AC 2012-5395: VISIONS OF SOCIAL COMPETENCE: COMPARING ENGINEERING EDUCATION ACCREDITATION IN AUSTRALIA, CHINA, SWEDEN, AND THE UNITED STATES

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Visions of Social Competence: Comparing engineering education accreditation in Australia, China, Sweden, and the United States

Abstract

This paper reports on a cross-cultural analysis of central accreditation requirements for engineering programs—focusing especially on issues related to social impact, social responsibility, and social analysis—in four different countries: Australia, China, Sweden and the United States. Upon comparing and contrasting the accreditation requirements documents and their treatment of "social" capabilities, we found that:

- Accreditation requirements in all four countries are similarly oriented to specific student-learning outcomes, where technical and social capabilities represent roughly equal proportions of the total number of requirements.
- Social capabilities represent a wide range of competencies, including very high-order social-analytic competencies (e.g., understanding the relationship between engineering and its social context).
- Important variations can be identified in how social capabilities are understood, with four distinct categories emerging: Social capabilities 1) as constraints, 2) as awareness, 3) as responsibility, and 4) as cultivation.

After reviewing, categorizing, and analyzing the key ways social-analytic competencies are articulated and understood in the four countries' accreditation documents, we identify key opportunities and challenges facing those seeking better integration of social competencies in engineering education. We conclude the paper with a review of our findings and our next steps.

Introduction

This paper investigates which and how social and technical competencies, or capabilities,[1] are represented in engineering education accreditation documentation in four different countries. The study is intended to shed light on how social competencies are articulated and understood in each national context and across contexts. A comparison of these understandings suggests challenges and opportunities for reforming engineering education to be more responsive to social needs in each context.

Recent years have witnessed increased emphasis on the social impact of engineering in North America and elsewhere, and this emphasis is now represented in many countries' accreditation requirements for engineering programs.[2] However, discussions about the role and place of "the social" in engineering education are nothing new. According to Leydens and Schneider, throughout the last century in the United States, there has been an ongoing culture-versus-utility debate around the role of humanities and social science (H&SS) content in engineering education, with engineering faculty generally coming down on the side of utility.[3] Despite early calls for better integration of H&SS and "engineering" content, segregation has endured between professional (math, science and engineering analysis courses) and general education (H&SS

courses) or "hard" and "soft skills"[4] or, in yet other words, technical and social content. In the eyes of Leydens and Schneider, the outcomes-based criteria of ABET EC 2000 have provided new opportunities for interdisciplinary collaboration and integration of H&SS (in their case, communication content specifically) approaches into engineering education.[5]

As a counterpoint, Seron and Silbey highlight difficulties for innovative engineering education initiatives to align with the instrumentality of ABET requirements.[6] Studying efforts at Franklin L. Olin College of Engineering and Smith College's Picker Engineering Program, Seron and Silbey found:

> Rather than [to] begin with the expertise grounded in mathematics and science and then teach how to apply that knowledge through known techniques, both programs asked students to become inquirers seeking knowledge, rather than implementers applying knowledge. As the programs sought legitimacy for their innovations through professional accreditation, however, the open-ended, exploratory processes of serendipitous learning were instrumentalized into a set of measurable procedures for acquiring standard, scientific expertise as the essential credential of the responsible engineer.[7]

Seron and Silbey tie the challenge of gaining legitimacy for these new innovative programs to what they see as an instrumental logic, which is part of what Riley refers to as the particular "mindsets" commonly found in engineering.[8] In light of Seron and Silbey's study, it becomes important to reflect on what is considered "common sense" within the engineering community, and how this gets agreed upon in the context of engineering. As discussed here, "common sense" is tied to the (often unspoken) social relations that constitute and govern much of human existence.[9] Of course, the common sense that a group of people share and understand is certainly not "common" to everyone. Engineering education accreditation documentation and their requirements can both be seen as a reflection of the dominant common sense in engineering within their national contexts as well as something that helps reinforce and propagate a shared common sense throughout the global engineering community.

One approach to exploring the relation between engineering common sense and engineering education accreditation is to study how the accreditation requirements (and, specifically, desired student learning outcomes) are interpreted and implemented in practice. Seron and Silbey's study exemplifies this type of approach.[10] Another approach is to focus on how key concepts are articulated and interrelated with accreditation requirement statements as a way to explore what opportunities, barriers and challenges arise out of the documentation itself. This is the approach we have taken in the study reported here. Our focus is on how social and technical capabilities are conceptualized in the accreditation documentation and what opportunities and challenges this represents in terms of educational reforms.

To broaden the discussion about engineering education accreditation, we believe an international perspective is needed, so we have studied engineering accreditation documents in four different cultural contexts: Australia, China, Sweden, and the United States. Prior work in the area of cross-cultural comparisons of engineering education accreditation is limited, but one study stands out: "Competencies beyond Countries" by Lucena et al.[11] One of the key conclusions of that study is that desired engineering competence is particular to context. Lucena et al. argue that while there are efforts toward transnational engineering education accreditation, local context still holds major influence.

With our interest in the representation of "the social" and "the technical" in engineering accreditation documents, we take a different tact than Lucena et al., namely by focusing specifically on understandings of social competence. We hope our comparative approach to this area will contribute to an under-explored niche of engineering education research.

Design of Study and Analytic Approach

The approach used in this research is a comparative study of the formal accreditation requirements for engineering education in four different countries. The main questions we seek to answer are these:

- *How are the desired competencies of engineering graduates represented in the central accreditation documentation in the four different national contexts?*
- *How, in particular, are social and technical competencies represented, and what is their relative emphasis across the four documents?*
- *What types of competencies are included within the broad category of "social" skills across the four documents, and what level of competency is expected?*
- *Can we identify trends in how social—and in particular social analysis—competencies are represented?*

We set about answering these questions by assembling a multinational research team. Team members situated within each of the four countries took responsibility for investigating the accreditation requirements of their national context. These investigators systematically reviewed the primary engineering education accreditation documentation, focusing on the sections that describe educational goals. The first step of this process was to define a common analytic framework for how "the social" and "the technical" could be categorized, which was done by half of the research team carrying out pilot studies focusing on the American and Swedish accreditation documents. Through an ongoing dialogue, a common understanding of how "the social" and "the technical" could be categorized was created.

For us "the technical" is represented by connections to the material world and properties like matter and energy and different kind of (technical) artifacts as well as by knowledge and skills in mathematics and natural science and (technical) "engineering" analysis, design, and experimentation etc. "The social" then is represented by connections to the living world, especially various aspects of human affairs and interactions, including professional interpersonal skills as well as social-analytic competencies.

Once a common understanding of how we could categorize "the social" respective "the technical" was established, the initial pilot reports could be finalized, which then became guides for the subsequent individual research reports for each national context studied. The individual reports were then compared to identify important themes as well as areas of convergence and divergence across the different contexts.

Conveniently, all four of the accreditation documents articulate educational goals in terms of desired/required student learning outcomes, which allowed a relatively neat item-by-item comparison. Our analysis determined how many (and which) learning outcomes focus on social capabilities, how many on technical capabilities, and how many on the integration of the two. Special attention was paid to the ways in which social and technical aspects of engineering capabilities are distinguished and differently treated in the accreditation documents. After categorizing the various learning outcomes for each context, we then compared the four countries' documentation again, this time identifying opportunities and challenges for integrating the teaching of technical and social components of engineering education in light of our analysis.

The scope of our analysis is limited to the central accreditation documents as texts. Although, as suggested above, we acknowledge the importance of how accreditation requirements are interpreted and implemented in practice, we do not consider those matters here. Looking at implementation in practice is a future step of our on-going study. Furthermore, with few exceptions, we do not interrogate the distinct cultural contexts of each accreditation document, which, while also important for understanding the big picture of engineering accreditation, is simply beyond the scope of this paper. Nevertheless, by taking a first step in systematically documenting cross-cultural similarities and differences in accreditation requirements, we hope this paper will provide an empirical touch point for farther-reaching analyses.

Accreditation Contexts in Comparison

Before addressing how social and technical capabilities of engineering graduates are represented in accreditation documentation, a bit of context is in order. Table 1 highlights key characteristics of accreditation organizations, processes, and documents in each context.

Table 1. Comparison of engineering education accreditation institutions in four countries[12]

		Australia	China	Sweden	United States
Organization	Accreditation agency	Engineers Australia (EA)	Committee of National Engineering Education Professional Accreditation (CNEEPA)	Swedish National Agency for Higher Education	ABET
	Type of organization	Professional	Semi-governmental*	Governmental	Non-governmental federation of 30 professional and technical societies
	Year founded	1919	2006	1969/1995	1932
	Target areas	Engineering	Engineering	All higher education programs	Applied science, computing, engineering, engineering technology
	Washington Accord signatory	Yes	No	No	Yes
Process	Voluntary/mandatory	Voluntary	Voluntary	Mandatory	Voluntary
	Length of validity	(Max) 4 years	Max 5 years	(Max) 4 years	Max 6 years
	Renewal	Every 4 years	Institutions request new evaluation	Every 4 years	Institutions request new evaluation
	Evaluators	EA members chosen for professional expertise and/or knowledge of engineering education context	Professional evaluators hired by Ministry of Education	Subject-expert, industry, and student representatives nominated and then appointed by Agency	Professional volunteers from industry and universities
Documents	Main document	Stage 1 Competency Standard for Professional Engineer	Criteria for Professional Accreditation of Engineering Education (Tentative)	Higher Education Ordinance (also, Higher Education Act)	Engineering Criteria 2000 (EC2000)
	Initial version date	1996/2004	2008	1993	1997
	Current version date	2011	2008	Updates 2011	2011
	Outcomes based?	Partly†	Yes	Yes	Yes
	Number of outcomes	10	8	12††	11

* CNEEPA is classified as a non-governmental organization, which provides voluntary accreditation. However, CNEEPA evaluators are hired by the Educational Ministry.
† Australian accreditation strives for balanced attention to educational program structure and student learning outcomes.
†† It is the five-year Master of Science in Engineering degree we are considering here.

Categorizing Competencies

The engineering accreditation requirements of the four countries studied show considerable similarity in how educational goals were articulated. Because the accreditation documentation in all four countries focuses on student learning outcomes, the accreditation requirements translate more-or-less directly into statements of (what are understood to be) the required capabilities of engineering graduates in each context. This section analyzes how these capabilities are articulated.

Since we are interested specifically in the relationship between technical and social capabilities, we first categorize the relevant accreditation requirements into "technical," "social," or "other" representations. As put forward in the documentation:

- Technical capability relates to knowledge and skills in mathematics and natural science as well as (technical) "engineering" analysis, design, and experimentation.
- Social capabilities include professional interpersonal skills as well as social-analytic competencies.
- Some capabilities fall outside either category, most notably lifelong learning.

At this general level of analysis, all four accreditation documents show considerable consistency. In the technical dimension, competence in mathematics, natural sciences, and engineering sciences and techniques are required of all graduates in all contexts. Similarly, all four countries also share a vision of the qualified engineering graduate as having the ability to identify and solve engineering problems through the application of theory and knowledge of design and experimentation. In the social dimension, all accreditation documents require competencies in communication, teamwork, and understanding the global and local environments of engineering work. Finally, all documents identify the importance of lifelong learning.

Table 2 provides a comparative overview of the stated learning outcomes by identifying the number of criteria in each document directed at: 1) technical, social, and other capabilities; 2) connections between technical and social capabilities; and 3) professional/interpersonal skills and social analytic competencies (both as sub-categories of social capabilities).

Table 2. Breakdown of student-learning-outcomes requirements in four accreditation documents[13]

	Australia	China	Sweden	United States
Total student outcomes listed:	16 (68 indicators)	8	12	11
No. referencing **technical** capabilities:	8	2	7	6
No. referencing **social** capabilities:	8	5	5	6
No. referencing **other** capabilities:	3	2	1	1
Number of social capabilities as **professional/interpersonal** skills:	4	2	2	2
Number of social capabilities as **social analytic** competencies:	5 (12 indicators)	3	3	4
References to **connections between "social" and "technical"**	2 (3 indicators)	1	3	2

We draw several observations from the relative representation of technical, social, and other capabilities.

- The total number of desired student-learning outcomes identified is roughly similar in each accreditation document, with the exception of Australian, which lists 16 “elements of competency” that are then broken down into 68 different indicators. Some of these indicators are in themselves as detailed the learning outcomes listed in the other three documents.
- The relative emphasis of outcomes categorized as technical and social are roughly equal, this time with the exception of China, where social outcomes dominate.
- In all four documents, the major capability falling outside the technical-social categorization (and classified as “other” in our scheme) is lifelong learning.
- Communication and teamwork skills are represented in all four documents (classified here as “professional/interpersonal skills”).
- Each document includes capabilities related to what we classify as “social analytic skills,” such as ethical reasoning, understanding of global and local contexts, or political awareness.

As our main interests are how a) “the social” and b) the relation between “the social” and “the technical” are represented, our attention now shifts to an assessment of how these features are manifest in the accreditation documents. For the most part, professional/interpersonal skills are conceptually straightforward in the accreditation documents, and there is agreement that good communication and teamwork skills are core competencies for engineers (even if the attributes of these skills are less-clearly specified). While we acknowledge professional/interpersonal skills are broad and potentially fruitful areas to unpack, our analysis brackets these questions and instead seeks to elaborate only what we have categorized as social-analytic skills. Table 3 lists the student-learning outcomes that we identified under this category exactly as they are formulated in each of the original accreditation documents.

Table 3. Competencies relating to social-analytic ability in four accreditation documents[14]

Australia	*Knowledge of contextual factors impacting the engineering discipline*	• Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline.* • Is aware of the founding principles of human factors relevant to the engineering discipline.* • Identifies the structure, roles and capabilities of the engineering workforce. • Appreciates the issues associated with international engineering practice and global operating contexts.
	Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline	• Appreciates the basis and relevance of standards and codes of practice, as well as legislative and statutory requirements applicable to the engineering discipline. • Appreciates the principles of safety engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the engineering discipline. • Appreciates the social, environmental and economic principles of sustainable engineering practice.
	Application of established engineering methods to complex engineering problem solving	• Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline.
	Application of systematic engineering synthesis and design processes	• Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process.*
	Ethical conduct and professional accountability	• Demonstrates commitment to uphold the Engineers Australia Code of Ethics, and established norms of professional conduct pertinent to the engineering discipline. • Understands the need for 'due-diligence' in certification, compliance and risk management processes. • Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment.
China	• Possession of decent humanistic and social science cultivation and a strong sense of social responsibility and engineering professional ethics. • An understanding of the laws and regulations on the production, design, research and development related to one's profession. Familiar with the policies, laws and regulations on environmental protection and sustainable development; a correct recognition of the impacts of engineering on the objective world and society.* • An international vision and an ability of cross-cultural communication, competition, and collaboration.	
Sweden	• Demonstrate the ability to develop and design products, processes and systems while taking into account the circumstances and needs of individuals and the targets for economically, socially and ecologically sustainable development set by the community.* • Demonstrate the ability to make assessments informed by relevant disciplinary, social and ethical aspects as well as awareness of ethical aspects of research and development work.* • Demonstrate insight into the possibilities and limitations of technology, its role in society and the responsibility of the individual for how it is used, including both social and economic aspects and also environmental and occupational health and safety considerations.*	
United States	• 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.* • An understanding of professional and ethical responsibility. • The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.* • A knowledge of contemporary issues.	
	* These outcomes refer to the connection between social and technical competencies.	

Now that we have identified the accreditation requirements related specifically to social-analytic competencies, including where they are connected to technical competencies, we are prepared to break down how the social-analytic dimension conceptualized in these requirements. To achieve this, we seek to identify how social-analytic competencies are framed in these documents.

This analysis was inspired by the phenomenographic research tradition,[15] which is based on the assumption that it is possible to describe the ways in which people conceptualize a certain concept in a limited number of qualitatively different categories of description. These categories are distinguished from one another in terms of the presence or absence of certain critical aspects of the concept. While, we have not conducted a detailed phenomenographic analysis of how "the social" is represented in the student-learning outcomes listed in Table 3, we applied the underlying principle of identifying qualitatively different conceptualizations of the concept in question. In practice, this entailed iteratively reviewing the student-learning outcomes in Table 3 while organizing the data according to the various themes (variations in conceptualizations of social-analytic competencies) that emerged. The multiple iterations of reading, organizing the data, and refining the emerging themes were a key part of the process.

Ultimately, we identified four distinct conceptualizations of social-analytic competencies:

- *Social as constraints* – particularly while designing, engineers should accommodate a variety of social constraints, including those economic, environmental, political, and legal.
- *Social as awareness* – engineers should understand social impacts of engineering activity, including potential negative impacts and limitations of technology.
- *Social as responsibility* – engineers should demonstrate professional and ethical responsibility, to their peers, society, and the environment.
- *Social as cultivation* – engineers should cultivate appreciation for the humanities and social sciences (China only).

Table 4 categorizes social-analytic competencies according to these four conceptualizations. We do not include every relevant competency, but rather those that are most illustrative of the categories. For example, the Australian document has a number of overlapping indicators for relevant elements of competency, which are not included in the table.

Table 4. Categorization of how social competencies are framed in each accreditation document[16]

	Australia	China	Sweden	United States
Social as Constraints	Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process.		Demonstrate the ability to develop and design products, processes and systems while taking into account the circumstances and needs of individuals and the targets for economically, socially and ecologically sustainable development set by the community.	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.
Social as Awareness	Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline. Is aware of the founding principles of human factors relevant to the engineering discipline. Appreciates the issues associated with international engineering practice and global operating contexts.	Familiar with the policies, laws and regulations on environmental protection and sustainable development; a correct recognition of the impacts of engineering on objective world and society. An international vision…	Awareness of ethical aspects of research and development work. Demonstrate insight into the possibilities and limitations of technology, its role in society.	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context A knowledge of contemporary issues.
Social as Responsibility	Demonstrates commitment to uphold the Engineers Australia - Code of Ethics, and established norms of professional conduct pertinent to the engineering discipline. Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment.	Possession of … a strong sense of social responsibility and engineering professional ethics.	Demonstrate insight into…the responsibility of the individual for how it is used, including both social and economic aspects and also environmental and occupational health and safety considerations.	An understanding of professional and ethical responsibility.
Social as Cultivation		Possession of decent humanistic and social science cultivation.		

Of the four categories identified, three dominate: social as constraints (present in all but the Chinese document), social as awareness (present in all documents), and social as responsibility (also present in all documents). The fourth category, social as cultivation is present only in the Chinese document.

The representation of *social as constraints* takes social forces as external constraints to (technical) engineering work and exists in two main varieties: In the US and Australia, the expression of "social constraint" is explicitly listed among a number of other non-technical constraints such as health, safety, and sustainability. In Sweden, the "social" dimension is subsumed under the constraints of sustainable development.

The representation of *social as awareness* emphasizes understanding engineering's/technology's impact on society, as explicitly referenced in the Australia, China, and US documents. International or global impacts are also mentioned in these three documents, while lacking in the Swedish document except in relation to communication. This category presents the greatest variation both within and across accreditation documents. For example, only Australia expects awareness of the interaction between the social and technical factors in engineering (as well as awareness of "human factors"), while Sweden includes an explicit requirement of "ethical awareness" and the US expects knowledge of "contemporary issues." In addition, only the Australian and Swedish documents highlight awareness of both the possibilities and limitations or adverse effects of engineering and technology.

The representation of *social as responsibility* considers engineers' broader obligations. This category exists in three slightly different varieties. In Sweden, it is framed as "individual" responsibility. The other three countries frame it as "professional" and/or "ethical" responsibility. Notably, only China presents an explicit articulation of general "social responsibility."

The representation of *social as cultivation* entails appreciating humanities and social sciences perspectives and again is present only in the Chinese document.

Opportunities and Challenges for Integration of Social Competencies

We believe our analysis of the accreditation documents above may point to opportunities for and challenges to better integrating the technical and social components of engineering education. Here, we identify several insights that extend from this initial phase of our study.

First, engineering education accreditation requirements in all four countries—Australia, China, Sweden, and the United States—show a number of striking similarities. For example, accreditation in all four countries is based on student learning outcomes. All countries' requirements also stressed students acquire both technical competencies (i.e., mathematics, natural sciences, engineering science and technology) and social competencies (i.e., political context, social and environmental implications, ethical responsibilities). This finding is consistent with the conclusion of Lucena et al. that there is an increasing trend toward international harmonization of engineering education accreditation.[17]

This trend is likely to be a mixed opportunity for those advocating greater attention to social dimensions of engineering practice. On one hand, as the study by Lucena et al. suggests, cross-cultural collaboration among accreditation bodies, and engineering communities generally, is likely to expand understandings of the diversity of ways social context impacts engineering knowledge and practice. On the other hand, international harmonization of engineering accreditation is most certainly tied up with "globalizing patterns of corporate opportunity," where corporate interests in a particular set of qualities of the engineering labor force may run roughshod over historical cultural distinctions in engineering that might better be preserved.[18]

Second, with the exception of China, the requirements of all four countries entail roughly equal attention to technical and social capabilities, at least in terms of the number of learning outcomes referencing each. In China, because of the national policy of education for "all-around development," the accreditation seems to place a greater emphasis on students' social capabilities than on the technical ones. This finding—that social competencies are attended to equally or more numerously than technical competencies across multiple national settings—might be illuminating to educators who are concerned about promoting social and contextual knowledge in engineering education. In particular, engineering education scholars might compare this relative emphasis with that found in engineering curricula in various national settings. Superficially, we know that engineering education in all four national contexts we have studied dedicate predominantly more attention to technical than social capabilities despite the apparent balance seen in the accreditation documentation.

The relative balance in treating social and technical competencies notwithstanding, accreditation documents in the four countries also indicate some conceptual barriers for integrating the teaching of technical and social components of engineering. To begin with, although each document approaches the relation between technical and social competencies somewhat differently, requirements related to technical and social competencies are typically presented as separate outcomes. Only infrequently do the learning outcomes address the interrelation between the technical and social facets of students' competence, with the Swedish document offering a notable exception: The few outcomes related to social competence all present the relation between technical work and its social consequences.

The conceptual division between the technical and social capabilities also is reinforced in the way each document characterizes the nature of the expected competence in technical and social domains. In the US document, most outcomes related to students' technical learning are characterized as achieving the applicable "abilities," whereas learning about social domains are mostly limited to achieving a level of "understanding."[19] In the Chinese document, social competence is categorized into soft qualities and hard qualities, to which technical knowledge and skills belong.[20] The Swedish document divides student-learning outcomes into three categories: knowledge and understanding, competence and skills, and judgment and approach, where technical competencies reside more in the former categories and social competencies more in the latter.[21] The Australian document also maintains three categories for competencies at different levels. Technical competencies dominate the requirements in "knowledge and skill base," and they are almost absent in the category of "professional and personal attributes," where social competencies preside.[22]

It is also worth noting that a significant proportion of social competencies in Australia and the US frame contextual factors in political, social, and ethical realms as “constraints” to which engineering endeavors must respond, rather than as part-and-parcel of what engineering is and does. Hence, these factors are outside and apart from “engineering,” even as engineers have to (reluctantly?) content with them to be effective in achieving their technical goals. This language of “social constraints” alludes to what we believe is an outdated, if popular, conception of engineer practice as being primarily, if not exclusively, scientific or technical in nature.[23]

Conclusion

This paper has compared the educational requirements for accrediting engineering education programs in four countries: Australia, China, Sweden, and the United States. After identifying some structural factors affecting the organization and process of accreditation in each country, we conducted a comparative analysis of the student-learning outcomes required in the accreditation document of each country, with a focus on articulations and representations of social capabilities in each country and the extent of integration between the technical and social capabilities.

We found that accreditation requirements in all four countries are similarly oriented to specific student-learning outcomes, and technical and social capabilities represent roughly equal proportions of the total number of requirements. These findings suggest that liberal educators of engineering might more creatively take advantage of the latitude afforded in accreditation to promote social and contextual knowledge in engineering education, but also that barriers to liberal education of engineers likely exist in the implementation of accreditation reviews in practice.

We also found that there is a significant conceptual divide between the technical and social capabilities maintained in all four accreditation documents, and social dimensions in the majority of contexts are framed as constraints for effective engineering work. We contend that maintaining such a divide between technical and social, especially while framing the social dimensions as constraints, is likely to inhibit meaningful integration of social-analytic capabilities of engineering education.

Finally, we noticed variations across the countries in their presentation of social-analytic capabilities as constraints, awareness, responsibility and cultivation in engineering education. We suggest that these variations reflect the dominant common sense within the engineering (profession) in each particular national context. Although a similar engineering common sense exists in all the four countries, each presents a particular articulation and respective emphasis at the national level, which deserves consideration in any contextualized application of the findings presented here.

As our research team moves forward on this project, we anticipate looking more closely at how these accreditation requirements are understood and acted upon by variously situated participants of accreditation review processes, including especially program developers and reviewers. Delving into the contextual factors impinging on accreditation reviews in specific instances will not only provide greater insight into how technical and social competencies are operationalized, but will also allow consideration of distinct cultural forces and their role in shaping distinct and shared visions of social competence.

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accreditation, where the *Stage 1 Competency Standard for Professional Engineer* can be downloaded. Information about accreditation in Sweden was acquired from the Swedish National Agency for Higher Education webpage: www.hsv.se. *The Higher Education Ordinance* can be found under "Laws and Regulations/The Higher Education Ordinance/ Annex 2: Qualifications ordinance" at www.hsv.se.

13. These outcomes are summarized from the following accreditation documents in four countries. US: ABET. 2010. *Criteria for Accrediting Engineering Programs: Effective for evaluations during the 2011-2012 accreditation cycle*. Baltimore: ABET, Inc. China: *Criteria for Professional Accreditation of Engineering Education (Tentative)*. Australia: *Stage 1 Competency Standard for Professional Engineer.* Sweden: *The Higher Education Ordinance.*
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18 Riley. 2008. We thank an anonymous reviewer for the quoted phrase.
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