Promoting Global Competency in Engineering Education: Designing the "Engineering Across Borders" Casebook

Laureen Elgert
Worcester Polytechnic Institute

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Abstract

While global competency in engineering is a multi-dimensional skill, programs often focus on language ability, international experience, and working with international professional communities. Increasingly, engineering educators recognize a 'third dimension' of global competency: an understanding of how engineering projects influence and are influenced by, social, political, economic, and environmental contexts. This paper proposes the concept of a casebook that effectively builds this understanding by simulating reflective, hands on experience with project implementation in developing countries. The casebook concept features in-depth, real-world social science case studies, supplemented with informational, explanatory, and analytical materials, to improve student understanding of the different ways in which engineering practice interacts with diverse contexts. Four case studies were selected and pilot tested with undergraduate engineering students, who were asked to write article reviews in response to prompts regarding the comprehensibility and educational value of the case studies. The pilot study assessed: how case studies foment a deeper understanding of how often-assumed 'universal principles' of engineering interact with contextual factors; and, how case studies might be supplemented with materials that improve this understanding. Student responses indicated that the case studies contributed to their understanding and insights into the social, economic and environmental embeddedness of engineering projects. Responses also provided valuable insights into how case studies could be supplemented to improve their educational value for engineering students. The casebook concept is a potentially valuable tool for improving 'third dimension' of global competency, and can be particularly helpful in settings where students have limited international opportunities, and little exposure to social science approaches to engineering.

Keywords: Global competency, case study, social context

Introduction

The engineers of tomorrow have a crucial role to play in discovering and implementing sustainable solutions to daunting international challenges related to food, water, energy, sanitation and infrastructure. They will increasingly find themselves in a globalized workplace, often in developing countries, engaging with cultures, engineering traditions, and physical environments very unlike their own. Yet, strikingly, engineering education is routinely criticized for losing pace against these changes (Rugarcia, Felder, Woods, & Stice, 2000) and inadequately preparing students for such demands and opportunities. This may be increasingly the case, as curricula lag behind the social changes in society (Davidson et al., 2010) that underline the importance of 'global competency'.

In response, American universities have demonstrated a growing interest in emphasizing dimensions of globalism in their engineering programs (ie: Global Engineering Program at Purdue University; Sustainable Engineering Program at University of Michigan, global competency as a 'pillar' of Worcester Polytechnic Institute's strategic plan). Universities and funding agencies are developing networks and resources to help educators engage their students in global sustainability (ie: the NSF-funded Center for Sustainable Engineering at Syracuse University). These dimensions of engineering education are understood as integral in education that prepares students for the unique social, political and ecological challenges of the 21st century (Davidson et al., 2010). There remains, however, a dearth of learning materials and resources that promote a deep understanding of the wider social, economic, and environmental sustainability of engineering projects, especially in the developing world.

This paper introduces and examines the concept of the 'The Engineering Across Borders Casebook' (hereafter referred to as the 'casebook'), a teaching and learning tool that will support the building of global competency among US engineering students. The casebook concept involves in-depth, full length case studies from the social sciences, researched and written by historians, anthropologists, geographers, and political scientists, that critically analyze engineering projects in developing nations, delving into the situated, context-dependent factors that lead to failures and unintended consequences. This use of full length articles from the social sciences, and the focus on the developing world are what set the casebook concept apart from the boxed case studies that typical engineering textbooks provide, or other projects that use case studies in engineering education, such as the Online Ethics Center for Engineering and Science (Benya, 2016). Theoretical and empirical engagement with concrete case studies will bring students face to face with the cultural, social, economic and environmental complexities that engineers encounter in the developing world, including the intricacies of project implementation, the subtle transformation of technologies in different contexts, and the potential for unintended consequences.

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Additions to the texts such as definitions, explanations and summaries, as well as supplementary materials such as newspaper articles, historical documents, films, and music, will add salience to the context and bring engineering work in the developing world "alive".

This paper begins by establishing three 'dimensions' of global competency, and the effectiveness of case studies as a teaching and learning tool. It then explains the selection process for a sample of four case studies, and a pilot test of these with engineering undergraduate students. Based on the literature review and pilot test results, I argue that a 'casebook' – including case studies and supplementary materials that showcase definitions, theory, history and contextual information - will help students and faculty understand the complex interactions between engineering projects and their socio-economic, political, and environmental contexts. Moving forward, such understanding, developed through greater engagement with social science studies of engineering, will be vital for achieving global competency in engineering education.

Global Competency in Engineering Education: The Need and the Gap

Global competency is understood as integral to education that prepares students for the unique social, political, and ecological challenges of the 21st century (Davidson et al., 2010). Global competency is increasingly recognized as a core skill for engineers and expected of graduates by potential employers, and by society more generally. Global competency is even built into the engineering education criteria adopted by ABET in 1996 for the accreditation of engineering programs: Engineering Criteria 2000 (EC2000). Criterion 3, which regards student outcomes, is particularly relevant and includes the following:

> "(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability,"
>
> "(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."

Despite the growing importance placed on global competency for a new generation of engineers, there is no consensus regarding its meaning or the particular characteristics that it implies. Indeed, there are a variety of knowledge and skills, aptitudes and abilities, and behaviors (Gary Downey et al., 2006; Jesiek, Zhu, Woo, Thompson, & Mazzurco, 2014) that enable professionals to work effectively and sensitively in physical and cultural contexts that are unlike their own. These broad definitions are generally accepted by professionals and academics, but more specific ideas about what constitutes global competency, and what is emphasized in global competency training, are often associated with particular places, people, and professions (Jesiek, Zhu, et al., 2014).

This ambiguity and divergence notwithstanding, the literature suggests three general threads of understanding regarding what global competency entails. These threads are not mutually exclusive. Rather, they represent 'dimensions' of global competency, from the most immediate and visible, such as language skills, to the more abstract and critical skills that promote understanding of the technology-context nexus (see Figure 1). The first dimension emphasizes the logistical skills that facilitate an individual's functioning in a non-native context. Competency in this dimension entails the ability to communicate (speak, read and write) in a non-native language, feeling and displaying comfort in cross-cultural situations, and understanding appropriate non-verbal communication in different contexts. An emphasis on this dimension of global competency has produced a laundry list of requirements to produce the "global-ready graduate" (Hunter, White, & Godbey, 2006), including things such as language training, international travel experience gained by undertaking an overseas project, fulfilling a work placement or participating in a field trip (Gary Downey et al., 2006), and coursework in international studies (Hunter et al., 2006; Lohmann, Rollins, & Hoey, 2006; Parkinson, 2009). Such requirements are assessed using metrics such as language tests, time spent abroad, and course credits earned.

The second dimension of global competency, is less individual and more interpersonal, and highlights the ability of students to work across "engineering cultures" with distinct culturally and historically determined ways of approaching engineering problems, projects, and careers (Gary Downey & Lucena, 2005; Gary Downey et al., 2006). Downey et al. invoke less tangible, less quantifiable skills in their definition of global competency as "working effectively with people who define problems differently" (2006). These authors identify three learning outcomes to assess global competency: knowledge of the similarities and differences between engineers and non-engineers of different countries, an understanding of how others perceive engineering work and how it fits into their lives and societies, and a predisposition to treat co-workers from other countries as bearers of valuable knowledge and an understanding of different perspectives (Gary Downey et al., 2006).

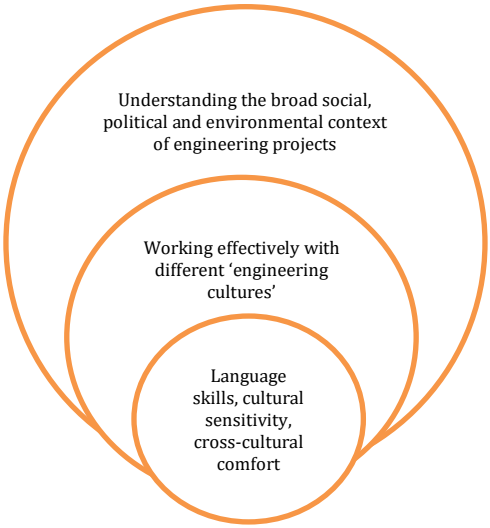

Figure 1: Three dimensions of global competency

The third dimension of global competency is not exclusive from the others, but relates more broadly to how engineering projects both impact and are impacted by the social, political, and environmental contexts where they are designed, and those where they are implemented. Implicit in this approach to global competency, as Cech explains, is a critique of the treatment of engineering as a purely "technical" space where social and political issues are considered peripheral to engineering practice (Cech, 2013). Other scholars agree that engineers need to receive at least some training in "fields that were traditionally viewed as tangential to engineering education, such as global socio-economic and political systems…" (Lohmann et al., 2006:120). In this third dimension of global competency, engineering educators have begun to articulate more specific criteria. They argue that students should be able to:

- Understand and anticipate potential unintended consequences of proposed design solutions (Grasso & Burkins, 2010)
- Recognize, analyze, and learn from design failures (Catherine P. Koshland, 2010), and
- Systematically assess impacts on all relevant stakeholders (Lucena, 2013; Schneider, Lucena, & Leydens, 2009).

Such concerns about socio-economic and political issues are relevant in all contexts where projects are executed, but may be particularly important in the developing world because of high levels of inequality and vulnerability, as well as the mix of local and international political processes (see, for example, Chapin, 1988; Cullather, 2002; Green, 2008). Furthermore, the intersection of engineering and development is of increasing interest to students with the proliferation of volunteer and service learning and organizations that engage young people with development abroad. These experiences may encourage engineering students to consider international careers, and bestow a growing importance on the training of globally competent engineers.

Global competency is in part marked by language skills and international experience. Of equal importance, however, is a fundamental understanding of how interventions are potentially transformed by context, and entail a plethora of unintended consequences, both positive and negative. As social and political leaders are calling on engineers to become more engaged with pressing social problems in the developing world (Amadei, 2004), there is a corresponding need to sensitize practitioners to the inadequacy of universal 'solutions' and the centrality of broader context. For example:

> While worthy of recognition and praise for directing engineers' attention to problems arising from global economic inequity, many engineering-for-development initiatives share problematic assumptions about technology's role in community development and fail to grapple with the broader forces that direct –implicitly or explicitly – most development interventions (Nieusmaa & Riley, 2010, p. 30).

Case studies for the challenge of teaching and learning global competency

An understanding and sensitivity to the dynamics of how practical engineering endeavors might interact with contextual factors is essential for a comprehensive approach to global competency. This dimension of global competency among engineering students, however, is somewhat under-examined and challenging, because, "it requires that they learn how to identify and grapple with the kinds of social, cultural and political considerations that frequently emerge when working on real-world problems in developing contexts" (Jesiek, Dare, Thompson, & Forin, 2014, p. 1). Traditional engineering instruction is ill-equipped to highlight such considerations, as it often emphasizes deduction based on theories and core principles first and applications only secondarily (Felder, 2012).

Case studies, by contrast, tap into an inductive or 'integrated' (Felder, 2012) mode of learning and build different skills than traditional engineering instruction. Students encounter richly contextualized real-life situations and are forced to discern the larger principles at work, just as in real-life job situations outside the classroom (Fuchs, 1970). Most students will better comprehend the principles and concepts if directly tied to facts on the ground and presented within a clear and engaging narrative. the intellectual value and potential for skills development of using case studies in learning (Scholz, Lang, Wiek, Walter, & Stauffacher, 2006; Wassermann, 1993). The value of case studies is particularly emphasized in the context of 'multicultural education' (Nieto, 2000).

The advantages of using case studies in education is well established. In her pioneering 1970's work, Fuchs argued that using case studies in engineering could help bring "outside reality inside the classroom" (Fuchs, 1970). It prepares students for on-the-job applications and increases motivation. A 1983 study by Henderson, Bellman, and Furman shows that cases can illustrate basic concepts and cultivate problem-solving skills. Richards et al. (1995) showed that case studies can help students better grasp the relevance of course material, facilitate active learning, and increase conceptual integration. Other studies suggest that case material facilitates memory of content, students' enjoyment of learning and class attendance (Hoag, Lillie, & Hoppe, 2005). Case studies have been found to increase students' critical thinking and problem-solving skills (Dochy, Segers, Van den Bossche, & Gijbels, 2003; A. Yadav & Barry, 2009), higher-order thinking skills (Dori, Tal, & Tsaushu, 2003), conceptual change (Gallucci, 2007), and motivation to learn (A. Yadav et al., 2007). Furthermore, case studies can even promote more critical reflection on students' own assumptions and perceptions. According to Prince and Felder, students who analyze 'authentic' ('real-world, professionally relevant') cases:

> "become aware of the kinds of situations and dilemmas they might have to face as professionals, gain both theoretical and practical understanding of their subjects, develop critical reasoning skills, explore their existing preconceptions, beliefs, and patterns of thinking, and make necessary modifications in those preconceptions, beliefs, and patterns of thinking, to accommodate the realities of the cases" (2006, p. 132:132).

These findings were corroborated by a 2010 study that found the use of case studies in engineering classes worked just as well as other methods in conveying concepts, yet did more to add a sense of realism and spark student interest. "Case-based instruction," Yadav, Shaver, and Meckl concluded, "can be beneficial for students in terms of actively engaging them and allowing them to see the application and/or relevance of engineering to the real world" (Aman Yadav, Shaver, & Meckl, 2010:56). In sum, according to the engineering education literature, case studies offer the following potential advantages to developing global competency:

- Problem solving and critical thinking skills
- Greater relevance
- Active learning
- Increased conceptual integration
- Increased motivation and longer retention
- Questioning of preconceptions

The Casebook Concept: "Flipping the Textbook" by Making Case Studies Central

Given the importance of using case studies centrally in education engineering to promote the development of global competency in the 'third dimension', the traditional textbook is 'flipped' in the casebook concept. Most textbooks, including engineering textbooks, offer short "boxed" case studies that are secondary to the conceptual, theoretical material. The casebook stands in contrast, by reversing this order; bringing case studies to the front and center of the learning experience. Drawing on the notion of flipping the classroom – where students gain exposure to new material outside of class and then use class time to do the harder work of developing a deeper understanding through problem-solving, discussion, or debate (Bergmann & Sams, 2012) – this project "flips the textbook". The case studies are the dominantly featured materials; the definitions, background and theoretical explanations required to analyze and interrogate the cases are 'boxed' for reference purposes, but do not take center stage.

The rationale behind the 'flipped textbook' is two-fold. First, case studies facilitate deeper learning and questioning of the learners' assumptions, as discussed above. Secondly, while understanding of such theory is crucial to a deeper understanding of engineering interventions, it often seems abstract and inaccessible to learners, particularly for engineering students, who often have limited exposure to humanities and social science approaches to science and technology. Concrete case studies can provide an accessible, textured, and engaging means for thinking about principles and concepts.

Project Approach

We designed a pilot test to assess and improve the benefits of using case studies to help students understand how engineering projects impact, and are impacted by, the social and environmental contexts where they are implemented. We began by building a corpus of case studies to use in the pilot test, and then gave students class credit to review the articles, with a specific emphasis on their implications for issues of technology in society. Finally, based on the student reviews, we determined what kinds of supplementary materials and information could help deepen student engagement with the case studies (See Figure 2).

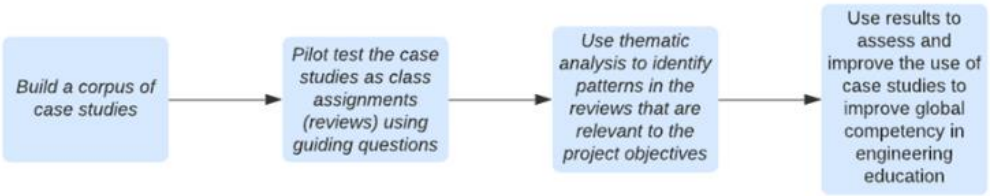

Figure 2: Project Approach

Build a Corpus of Case Studies

We identified case studies for this project by searching literature databases and querying listservs to draw recommendations from a broad range of experts, including academics, instructors and practitioners. We sent an email, to 5 relevant listservs reaching academics and practitioners in geography, history, development studies and environmental studies and global engineering in the United States and abroad. The email solicited suggestions of:

> Engaging and thought-provoking case studies which illustrate and analyze the social, political, cultural, environmental and/or economic complexities of project design and implementation in the 'real world'. These should be case studies that are already published in journals, books or working papers. Particular emphasis is placed on case studies that are clear, compelling and accessible to a wide-ranging audience, that provide concrete examples of the impacts of implementing science, technology and engineering projects. Examples of case studies could include such projects as: dams, roads, health care, urban infrastructure, agricultural innovation and information technology.

A preliminary scan of these suggestions produced 5 potential inclusions. We emphasized the following criteria in case study selection:

- a focus on engineers and other technicians in cross-cultural settings;
- illustration of the social, political, cultural, environmental, or economic complexities of project design in such settings;
- a 'pull' for readers with clear, concrete narratives; and,
- provision of opportunities for classroom application in a wide diversity of fields.

Around 30 people responded to the solicitation for case study suggestions, with a total of 47 suggestions. From many good possibilities, four case study articles were chosen for their close fit to our criteria, outlined above.

> Cullather, Nick. "Damming Afghanistan: Modernization in a Buffer State." The Journal of American History 89.2 (2002): 512-537.
> Cullather tells the story of the Helmand Valley dam authority, a project begun by a private American engineering firm in the early 1950s, then expanded by the U.S. Agency for International Development during the 1950s and 1960s. Hamstrung by Cold War competition and internal Afghan politics, the dam ultimately failed both environmentally and socially: the dam caused water logging and salinization and the associated resettlement project alienated the traditionally nomadic local population.
>
> Chapin, Mac. "The Seduction of Models." Grassroots Development 12.1 (1988): 8-17.
> Chapin presents the Mexican government's attempt to promote sustainable development by recreating a successful technology of the region's past, Aztec chinampas or man-made islands, that were highly productive yet required no significant capital inputs. Technicians attempted to build traditional chinampas with modern engineering and construction technology, but failed because they overlooked the wider social, economic, and political context in which the farmers live, and had not researched the market situation. Despite failure, the depiction of the chinampa system as a viable alternative continues in the literature.
>
> Green, Rebekah A. "Unauthorised Development and Seismic Hazard Vulnerability: a Study of Squatters and Engineers in Istanbul, Turkey." Disasters 32.3 (2008): 358-376.
> The explosive growth of cities around the world but especially in the developing world during the last few decades is one of the most important challenges of the twenty-first century. Green discovers how this challenge is manifest in the context of "earthquake engineering" in Istanbul, Turkey. Intense distrust of professional engineers and contractors has led Istanbul squatters to believe that, compared with commercially built housing, self-built squatter's shacks will be not just cheaper but also safer.
>
> Roy, Arundhati. The greater common good. (1999) http://www.narmada.org/gcg/gcg.html.
> Roy challenges the wisdom and discourses around large scale 'development' projects, by examining how the Sardar Sarovar Dam, engineered by the World Bank, created profound 'losers' in the development process. Overshadowing promises of creating clean, cheap and domestic energy to fuel the country's economic development, were social tragedies of the displacement of thousands of rural people from the Indian countryside. Roy argues that dams are a means of social control, and embody the political position that supports the sacrifice of poor rural people for 'the greater common good'.

Pilot Test Case Studies

We tested the original case studies in an undergraduate environmental studies course in the social sciences. The majority of the 28 students in the class were engineering majors, and represented all years, from freshmen to seniors. Students in the class earned credit for the individual completion of weekly written article reviews of around 500 words, following prompts designed to elicit responses that we used to assess their comprehension and analysis of the case study, providing insights into whether and how case studies could improve 'third dimension' global competency. The following prompts provided the students guidance for completing the reviews:

- List and summarize the main points of this article.
- In the case study, what worked well? What went wrong? Of the various factors involved, which were the most important? Why?
- What does this article say about the complexities of using technology for development?
- Were there concepts or terms used in the article that you had trouble understanding? Are there topics that you think should be discussed before

this article is assigned? Is there background information that you would have found helpful having before reading the article?

Thematic Analysis

Thematic analysis was used to identify, analyze and report patterns within the data (Braun & Clarke, 2006, p. 79). Broad thematic analysis was undertaken to organize the data from the student reviews according to two primary research objectives. More specific themes were then identified to describe the data in greater detail (Braun & Clarke, 2006). The first objective was to capture the comprehensibility and accessibility of the article content and understand the extent to which the case study managed to foment high-level engagement with the influence and impact of context on the engineering initiative. In other words: How does engaging with the casebook case studies promote engineering students' global competencies? (See Table 1). Did the students understand about what the paper was written? Did they enjoy the article? Were they interested in the case? Did students understand the complexities of the relationship between engineering projects and social, political and environmental context? Did the case study convey the contingencies and limitations of what are often taken as 'universal' and 'neutral' engineering solutions? The second project objective was to establish the types of additional materials or information that could enrich the students understanding of the case study and its implications. In other words: How can the structure and scaffolding within the casebook be improved in order to better promote students' global competencies? (See Table 1). For example, were there 'structural enhancements' such as summaries and identification of key quotes that could help students understand long and complex texts? Does the article feature definitions and concepts that might require further explanation or background to enable students to appreciate the case study more fully? Is there a broader theoretical or intellectual tradition or evolution that this case study is embedded in or a part of, that would help illustrate changes in discourse and policy over time?

Results

Table 1 summarizes the main insights that the student reviews of the case studies provided into the value of the casebook concept for improving students' third dimension global competency: understanding of the ways in which science and technology are transformed by context and the ability to critically question the often-assumed universality of engineering principles. The pilot test also provided further insights into the types of case study characteristics that most readily contribute to student development, and provided concrete guidance around the kinds of 'supplemental' definitions, backgrounds, historical points and further readings, films, poems, etc. would be most helpful for improving comprehension.

Table 1: How case studies contribute to global competency and how to improve this contribution

Main Objectives	Thematic Insights Drawn From Learner Responses
How does engaging with the casebook case studies promote engineering students' global competencies?	Transformation of technology in different temporal and spatial contexts Role of community engagement and local knowledge Case studies introduced an 'intimacy' with context Legitimacy of different perspectives
How can the structure and scaffolding within the casebook be improved in order to better promote students' global competencies?	Visual cues and clear organization Highlighted text Historical situation of the case Theoretical context

The teaching/learning value of case studies

In their review assignments, many students indicated a recognition of the vital importance of context in project development and implementation. They commented on how the functions and outcomes of engineering and technology projects can be fundamentally changed by 'transplanting' them in time and space:

Using technology is extremely complex. Just because a technology works in one area at one moment in time, it does not guarantee it will work anywhere else or at another point in time… A technology could work in one society, but that does not mean it will be successful in the next.

Transplanting the technology to regions outside of the area and time period in which it flourished creates many potential problems.

Overall, numerous difficulties arise in implementing new forms of sustainability development into new areas having different social, economic and environmental conditions.

One student emphasized the importance of 'history and background' in understanding the complexities of how technologies are historical context, and the importance of history:

The author did a great job of supplying enough history and background knowledge so we could see why the technology did not work there.

Certain aspects of the idea were lost in implementation because 'development' was not the overall goal, but seeing through the project with the exact same details as in the past.

Many students recognized the importance of local involvement in project design and implementation. They cited the importance of 'insider knowledge' and 'communication' with local people to develop understanding of context and perspectives that can deeply impact how technology is adopted, used and how it fits with local perspectives and institutions.

The article stresses communications so that larger corporations and scientists can gain first-hand information from inhabitants… what looks good on paper may not be the best way to go about things when the method fails in practice…a lack of communication can destroy project goals.

They ended up failing, for their lack of knowledge of how the community itself uses the technology.

All the ideas of the scientists and ecologists sound perfect until they start to work on them without taking into account the peoples' thoughts and ideas.

External entities were trying to improve things with their external technologies, but the project failed because of their lack of communication with the villagers.

Many students commented on the 'intimacy' of case studies: the way the cases bring the reader into an unfamiliar, and often surprising reality by 'immersing' them in the context:

Prior to reading this article, I still had uncertainty as to how social aspects of communities directly related to natural hazards… this article made it much more clear to me by giving a clear example.

It is mind boggling to think that people completely distrust professionals who have been trained… though I understood where the urban poor were coming from, it takes being completely immersed in that mindset to fully grasp it.

I had never imagined something like this social opposition to engineering ever being a possibility…

This seemed like a real-world article. By that I mean, this seemed like a very relatable problem and I could see how this is an issue and how complex of an issue it is. I could relate to the issue.

Illustrating further, the enhancement of a greater contextual understanding local people's potential reaction to engineering interventions, one student highlighted, with surprise, that the Green article revealed 'legitimacy' and 'reason' behind what initially seemed 'ridiculous claims'. This student noted the important role of emotion and voice:

To someone who is familiar with engineering design and standards it may seem ridiculous to hear claims from the poor that they are able to construct their own homes, however, the author's insight into the thought and emotion behind these claims makes the reasoning more clear. These people have legitimate reasons for thinking like they do. The author gave a voice to the poor and their point of view made the article much more thought provoking and interesting.

Improving the teaching/learning value of case studies

The student reviews also provided clear direction for making the case studies more intellectually accessible, and improving the effectiveness of communicating the role of context in engineering. Students had a strong preference for articles that featured visual cues and organizational structures that they found to facilitate understanding of the article content. For example, students appreciated the overview provided by abstracts, subtitles, and summative graphs and tables, and found that this base knowledge facilitated greater attention to detail and overall understanding when they read the article. Students cited the non-use/use of these types of features to account for greater comprehension and closer engagement with Green (2008) and Chapin (1988), and lesser in the cases of Roy (1999) and Cullather (2002). One student commented on Chapin, saying:

I also did not like that the article did not have an abstract and clear subsections. Articles formatted with these sections are easier to read and help the reader ascertain the main points of the article before getting lost in the details.

Students also found boxed information, such as keywords, highlighted quotations, background and history very helpful. Some articles and article formats provide that, such as Chapin's article, the Seduction of Models. Students commented on Chapin's elaboration of background and history as helpful, and the highlighting of specific quotations from the article that underline some of the article's key points.

> *The author did a great job of supplying enough history and knowledge so that the reader could comprehend certain topics and brought everything full circle… more background information is always valuable.*

While it might be assumed that shorter articles are better for undergraduate readers, this proved not to be entirely the case. With the right kind of background and history, at the right times, in the right language, students will invest the time to read. For example, one student complained that,

> I did not like that this article was so short! I really enjoyed reading it, and did not realize how much I had read til (sic) I already read more than half of the article!

The way in which structure, subtitles, summaries and 'boxed' information in the case studies promoted student learning, informs the way in which more complex case studies could be supplemented to make them more accessible and understandable to undergraduates. For example, adding article and section summaries and boxing key, indicative phrases would assist comprehension, even of long and complex articles. The article reviews also provided other excellent insights into what types of supplementary information and materials could improve and heighten students' understanding of, and engagement with, the case studies. For example, basic definitions and/or synonyms of certain non-technical words that may be sophisticated for an undergraduate audience could be linked through hyper-text to definitions. This could help students avoid getting caught up or distracted by unfamiliar words (students highlighted such words as 'juxtaposed', 'squatters', and 'de facto', as such words). Historical context of the case could also contribute to a greater understanding of how different approaches and perspectives on engineering projects arise. One student commented:

> There was not much focus on the inception of the stigma or engineers… it is a shame that the only focus was on current perceptions. I think more detail on the subject's roots could have helped to clarify and validate the peoples' reasons for thinking this way.

Finally, analysis of the student reviews made it clear that supplementary materials should expand upon the conceptual and theoretical foundations of the case study and the arguments it makes. Showing how the case studies fit within a larger theoretical tradition of critical thinking around vulnerability (Wisner, Blaikie, Cannon, & Davis, 2004), expertise (Irwin, 1995), 'high modernism' (Scott, 1998) and globalized development (Li, 2007) will both help students to more deeply understand the case study, and enable them to apply the lessons of the case studies to engineering and society problems more generally.

Discussion

Data from the student reviews of the four cases in the pilot study, suggest that the use of social science case studies can, indeed, foment the development of 'third dimension' global competency, or 'holistic engineering', by stressing and illustrating the importance of context in developing and implementing engineering interventions and assessing their outcomes. Much of the social science literature features an approach to engineering and technology that is fundamentally different than that which is often emphasized in traditional engineering education, by recognizing influences that have been considered 'peripheral' in more traditional engineering perspectives (Cech, 2013a, Lohmann et al., 2006a). A greater understanding of these influences is increasingly recognized as a vital part of global competence. The cases feature various ways in which engineering interventions are not neutral, technical, and failsafe solutions to problems, but are, rather, fundamentally embedded in local social, economic, political and environmental institutions. More specifically, the cases have pushed students to consider potential unintended consequences (Grasso & Burkins, 2010) that result when standardized plans are implemented in unfamiliar contexts. Secondly, the cases have encouraged students to recognize, analyze and learn from design failures (C.P. Koshland, 2010) by considering the importance of community engagement and local knowledge and considering unique histories and backgrounds. Thirdly, the cases have helped students to recognize diverse stakeholders in engineering interventions and assess how they are impacted differently (Lucena, 2013), by promoting a deep, 'intimate' understanding of local perspectives.

Despite these benefits of introducing engineering students to social science literature, for inspiring a generation of 'holistic engineers', this body of work may not often be entirely accessible to many engineering students. Case study research in anthropology, history, sociology, and development studies takes on a style, format, epistemological orientation, and theoretical basis that are set apart from traditional engineering studies. Central to the casebook concept, therefore, is the consideration of how to adapt the structure of case studies, and how to supplement them with informative and meaningful materials in order to create greater opportunities for engineering students to engage them. This pilot study generated concrete ideas on how to make social science case studies more accessible to engineering

students, such as organizational cues (subtitles, abstracts), highlighting important and indicative text, and providing narratives and other materials that examine the case's historical and theoretical context.

Conclusion

In recent years, as the challenges of working in an increasingly globalized world have grown, engineering educators have called for more emphasis on developing global competency among students. Global competency is often associated with foreign language skills, experience living and working in unfamiliar territories, and an understanding of international 'engineering cultures'. A 'third dimension' of global competency, increasingly recognized as equally important but under-emphasized, is a broader appreciation for how technical and engineering projects both transform, and are transformed by, socio-political and environmental contexts. 'Holistic engineering' as this third dimension has been called, acknowledges that the interplay between engineering and society raises complexities that are often difficult to predict. This understanding runs counter to the realist epistemological orientation of many engineering students and instructors, that engineering interventions are socially 'neutral' and satisfy technical requirements independently of socio-political, economic and environmental influences. Third dimension global competency is, therefore, perhaps the most challenging area of global competency to improve, especially without hands-on, overseas experience.

Using the established effectiveness of case studies as a teaching and learning tool, this paper has argued for the concept of a 'casebook' to advance knowledge of this contextual aspect of global competency by zeroing in on the special challenges of project design in the increasingly important but mostly understudied developing regions of the globe. The developing world, where many of the most daunting engineering challenges of the twenty first century lie, is also where profound economic, cultural, and environmental differences have often stymied technological projects. The casebook will help engineering education more effectively and comprehensively foster global competency, particularly the 'third dimension' global competency – holistic engineering. Evidence from the pilot test of case studies with undergraduate engineering students suggests that case studies are indeed effective tools for facilitating deeper learning and understanding of the kinds of intangible, complex, and often unfamiliar ways that western/northern-designed engineering and technology projects, 'misread' physical, social and economic landscapes. Supplemental materials, such as summaries, background, definitions, history, and theory could transform even dense and difficult academic articles into student-friendly case studies that highlight cultural, socioeconomic, and environmental influences on the 'behavior' of engineering projects.

In addition to the individual benefits of the casebook for improving global competency, the proposed casebook will contribute to a better understanding and dialogue of the wider issues of engineering and society within and among the networks of the engineering education community. It will do this by introducing critical engagement of engineering projects, now well established in the social sciences, to this community. The casebook concept, therefore, is part of a bigger sea change in both the engineering disciplines (leading to a greater engagement with social science) and social science (a greater interest on behalf of anthropologists, sociologists, geographers and historians in the practice of engineering and the implications of such practice).

A final benefit of the casebook concept, is that it will contribute to developing global competency and international perspective for many engineering students who, for financial or personal reasons, do not have the opportunity to travel or work abroad as a part of their undergraduate experience. Without global training, such students may be viewed as less "globally competent" than their more mobile peers, have fewer future opportunities, and become less recognized as leaders in their field. For such students it is particularly important that classroom-based opportunities for developing global competency are both available and of high quality. This casebook will offer such students an opportunity to consider, experience, and analyze cross-cultural project design, despite potential limitations on travel.

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