Research Brief
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Considering Context: A Study of First-Year Engineering Students

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As engineers contribute to solving the increasingly complex problems facing our society, there is a growing need for the engineers graduating from undergraduate programs to deeply understand the context within which they are solving problems. There is a particular need for engineers who recognize the complexities of global and societal issues and respond to those complex issues with the solutions they develop.

Implications of Findings

The finding that students who emphasized context (the riverbank and surroundings from a natural and social perspective) in the Midwest Floods (MWF) problem also were likely to emphasize context in the information gathering task suggests that there is an aspect of the student's ability and inclination to situate design problems in context more generally that is not an artifact of a particular design problem itself nor the student's knowledge of or interest in the task domain.

Our findings that women emphasized design context more than men suggest that first-year students' experiences, interests, and ways of knowing are also sources of this variation in how broadly students scope design problems. As discussed below, women and men tend to exhibit differences in patterns of intellectual development, and women may perceive that there is a mismatch between what engineering has to offer them and what and how they know about their world. This is especially unfortunate if first-year women's greater emphasis on context is associated with their different ways of knowing, because those who are discouraged from engineering leave for precisely the reasons we want them to stay. The gender differences in the present study suggest that first-year women are more ready than men to do engineering in context, yet the literature shows that they are less likely to be recruited and retained.

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While difficult to achieve, there is still a practical need to have graduating students achieve the ABET outcomes described previously and enter the work world better prepared to participate in the global society. There is also a need to support the engineering faculty who typically teach design courses, some of whom do not have the experience or expertise to develop classroom materials to teach these topics. Both the students and the faculty need access to research-informed classroom materials and assessment instruments to ensure that engineering students include global and societal issues in their engineering design processes.

Method and Background

The importance of incorporating contextual issues into the undergraduate curriculum is widely acknowledged in the engineering education community. ABET 2000 assessment criteria incorporate context in two of the eleven learning outcomes expected to be achieved by engineering graduates. The

recent National Academy of Engineering report "The Engineer of 2020" strongly stated, "Successful engineers in 2020 will, as they always have, recognize the broader contexts that are intertwined in technology and its application in society."

The Academic Pathways Study (APS) research element of CAEE is a multi-institution, mixed-method, longitudinal study which examines engineering students' learning and development. Data were collected from forty students at each of four CAEE institutions for a total of 160 participants using surveys, structured interviews, and ethnographic observations. Students were also asked to perform simple engineering tasks during timed sessions at the conclusion of interviews. This paper describes a subset of the first-year data gathered for the APS—findings from a brief engineering design task and findings from an engineering design question in the spring survey in the first year of the study.

Midwest Floods Problem

In Spring 2004, 124 first-year students were asked, "Over the summer the Midwest experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi?" Students were given 10 minutes to write down their answers on paper.

The MWF problem has been used in previous studies of design behavior in engineering students. The problem is intended to provide a problem-scoping goal orientation, directing respondents to think about the constraints, or factors, to be considered given a proposed solution approach to a broad-based, real-world problem.

A coding scheme was used that categorized factors as detail- or context-oriented, based on a finer-grained coding scheme (for details, see full text article at the link below).

Information-Gathering Question

In addition to the paper-and-pencil task, a quantitative survey that collected data on the students' experiences and engagement in their higher education was administered twice in each year of the APS. During the spring administration in their first year, we asked students to answer a closed-ended question about the information they would need to design a playground (adequately answered by 143 students). The students were asked to select five kinds of information (from a total of 16 options) "you would most likely need as you work on your design." The purpose of the information-gathering task was to orient respondents toward the information-gathering component of the design process.

Interpreting the Data

We were interested in the extent to which students situated the MWF and playground information-gathering problems in context.

For the MWF problem, we used the concepts of design detail and design context to quantify and compare students' breadth of problem-scoping. Ideas focused on the wall or the water and from a technical or logistical perspective were interpreted to be oriented toward the detail of the design problem. All other ideas were considered oriented toward the context of the design problem (for a detailed description, see the paper at the link below). An analogous interpretation for the data gathered for the playground design task was developed. This interpretation of the kinds of information needed to perform this task was categorized as detail- or context-oriented.

What We Found

Midwest Floods Problem

Certain kinds of factors were much more frequently cited in the responses—the (wall, logistical) code pair being the most frequent. This code pair, together with (wall, technical) and (water, natural), accounted for over half of the segments. The code pair (wall, logistical) comprised factors such as the site (location) for the wall, how and when the wall would be constructed, and budget considerations. The next most frequent code pair, (wall, technical), comprised factors such as the dimensions of the wall and the materials from

which it would be constructed. The code pair (water, natural) matched segments discussing the natural phenomena of rainfall, flooding, water level, etc.

At least in aggregate, the study participants seemed to give substantial consideration to both detail- and context-oriented factors. Technical and logistical factors related to the wall design dominated the detail-oriented factors. Among the context-oriented factors, participants more frequently considered the natural environment than social factors.

Women's responses contained more segments by a statistically significant margin. On average, women's responses consisted of about 13 segments, and men's responses consisted of 10 to 11 segments. No gender difference was found in the number of detail-oriented segments, however, women's responses included a statistically significant greater number of context-oriented responses than men's. On average, women appeared to be paying more attention than men to context-oriented factors, but not at the expense of detail-oriented factors.

Information-Gathering Task

For each of the 16 kinds of information, we computed the percentage of participants who included it as one of their 5 selections. Budget and Safety were the most commonly selected kinds of information, with over 75% of participants including one or both of them among their 5 most needed. In contrast, less than 10% of participants selected Utilities and Supervision concerns, possibly because the meaning of those items was less clear.

Given the gender differences in context-orientation in the MWF problem responses, an analogous analysis for gender differences was performed for the playground responses. Women tended to select more context-oriented kinds of information than the men, with the difference for 6 of the 16 kinds of information being statistically significant. A larger percentage of the men included three detail-oriented items in their selections: Budget, Material costs, and Labor availability and cost. On the other hand, a larger percentage of the women selected three context-oriented items: Neighborhood demographics, Handicapped accessibility, and Utilities.

Combined Data Sets

The MWF problem and playground information-gathering question are very different in format and provide different kinds of data. However, responses to both questions yield quantitative measures of the extent to which students consider the context of a specific engineering design problem. We examined the correlation between the number of context-oriented segments from MWF and the number of context-oriented kinds of information from playground information-gathering (115 participants had responses for both questions). The correlation between the two counts is indeed positive and significant, if not particularly strong.

In both the MWF and playground information-gathering responses, we observed a variety of problem-scoping approaches. Although the factors students most frequently cited were detail-focused (logistical and technical details related to the retaining wall), most students were relatively balanced in their emphasis on detail and context.

Having found that beginning engineering students, particularly women, are sensitive to important contextual factors, we suggest that efforts to broaden participation in engineering should consider legitimizing and fostering context-oriented approaches to engineering earlier in the curriculum.