Work in Progress - Prototyping the Engineer of 2020: A Curricular Examination of Two Exemplary Institutions Preparing Undergraduate Engineers

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Abstract - **Highlighting two higher education institutions that have been identified as exemplary in preparing engineering undergraduates for 2020, this work in progress paper focuses on what these institutions are doing to prepare their students. Using case study approaches, findings suggest that engineering undergraduate students gain contextual competence, design and problem solving, and interdisciplinary competence skills through curriculum redesign efforts at the Massachusetts Institute of Technology and Howard University. These design efforts include innovative teaching strategies, year-long undergraduate research opportunities, and extracurricular activities.**

Index Terms - engineering undergraduate curriculum, undergraduate research experiences, STEM education

INTRODUCTION AND PURPOSE

Calls for greater accountability, increases in undergraduate enrollment, changing demographics of undergraduate students, and specific demands from industry to prepare graduates with certain skills have contributed to significant calls for reform in the undergraduate curriculum in U.S. higher education [1]. One recent effort to guide the reform of the engineering undergraduate curriculum is the Engineer of 2020 initiative. These reports present a forward looking approach to identifying the attributes of engineers who are capable of responding to the needs and environment of the 21st century [2, 3]. Three attributes of the Engineer 2020 were the focus of this study: contextual competence, design and problem solving skills, and interdisciplinary competence. Contextual competence involves "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" [4]. Design and problem solving competence involves the ability to "design and conduct experiments," as well as "an ability to identify, formulate, and solve engineering problems" while interdisciplinary competence includes "an ability to function on multi-disciplinary teams" [4] (p. 2).

The purpose of this session is to present findings from two case study sites (MIT and Howard University). The institutions were identified by using a comprehensive database that studied the impact of the EC2000 standards on programs and student learning in preparing engineering undergraduates in the three skill areas identified. The identified case study sites are part of the larger study titled *Prototyping the Engineer of 2020: A 360-degree Study of Effective Education* (P360), funded by the National Science Foundation.

METHODS

Through in-depth case study analysis, we employed qualitative interviewing techniques with approximately 78 engineering undergraduate students, 35 faculty members, and 30 administrators to identify the curricular, instructional, cultural, and organizational features that support innovative engineering education aligned with the Engineer 2020 goals. In addition, we performed document analysis of materials (e.g., syllabi, publications, institutional data) collected during the case study visits.

FINDINGS

Findings suggest that engineering undergraduates at both institutions gain these competencies through curriculum redesign that includes the use of innovative teaching strategies, undergraduate research opportunities, and extracurricular activities. Specifically, the engineering curriculum at MIT was redesigned for first and second year courses, emphasizing applied experiences and instruction by senior faculty members. Howard's engineering curriculum focused on integrating engineering and liberal arts courses in addition to purposeful faculty/student interactions. Early (i.e., beginning at freshman year) undergraduate research opportunities and internships reinforce design and problem solving skills. Early experiences also enable students to see the "context" which engineering principles are applied. Through collaboration and exchanging ideas with peers across disciplines and seeing the broad-based application of their research, students enhance their own interdisciplinary competence.

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Curriculum Redesign

Undergraduate engineering programs at MIT and Howard University underwent curriculum redesigns that aided in their overall objectives to meet ABET criteria to improve learning outcomes [4]. For purposes of this paper, curriculum redesign consisted of formal measures institutions took to account for "what" and "how" students were learning from engineering courses. Thirty-two participants (n=19 from MIT, n=13 from HU) referenced curriculum redesign changes taking place in their engineering programs.

Innovative Teaching Strategies

Both institutions employed innovative teaching strategies by first carefully assessing how and through what means students were learning. Innovative teaching strategies involved lecturing in ways to link disciplinary knowledge to reality for students, having professors teach classes, as opposed to graduate students or post doctoral researchers, using learning contracts, having personal interaction with students during and outside of classes, assuring students that faculty are 'in it" with them. Thirty seven participants (n=20 from MIT, n=17 from HU) referenced innovative teaching strategies taking place in their engineering programs.

Undergraduate Research Opportunities

Students at both institutions can participate in undergraduate research opportunities throughout the academic year. MIT, for example, gives students beginning at the freshmen level, opportunities to work with faculty on structured research projects through a longstanding program called UROP (Undergraduate Research Opportunities Program). HU students, similarly have an opportunity to engage in research through the HUSEM (Howard University Science, Engineering, and Mathematics) program. At both institutions, interested students may engage in research with a faculty member even if they are not in UROP or HUSEM. Forty-one participants (n=20 from MIT, n=21 from HU) referenced how beneficial research programs were for their students in helping them experience "real life" applications of disciplinary knowledge.

Extracurricular Activities

Students and faculty members at MIT and HU spoke about the role extracurricular activities played in the lives of their students. The most referenced clubs or organizations were the Society of Women Engineers (SWE), the National Society of Black Engineers (NSBE), the American Society of Civil Engineering (ASCE), and the Tau Beta Pi honor society. Students also engaged in volunteer work related to engineering in international countries and within their cities (Cambridge, Boston, Washington, DC area). There also seemed to be a strong sense of students building "community" amongst themselves. Participants referenced how the students worked with each other daily in study groups. Particularly at MIT, faculty took note when their students studied, noting that most studied in groups late at night. The institute then implemented a policy that they would not hold class sessions at 8am. In total, thirty-five participants (n=11 from MIT and n=24 from HU) referenced extracurricular activities as being an important aspect in student development and learning engineering concepts.

SESSION FORMAT

These are examples of effective strategies two institutions with undergraduate engineering programs are implementing to prepare their students for the future. Presenters will discuss these findings in more detail and suggest ways in which engineering programs at other institutions might expose students to opportunities that increase their students' contextual competence, design and problem solving, and interdisciplinary competence skills.

Presenters will engage audience members about how they have been effective in producing engineering students with these attributes. Implications for policy and practice for faculty members and department chairs in engineering programs will also be discussed.

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