Global Learning and the Transformation of the 21st Century Science and Engineering Curriculum

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ABSTRACT
Consistent advocacy for the preparation of globally competent science and engineering students has not resulted in a universal commitment to this work. Notwithstanding, this imperative could not be greater given the rapid transformations being wrought by globalization, and the major global problems currently facing humankind. This paper uses two examples to demonstrate how compliance with ABET standards relative to global education can guide the adoption of a vision for global learning by science and engineering disciplines. This vision, defined in terms of three fundamental themes including environmental sustainability, diversity and global engagement can be used as a strategy to infuse global learning in the curriculum and offer students multiple and substantive encounters with global perspectives. The paper insists that this work must be owned and driven by faculty in each discipline and that the themes of global learning should be infused in the curriculum through the lens of that particular discipline. Developing global learning outcomes, strategies to realize these outcomes, and assessment strategies to establish that the learning outcomes adopted are being realized are key tasks of faculty who wish to infuse global learning in the major. Tweaking existing assessment practices can save significant time and resources.

Keywords: Global learning, engineering, curriculum

INTRODUCTION
The era of globalization in which we now live has brought sweeping and fundamental changes to practically every aspect of our human experience. Be it in trade, transportation, communication, or entertainment, our lives are influenced for better or worse. National borders have receded in importance as issues, once localized, have become global problems confronting the human species, including environmental degradation, water scarcity, global pandemics, terrorism, food scarcity, and the multi-layered challenges around energy. These global problems all require global solutions and scientists and engineers must be in the vanguard in helping to identify and ultimately resolve these problems.

HIGHER EDUCATION'S RESPONSE TO GLOBAL CHALLENGES
In light of the fact that the environment within which our students will pursue their respective careers is global, it follows that the preparation they receive within the academy should be compatible with this reality. Educators should feel an increasing obligation to construct curricular and co-curricular pathways for
students to test their learning in the context of more increasingly complex real-world issues (Elrod and Hovland, 2011). Nair (2011) argues that the western canon, which was once deemed adequate for a literate person has now been superseded by a set of new literacies, including scientific and technological, that “is requisite to participation in a globally interconnected world.” In short, scientific literacy requires that individuals possess the skills, knowledge and dispositions to effectively negotiate a global landscape. One would therefore assume that higher education in general, including science and engineering disciplines, would respond to these new realities by systematically aligning the academic experiences offered students to ensure that they have multiple and substantial encounters with global perspectives as a way of preparing them to be globally competent. Sadly, as confirmed by the American Council on Education “overall, internationalization does not permeate the fabric of most institution; it is not yet sufficiently deep, nor as widespread as it should be to prepare students to meet the challenges that they will face once they graduate” (Green, Luu and Burris, 2008).

CALLS FOR GLOBAL LEARNING OFTEN IGNORED

There is no shortage of reports, recommendations or pronouncements that call for the preparation of globally competent college students, including engineering majors. The American Association of College and Universities, through its Shared Futures Project (Global Learning), its LEAP Project (Essential Learning Outcomes) and its Project Kaleidoscope (focus on STEM disciplines) has done significant work in this regard over a number of years. In 1995, the American Council on Education through its Commission on International Education issued a blueprint to guide institutions in developing students with global competencies for success in a competitive and global environment. Fifteen years later, however, the overall goal to evolve international education more universally throughout higher education so that all students attain intercultural competence, understanding of global systems, and an aptitude for solving practical problems oriented around real world issues has yet to be fully realized. Even though areas of study that traditionally kept global-oriented experiences at the periphery of their curricula have recognized and promoted the case for global learning, change has been slow. Environmental engineering education programs as one example, were acknowledged by Bishop (1999) twelve years ago as being slow to follow the lead of a profession that had already become globally oriented. This is still largely the case today.

Employers too have been adding their not inconsiderable voice to this matter, saying that the most effective hires are those who bring global skills to the workplace. The

Collegiate Employment Research Institute (2010) at Michigan State University, for example, recently published findings from a study showing that global competency among young professionals is increasingly being sought by employers and that understanding the global context is one of six competencies that has grown the most in importance to employers over the past five years they need students.

ACCREDITATION CALLS FOR GLOBAL LEARNING

In the American system of higher education, no other entity commands the credibility and respect associated with articulating standards that students must demonstrate in order to be deemed competent in a particular discipline as accreditation agencies. This credibility and respect is, by extension, accorded to academic units that have been granted entry to the exclusive club of accredited programs. In this regard, it is therefore salient to examine the position of ABET (formally known as Accreditation Board for Engineering and Technology) regarding global education.

Criterion 3 of Engineering Criteria 2000 improved upon the previous list of eleven measurable program outcomes to include language related to the global context of engineering. Currently, the outcome for Criterion 3 (h) calls for “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.”

Thus, a program’s curriculum is compelled to include some elements of global learning to be in full compliance with the outcome of Criterion 3 (h). In addition, and perhaps more compelling, EC 2000 provided a clear and much more concise description of the relationship expected between a program’s educational objectives and its institution’s overall mission and its professional constituency, than what was found described in the previous conventional criteria. Criterion 2, Program Educational Objectives, currently states that a program’s educational objectives must be consistent with both “the mission of the institution” and with the “needs of the program’s various constituencies.” In this regard, compliance with Criterion 2 requires that an engineering program ensure its curriculum aligns with the institutional mission, and as institutions become substantially more globally oriented, programs must also noticeably evolve in this direction.

WHAT DOES GLOBAL LEARNING MEAN

At Northern Arizona University, we have sought, over the past two years, to make global learning central to the academic experience of all majors, including science and engineering majors. We concur with Olsen, Green and
Hill, (2006) when they define global learning “as the knowledge, skills, and attitudes that students acquire through a variety of experiences that enable them to understand world cultures and events; analyze global systems; appreciate cultural differences; and apply this knowledge and appreciation to their lives as citizens and workers.” In effect, global learning is not an end in itself, but rather leads to global competence which is the ultimate aim of our efforts. Global competence will therefore be achieved through intentional curricular and co-curricular experiences that foreground global learning.

We have identified three central themes to global learning that are necessary for the evolution of globally competent science and engineering graduates. They include environmental sustainability, diversity and global engagement. Global engagement is a necessary theme because “science is a global enterprise. The common laws of nature cross political boundaries, and the international movement of people and knowledge made science global long before ‘globalization’ became a label for the increasing interconnections now forming among the world’s economies” (Science and Engineering Indicators: 2010). Diversity is imperative because solving the most pressing issues we face as a nation and as a species requires that we succeed at working collaboratively with others from diverse cultural backgrounds who often define problems differently (Downey et al., 2006). Environmental sustainability must be among the three themes because scientific principles are often key to discovering practical and affordable sustainable strategies, but more significantly, nothing will matter without human survival. Integrating global learning into science and engineering curricula, therefore, requires weaving these concepts into the multiple academic experiences students encounter in such a way that these are no longer optional ideas for consideration in one’s free time, but central to how students come to understand these disciplines and foundational to professional practice.

AN APPROACH FOR ADVANCING GLOBAL LEARNING IN ENGINEERING DISCIPLINES

Having articulated these themes of global learning, we believe that departmental faculty are best suited to determine how to establish global learning opportunities within the curriculum and co-curriculum. To this end, faculty must engage in three essential tasks as they embark on this project. They must first establish global learning outcomes for students expressed in the language of the discipline and considered in terms of the three themes of global learning. In effect, faculty must seek to construct a profile of what a globally competent computer scientist or electrical engineer, for example, would look like upon graduation. This vision is fundamental to the global learning project as it effectively serves as a guide for the kind of interventions that must be made in the curriculum and even in the co-curriculum that can guarantee students multiple and substantive encounters with global perspectives.

The second task is to determine the strategies that will be used in the curriculum to facilitate appropriate learning experiences for students. It may involve making changes in the gateway course and/or the capstone course, introducing a study/research/internship abroad requirement, requiring additional semesters of a second language, or addressing global themes in the first year seminar among others. The notion that these concepts can be captured in a one-course requirement is now passé. These strategies should be multiple, spread throughout the program of study and inserted in a manner that facilitates a seamless progression through the major.

Developing assessment strategies is the third task of faculty as it is important to establish that the strategies that are being pursued do, in fact, help students to achieve the global learning outcomes adopted. Assessment protocols do not all have to be created anew. Making slight modifications to existing assessment tools, including those used for individual courses, surveys administered to graduating seniors, and questions appended to national surveys like the National Survey of Student Engagement can provide important information on the extent to which students are acquiring a global orientation in their respective disciplines.

GLOBAL LEARNING COMMITMENTS REFLECTED IN THE ENVIRONMENTAL ENGINEERING CURRICULUM

The Environmental Engineering program, although still in the process of redesigning its curriculum to give students meaningful opportunities for engagement with global learning, has made the following commitments with respect to global learning outcomes:

1. Graduates will possess foundational skills in mathematics and in the chemical, physical, and biological processes of the earth’s atmosphere, biosphere, hydrosphere, and lithosphere, as well as the ability to apply these skills to advanced topics and problems appropriate to environmental engineering.
2. Graduates will be able to properly apply tools and methods of design, experimentation, modeling or simulation, and analysis to inform decisions throughout the process of design.
3. Graduates will be able to define and analyze complex local and global environmental engineering problems, and devise and document sustainable engineering design solutions that are globally and culturally appropriate.
4. Graduates will be able to communicate effectively, both written and orally, within multi- and interdisciplinary
teams, have a disposition for collaborating with indigenous or other global cultures, and possess skill in more than one language.

5. Graduates will understand relationships between professional engineering and public and private organizations, and the mutual impacts that global environments and diverse societal and political systems of the world can have on one another.

6. Graduates will understand the importance of and be motivated to continually learn about emerging global
and professional issues that will improve professional skills and abilities, and that adhere to and promote the standards and ethics of engineering practice in local, indigenous, and global contexts.

The following is a chart that reflects the extent to which courses in the Environmental Engineering major (and other graduation requirements) reflect the themes of global learning:

<table>
<thead>
<tr>
<th>Course</th>
<th>R/E</th>
<th>LS</th>
<th>G</th>
<th>S</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENE 150 Introduction to Environmental Engineering</td>
<td>R</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EGR 186 Introduction to Engineering Design</td>
<td>R</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>CENE 330 Air Quality Engineering</td>
<td>R</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>CENE 332 Solid and Hazardous Waste Management</td>
<td>R</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>CENE 386W Engineering Design: The Methods</td>
<td>R</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENE 476/486C Capstone Prep &amp; Design</td>
<td>R</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>CENE 535 Sustainability of Environ. Biotech. (New)</td>
<td>E</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENE 484 Undergraduate Research in Engineering (New)</td>
<td>R</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>XXX 101/102 First year Language</td>
<td>R</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>LS Global Diversity (from course list focused on contributing to program outcomes)</td>
<td>R</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS Ethnic Diversity (from course list focused on contributing to program outcomes)</td>
<td>R</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PHI 331 Environmental Ethics</td>
<td>R</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Ex: ENV 495 Global Environmental and Climate Change/Other interdisciplinary courses relevant to program outcomes</td>
<td>E</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

R = Required, E = Elective, LS = Liberal Studies Program, G = Global, S = Sustainability, D = Diversity

The framework for changing the program’s curriculum to become more globally oriented and to integrate international study, is strictly founded on the idea that it will not be done unless we ensure compliance with ABET’s EAC accreditation criteria. To this end, the assessment process has been enhanced with new tools that provide a universal approach for collecting and evaluation curriculum and course data regardless of the institution from which these data are derived. Once these data are collected, the program is able to evaluate the curriculum’s ability to comply with ABET EAC accreditation criteria regarding student outcomes, the professional component of the curriculum, and the proficiencies and abilities that a program-specific curriculum must provide. The program faculty members are not only gaining a better understanding of the curriculum beyond just the courses that they teach, but are also recognizing efficiencies in the entire assessment process, such that the long-held perceptions of increased workload are being dissipated.

GLOBAL LEARNING COMMITMENTS REFLECTED IN THE ELECTRICAL ENGINEERING AND COMPUTER SCIENCE CURRICULUM

Like the Environmental Engineering program, the Electrical Engineering and Computer Science program aims to align its curriculum with ABET learning outcomes as a way of advancing global learning in the curriculum to guarantee global competence among our majors, but also to more closely comply with ABET standards. The following are the global learning outcomes developed for these majors:
• Technically competent and prepared for leadership and professional practice in a global workplace with strength in design, problem solving, communications and teaming
• Experienced with and having an understanding of diverse populations, such as those existing in the American Southwest
• Well grounded in sustainable engineering design guidelines and environmental policies
• Ability to function in disciplinary, multidisciplinary and diverse teams
• An appreciation and understanding of the global and diverse nature of the origins and development of science and engineering

The following are curricular strategies implemented to help students realize these global learning outcomes:

**Strategies to Achieve Sustainability Learning Outcomes:**
- Junkyard Generator Lab - EE364 Electromagnetics (R) students build generator out of “found” or recycled items
- Sustainable methods of power generation - EE386 Engineering Design and EE401 Power Systems
- Efficiency via design minimization - EE110 Digital Logic (R), EE215 Microprocessors (R)
- Spectral Efficiency (maximizing use of limited spectral resources); EE348 Signals and Systems, EE430 Communication Systems

**Strategies to Achieve Global Engagement and Diversity Learning Outcomes:**
- Address the global and societal context of Electrical Engineering - EE386 Engineering Design (R) and EE401 Power Systems (senior elective)
- Address historical perspective and biographical information on inventors and scientists - EE110 Digital Logic, EE188 Electrical Engineering, EE215 Microprocessors, EE325 Engineering Analysis II, EE348 Fundamentals of Signals and Systems, (all required courses), EE430 (senior elective)
- Development of a new multidisciplinary course on the history of science and technology (Engineering and Civilization), that presents the global contributions to engineering by many different cultures throughout history. (R) Required

**ASSESSMENT OF GLOBAL LEARNING OUTCOMES**

Although both departments are still developing effective assessment protocols, there is no expectation that major investments will be made in the development of new and comprehensive assessment tools. Existing assessment strategies such as final exams, research papers, the capstone project and the survey of graduating seniors will be tweaked to get at information that speaks to student achievement of global learning outcomes. In regard to developing indicators that allow global learning and global competency to be measured, rather than recreate a unique set of indicators, the Environmental Engineering program has found those suggested by Parkinson (2008) to be very useful and also remarkable compatible with the three themes of global learning adopted at Northern Arizona University. Over time, these will be refined for a more precise fit with the program’s global learning focus. Additionally, efficiencies in the overall process of assessing the program have been created by redesigning existing assessment data collection tools in spreadsheets so that simultaneous evaluation of the data occur.

**CONCLUSION**

Although the imperative for global learning in the Engineering curriculum is now greater, the challenges in the way of such transformation have also grown. Budget cuts have hit colleges and universities very hard and in ways that create a great deal of anxiety and uncertainty among faculty. Fewer resources mean heavier teaching loads, larger class sizes and a declining commitment to tenure track positions. And yet, among the few things that faculty still control is the curriculum. It therefore still remains an obligation for faculty to ensure that the learning experiences they facilitate are relevant to the environments their students will inhabit upon graduation. A world that is increasingly interconnected and interdependent, that requires collaboration with people of different cultural backgrounds to solve the major challenges we face and whose future will be preserved or destroyed by human action, calls for graduates who are equipped with the skills, knowledge and dispositions to both understand and negotiate this world. Putting global learning at the center of our efforts to prepare engineers for the 21st century will help ensure that we make it through this century.

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