Infusing a multicultural approach to education in the engineering and science curriculum

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Abstract

Over the summer of 1997 I participated in a workshop for infusing multiculturalism across the curriculum. The workshop was based upon guidelines established by the American Association of Colleges and Universities (AAC&U)[1] and has been sponsored by Loyola College in Maryland for its faculty for the past two summers. Faculty from the humanities, social sciences, fine arts, business, and engineering have participated in this workshop. It is often difficult to attract engineering and natural science faculty to this kind of activity. One important outcome was improved dialog among faculty across the disciplines.

Such a multicultural approach to education is an important step for improving the "classroom climate". It can be important for the recruitment and retention of underrepresented groups such as women, minorities and non-traditional engineering students. A multicultural approach to engineering education has the potential benefits of better preparing our students for teamwork and the global marketplace, and fostering different learning styles, creativity and innovation.

This paper provides some recommendations for changing engineering courses, specifically, an introduction to engineering course. For example, one might place engineering design problems in a social, cultural, historical, as well as, technical and economic context.

I. Introduction

One possible understanding of the goals of diversity in the curriculum is that it intends to create an environment in which everyone can see themselves reflected, a system in which everyone feels some sense of "ownership" or stake in the outcome of the enterprise. This requires that each member of the diverse community has some appreciation for and sensitivity to the cultural background, history, mores and norms of the other. In the academic setting, there is a need to create an open and safe environment in which each can learn both to talk and listen, explore the self and the other. By truly learning one's own culture and exploring another, one returns with an understanding that far exceeds the sum of the parts. Multicultural education seeks to enable the student to appreciate the variety of perspectives that each of us represents and that various identities, even embodied within one person, provide unique positions from which one interacts with and views the world.

In this paper the importance of such issues for engineering and science education is explored.

At the time I participated, the basic workshop conducted at Loyola College in Maryland in infusing diversity across the curriculum consisted of twelve all-day sessions over three weeks.

One week consisted of general discussions of pedagogy, micro-teaching exercises and other practical exercises. The other workshop activities consisted of lectures from distinguished guest faculty in fields such as English literature, American studies, Economics, Biology, Women's Studies, and Theology, who also led discussions addressing the new material they presented as well as general questions of content, curriculum change, and classroom management. One of the greatest benefits of the workshop was the chance to exchange ideas and expertise with colleagues across disciplines, with whom one might not ordinarily interact. This led to some stimulating exchanges and a growth in mutual understanding and respect.

In order to participate in the institute faculty had to provide their objectives for applying to the program. My personal and professional objectives for applying for a position in the summer institute were as follows:

- Personal development and sensitization.
- Develop some background in general source materials.
- Contribute my perspectives from a science rather than a "liberal arts" discipline to the group.
- Learn about the scholarship and pedagogy relative to "classroom climate" issues, which are central to concerns about the continuing poor recruitment and retention of women and minorities in engineering and the physical sciences.
- Become an advocate and resource for both students and faculty in the sciences.
- Be able to respond intelligently to critics and skeptics.

II. Women and Minorities in Engineering and Science: Why care?

It is to the continuing shame of academic engineering and physical science departments in this country that women and minorities are still so poorly represented in these professions. One only has to look at the progress that has been made in other "aggressive", visible, and lucrative fields as law, medicine, and government to realize that technical fields are lagging well behind in developing a diverse workforce and pipeline. From elementary school science to the highest ranks of the professorate, the numbers are dismal. Many faculty and practitioners remain resistant to these issues. What may eventually change the national situation is the very practical fact that engineering and technology firms can no longer afford to operate under the *status quo*. Engineers and scientists are no longer sole inventors, but must work in teams, which are becoming increasingly international. It is a pragmatic argument that we must train our students to operate in the global marketplace, in whatever career they choose. To prepare all of our students to function in the larger world, our own view must become more global or diverse. Numerous sources sound twin themes of the globalization of the economy and job market as well as a general trend towards increased enrollments of non-traditional students in higher education.

We need to tap into that underutilized pipeline of women and minority students if we are to have healthy and vital programs in the sciences and engineering. If we choose, *de facto*, on recruiting from a restricted applicant pool, we will find that pool very limited. The attraction of the physical sciences and engineering has always been limited, even among the general American white male population, and perhaps increasingly so. There is no reason to think that the next great scientific breakthrough could only come for such a narrow segment of the population.

Pragmatic arguments hold equally well at the level of the viability of individual academic departments in the sciences and engineering. If departments don't diversify, they won't be able to attract the kinds of students and funding that they need for long-term survival. To attract and retain non-traditional students, understanding good pedagogy and issues of diversity becomes an

imperative, every bit as important as one's knowledge of circuit theory or mechanical structures.

Those who go on to graduate school will also have to meet and compete with an increasingly diverse group of colleagues. Many times, different styles of teaching, learning, working, and experimenting, which may arise from different cultures, can become real sources of friction in the lab and workplace. Cultural norms have a powerful influence on problem solving, engineering design, and even the progress of basic science, in contradiction to the belief in "scientific objectivity".

These problems also spill over into the realm of the political. The problem is not technically illiterate policy-makers, but also politically-illiterate scientists who feel a sense of privilege accruing to themselves and then do not understand it when the public rejects that notion, or who can only grumble when the public and legislative bodies have no basis for competently debating policy issues with a technical component. Having a more diverse group of scientists and engineers changes the way that science and technology are perceived by the larger public and will eventually influence policy and funding issues.

One possible response to this challenge is to make explicit the connections between scientific culture and other human cultural enterprises and relationships. For example, an approach to science and engineering education that is more historical makes central the human nature of the scientific endeavor. Such an approach could benefit our students by demystifying the process and allowing the subject material to become more approachable. The concept of objectivity, although central to scientific methodology in theory, is not the case in practice, and it is useful for students to understand, in a disciplined, critical way, the validity of questioning received wisdom from "objective theories". One can find examples from all of the scientific and engineering disciplines of individuals who did just that and made immeasurable contributions as a result. This is a more honest portrayal of the way that science and engineering is actually practiced.

One needs creativity and imagination to be a successful innovator in science and engineering, part of the ability to innovate arises from different life experiences and interacting with people of different backgrounds and technical training. Multiculturalism education in this context might have a meaning more akin to interdisciplinary.

When asked for a metaphor for multiculturalism the phrase "thinking outside of the box" was suggested. This is a very useful metaphor both for multiculturalism and for the kind of creative problem-solving that we want to teach in engineering. The best engineering design solutions often come about by thinking "outside of the box" of our assumptions about the constraints or ground rules for that problem. Similarly I think the goal of multicultural education is to enable us to think at least briefly outside of our solipsistic or cultural boxes.

III. Specific ideas for teaching and application to a course

So-called neutral teaching may actually keeps courses less accessible to students from non-traditional backgrounds. For example, as one study showed[2], there were no differences in ability, industriousness, motivation or background that were not nullified by making the social systems work more equitably for academic achievement. Grading and teaching practices can perpetuate social class differences without realizing it. Students need feedback and a chance to improve. They don't know what they know or don't know. That is, they haven't learned to recognize mastery of the material. If students go to a good college preparatory school they learn the expectations and literary conventions that vary among disciplines. Many students, however,

especially in their first year, need specific guidance in this area. A couple of useful techniques might be to have students explain their approaches to scientific problem solving in a few sentences, or have them make up and grade their own questions. A small effort showing the students what you want them to do can lead to increased performance by students who have not previously leaned how to proceed. Another example is to provide grading mechanisms more flexible than a "one-shot" exam or a single project deadline with chances for feedback and improvement along the way. Yes, we should have expectations for responsible professional conduct, which includes deadlines, but teach and foster that to freshmen and sophomores and assess and expect it in juniors and seniors. The key pedagogical shift is to see the teacher as coach rather than as a filter of the fit and unfit. These ideas are truly useful for all students, whether male or female, majority or minority.

There are many concrete ways in which these ideas can be applied:

- Teach the history of the field.
- Find role models. Tried and true, maybe even trite, but it is an important element for improving and diversifying the image of engineers.
- Create units on ethical, environmental, social constraints on engineering design. Don't be afraid to discuss the ethical/political ramifications of major advances in the sciences and technology.
- Set problem solving in a meaningful and complete context. An example might be the problem of water supply for a rural area. This could be a class problem-solving exercise that incorporates more than just technical issues.
- Work with verbal metaphors and visual imagery as well as mathematical analysis. Mathematical analysis can be geometric as well as algebraic.
- Work with techniques for different learning styles. Have your students take a learning styles inventory such as Kolb's cycle[3].
- Finally, Go back and question the basics. Students often get stuck on the conceptual axioms of a technical field. For example, in a typical electrical engineering course on digital logic and Boolean algebra one might mention or explore the idea of why binary? Is there some inherent reason that is the logic to use or is it based on our western social penchant for dualism? This may seem like sterile intellectual debate until one realizes that someone took the question seriously and developed multi-valued logic systems, which is now known as "fuzzy" logic. Japanese manufacturers, in particular, have picked up on this in developing their technologies and adapted it even into consumer electronics and appliances.

These ideas were applied to transforming a one semester, two credit, introductory course for all prospective engineering majors. This course is intended to introduce students to engineering and design. There are segments of the course which deal with design, problem-solving, spatial visualization, teamwork, and professionalism. Some time is spent on engineering achievements, and often some historical background and anecdotes are added. The main transformation of the course is to infuse it with the <u>social context</u> in which engineers work and the <u>historical background</u> of the discipline. I think both social context and history are the best approaches for introducing multicultural and gender issues into the engineering classroom.

Specific objectives of the course related to fostering student growth, student retention, and classroom diversity were:

- Bring the social context of engineering problem-solving and decision-making to the fore in a number of exercises. To fully appreciate that technical considerations alone do not drive

such decisions, but that they are always made within a cultural, economic, legal context.

- To provide images and models for the students, either in your own person, guest speakers, or both, of technically competent people who are "different" in some way from the stereotypical image of the engineer/scientist.
- To provide a classroom environment in which all students can feel comfortable, see themselves as successful, competent, engineering students and future professionals.

There will always be challenges in the process of transforming a course. Briefly stated, two of the most complex challenges to transforming any engineering course are:

- The demands of coverage and sequencing of courses, the general content/fact-focused nature of engineering education, and the constraints placed on the curriculum by accreditation issues.
- The current homogeneity of the student body interested in engineering.

Finally, some brief examples of possible classroom assignments and activities that have been used for this Introduction to Engineering course are provided:

- "High" technology programs and their social, historical, and environmental impact: For example, topics in space exploration such as the Apollo program or the Challenger disaster. Classroom discussions can involve questions of public funding for such large scale projects and their place relative to other social needs, as well as contrasting images of the astronauts of the Apollo era with those of the current space shuttle missions.
- Ancient technologies: For example, ancient irrigation systems used in the American Southwest to this day[4]. Students focus on the social, historical and technical context for this kind of problem-solving. Unit on problem-solving within different constraints and cultural contexts, issues such as the appropriate use of technology, and environmental engineering as a discipline.
- Ethics and Professionalism: Two class activities. One involves bringing in guest speakers to discuss the engineering profession and career issues and choices. Broaden the range of speakers who visit during a segment on professional issues[5]. The second activity involves providing appropriate engineering case studies for ethics and other professional issues such as minority business set asides.
- Image of the engineer: Use more "literary" references such as the works of Petroski and Florman[6,7], to discuss the image of the engineer/scientist in our society. The semester usually starts with a "technical autobiography" where the students describe their background and familiarity with technology and engineering. That exercise could feed nicely into one on learning styles. Surveys investigating student stereotypes about the image of "the engineer" will be distributed at the beginning and end of class to evaluate any changes in attitudes and preconceptions.
- Learning Styles: Chapter in course text discusses this.[8] Numerous other references on "right-brained" thinking and creativity are available. Have the students take a learning styles inventory, such as Kolb, Hermann Brain Dominance Indicator (HBDI), or Myers-Briggs and discuss its interpretation as well as strategies for academic success and learning based on them.[9-13]
- Segment on computing facilities and resources begins with some background of the history of computing with an emphasis on the contributions of women and other underrepresented groups. Internet browsing may be the best way to get information for this topic.[14-17]

IV Conclusion

It is important for engineering and science faculty to become involved in activities such as the multicultural curriculum workshop described in this paper, which are normally thought of as exclusively for liberal arts faculty. A number of advantages come from such involvement, including improved communication and respect among faculty, and improved courses for attracting and retaining non-traditional engineering students, especially women and minority students. The example of transforming an introduction to engineering class is briefly described, including concrete examples of activities and teaching techniques that were originally motivated by a multicultural approach to engineering education, but that benefit all potential engineering students, engineering departments and the future engineering workforce.

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Biographical Sketch

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