step is making sure that there are motivated faculty and students which is consistent with findings of other institutions [9]. Once established, the following guidelines are used to evaluate the value and feasibility of an engineering experience. This includes:

1. Engineering Topic Discussion: The first question is whether the host country's university can provide an ABET accredited course experience which warrants credit toward the degree. Approval is rare but could occur if the university's program is a current ABET accreditation, or at least has another engineering ABET program that maps to engineering electives the student is pursuing. However, the likely scenario is the SE123 experience. The elements of an SE123 proposal and instructional memorandum include the purpose, a general course scope, research proposal with research questions, academic objectives, performance assessment, and administrative guidance. The proposal then provides the program director with the ability to validate the rigor in the course, and ET hours earned upon completion. Finally, the program director and academic counselor ensure that the SE123 experience maps adequately to the overall program of study for graduation requirements.

2. Synchronous Course Delivery: While most universities afford students with adequate access to technologies, others cannot. As such, a full check with the university to ensure regular communications via teaming software (e.g., Zoom, MS Teams, or WEBEX) is validated, and meeting schedules are developed around courses validated for cultural immersion. It is widespread practice to accomplish SE123 using a 'milestone' driven approach which emphasizes the phases of the systems decision process in Figure 1 and provides unstructured time for the student to be creative and innovative in their technical problem-solving approach. Important in planning is to be clear with meeting frequency, communication modalities, and written assignments [9].

3. Stakeholder Investment: Assuming a motivated student and faculty mentor, the question turns to the willingness of the host institution to help facilitate the research. This includes adequate time, facilities and technologies offered to the student, but more importantly the willingness of faculty and staff to function as catalysts in setting up connections with stakeholders who the student might need to work with for data, or simply to better understand and frame a technical challenge in the context of the culture. This is where deep experiential learning occurs, and as such is a key attribute of a successful SE123. Other US agencies often can serve as facilitators to arrange for stakeholder meetings as well, and most certainly when the applied research is useful to the country team.

EM Tools and Techniques – Empowering Creative Confidence

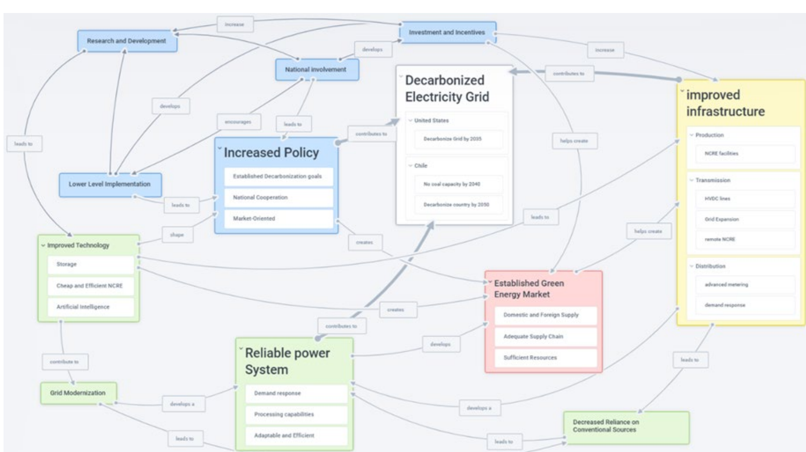
Engineers prefer rules and structure. Engineering Students benefit from a well-defined rubric and learning objectives to guide and focus their efforts. However, a synchronous study-abroad effort can be imposing for the faculty member and student. This is usually due to the 'messy unknown' [10] of tackling an ill-defined technical problem, in the real world, and with real stakeholders. The faculty and student must understand that a semester abroad experience requires an adaptable approach so that the complex adaptive system of interest which they are studying requires creativity to solve [11]. For undergraduate students, this experience represents their first exposure to adult education.

The student must be open and welcome in their adjustment to a learning model of pedagogy to andragogy for success. Pedagogy implies there is a dependence on the instructor. The worth of learning resides within what the instructor provides, adheres to standards, and is highly organized [12]. In a model of andragogy, the student must become intrinsically motivated to embrace self-learning, experimentation and problem-solving. They do this while examining real life applications for fulfillment of their own potential to develop engineering and technical competencies [12]. To this end, the faculty member must serve as a facilitator and motivator who inspires the student to seek deep understanding and knowledge of technical problems while seeking innovative solutions. Additionally, the faculty member should guide the student in assessing which EM tools are best applied.

The initial problem agreed upon might not be the redefined problem following a robust literature review and stakeholder analysis, and there is not one EM tool or method sufficient to solve every problem. And so, the faculty member be agile in facilitating discussion with the student and guiding adjustments in the research questions being asked and solved. The right means, or EM tools which facilitate the analysis could very well change, and both the faculty member and student must prepare for this reality and meet it with creativity and confidence in their unique application of the EM discipline for purposes of addressing the country problem.

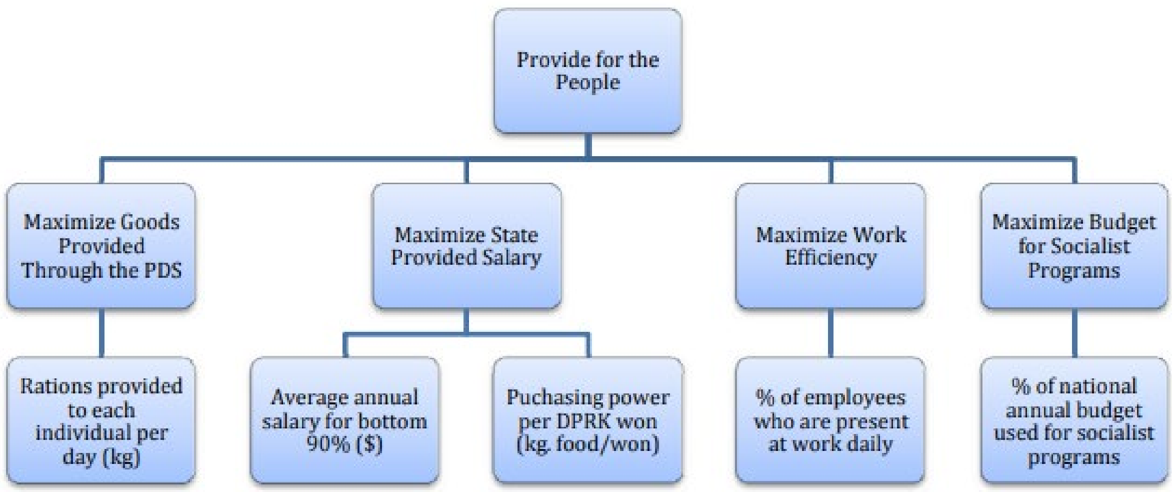
To describe briefly the EM means employed for more detailed technical analysis, the first three steps taken in most all study-abroad experiences include a systems thinking analysis, functional decomposition and value modeling of the problem, and a solution design ideation effort which may apply a combination of EM or Operations Research models, cost engineering analysis, and eventual evaluation of alternatives. Figures 2, 3, and 4 are representations of different student works which all resulted in accepted or pending conference proceeding papers with professional societies.

At the forefront of any SE123 experience is a systems-thinking and problem definition phase. Gaining a thorough understanding of the system through literature review and by engaging with stakeholders, a student studying EM can identify complexity of a system focus efforts on analyzing and solving the 'right' problem. For example, one West Point EM student created a systems diagram (see Figure 2) to help guide global investors in making green energy market investments and agreements. This system diagramming is explicitly discussed in Domain 9 of the EM Body of Knowledge and helps to create a mental model of the system complexity. The technical problem statement typically only appears after many weeks of personal engagements with citizens of the country. This system understanding enabled the student's ability to assess and update system complexity as research and engagements were conducted. It exemplifies the adult learning, or andragogical [12] approach needed to understand a complex system and it assists the student and faculty mentor in shared understanding of how best to apply ideation techniques and EM methods in follow on efforts.



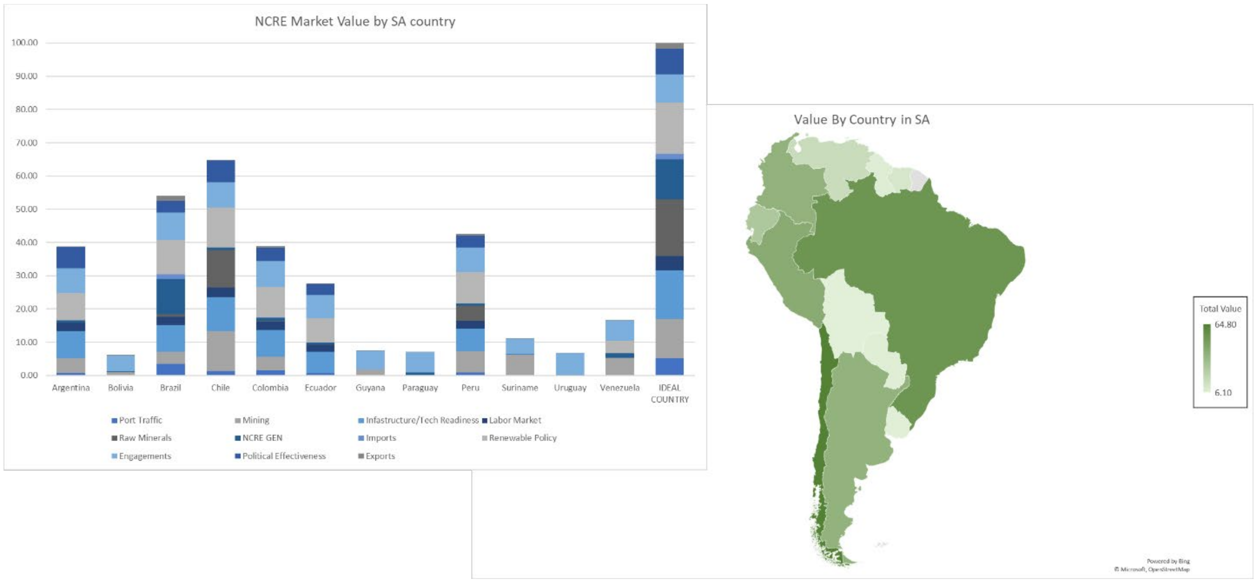
(Figure 2: Example Systems Diagram for an Engineering/Technical Problem on Green Energy)

Framing the problem for evaluation of design alternatives is enabled through detailed functional decomposition and value modeling. Figure 3 is one example of a larger value model tree conducted by a student studying informal marketplaces in China. This work was published as a white paper by West Point's Dept of Systems Engineering EM program in close support of the project sponsor, the United States Institute for Peace. The top function is evaluated through the lens of objectives in the second level, and its bottom level 'value measures' become the metrics used to analytically assess alternatives via an additive value model.



(Figure 3: Value Model of the human component of Chinese informal markets)

Ideation of design solutions, which are informed by either deterministic and stochastic models and when applicable simulations, assist the student in analysis of alternatives, and thus, improve decision quality about technical engineering solutions. The diversity of model applications can range significantly based on the problem being researched. Figure 4 represents one deterministic 'stacked bar' value chart and corresponding map which captures clean energy partnership potential based on infrastructure and raw materials for mining. The student worked during the study-abroad in Chile to engage with local companies, governmental officials, and the United States embassy to determine how a decision tool might help guide donor nation investment efforts.



(Figure 4: Additive Value Model Outputs of South American Green Energy Partner Potential)

Evaluating and Assessing the Experience

The study-abroad experience can be difficult to evaluate and assess. Little, Titarenko, and Bergelson [9] looked at paying close attention to the student and faculty workload and the first-hand experience of the international learning experience for the student. West Point's EM program evaluates student outcomes against a similar number of indirect indicators through surveys and instructor feedback. However, one distinction is the direct indicator, or culminating deliverable in SE123 which is the peer-reviewed worthy technical article students are required to write. Each student must present an article and associated model artifacts that meet the rigor expected of an undergraduate research effort and is consistent with the ABET EAC student outcomes. ABET student outcome three which is "an ability to communicate effectively with a range of audiences" [3] via the written word and oral 'in progress reviews' with the student mentor over the study-abroad duration. The effort is assessed much like a culminating student capstone project. Both oral and written presentations assess if the student is meeting the standard in accordance with appropriate engineering design principles and applications, and by accounting for constraints.

It can be equally important to consider the development of non-technical skills in an EM undergraduate. Braskamp, Braskamp and Merrill [13] suggest a holistic development framework of cognitive, intrapersonal, and interpersonal skills against cultural, curricular, and community immersion in a culture. This 'whole person' evaluation is similar to an assessment within the West Point Leader Development System (WPLDS). For EM students, this means that study-abroad experiences can provide benefits beyond just technical skill development. Students can grow as leaders of interdisciplinary teams with expanded understanding of diverse cultures. In essence, these experiences help to develop skills of a well-rounded engineer leader who becomes confident in their ability.

Conclusion

The case-based approach presented in this paper is based on the belief that study-abroad experiences can prepare future EM majors for technical challenges. It is scalable to other programs, but certainly would require determination of the approach's feasibility, suitability, and acceptability for each unique program. This adult learning model requires a significant and mature investment from all parties, and as such, the selection of students and faculty mentors is an important task in and of itself.

Technology, structure, and assessments are used to facilitate adult learning, which may not have been possible or acceptable in the past and present opportunity to explore new spaces that previously had been too constrained for consideration. So, while there is widespread support for study-abroad experiences, they remain difficult to resource. The hope is that the lessons presented in this paper can inspire others to become curious in the pursuit of EM student development in a comparable way. Future work in the EM program at West Point will aim to refine assessment methodologies beyond ABET mapping, codify the selection screening process for students and faculty mentors, and develop more effective techniques for faculty mentoring.

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