article:2440

Characterizing Design Learning: A Mixed-Methods Study of Engineering Designers’ Use of Language

Key Words: design, language, community of practice, multi-method

Using multiple quantitative and qualitative methods to examine engineering design learning, we found that as a result of taking a course in engineering design and/or studying engineering for four years, students acquire engineering design language that is common to a larger community of practice as well as situated within their own programs and institutions of higher learning. The study also suggests that engineering design language shapes the knowledge that students have about engineering design. Finally, students did not always put their design knowledge into practice, suggesting the need for educational improvements, as well as research to better define the kinds of knowledge necessary to bridge this gap. We analyze data from two distinct sources: 1) the Academic Pathways Study (APS) of the Center for the Advancement of Engineering Education (CAEE), and 2) classroom based data from a first-year engineering design course taught at a Midwest university.

Research and Practice Implications

Using multiple methods to gather and analyze data is necessary to paint a more comprehensive picture of complex phenomena like student learning and development. By analyzing the experiences of students from a number of different perspectives, we are able to broadly consider wide-ranging theories like sociocultural learning theory and adaptive expertise. In particular, our work concentrates on how students use engineering design terminology as they engage in various design tasks. That is, our studies illustrate how students appropriate and use the “language” of engineering design through their coursework and related engineering education activities such that they can engage in the discourse of the community and therefore, become members of the “community of practice.” Our findings show that students do acquire engineering design language through engagement with engineering curricula, programs, and institutions.

We describe three lenses for researching and evaluating the extent to which student designers develop both their understanding of engineering design through the use of language, and their ability to use this understanding to develop solutions to engineering design problems. The *select* and *generate* lenses (discussed below) can be used to assess both students and curricula/programs/institutions by addressing the question: Are our students learning what we intend for them to learn? Using tools like these, researchers and practitioners can measure the extent to which language is being acknowledged and translated into thought by their students, as well as the effectiveness of their courses and programs in conveying local and global priorities for engineering design. Assessment tools should continue to be developed to measure the acquisition and use of engineering design language and thus, measure students' ability to make meaning of their engineering design situations. To demonstrate the effects of design pedagogy on students' design learning, future research should be conducted at institutions offering different kinds of design education (e.g., institutions with a focus on engineering design versus those with a focus on engineering analysis; institutions with strong experiential learning components; institutions with an interdisciplinary approach to design, etc.).

The *demonstrate* lens (discussed below) is itself multi-faceted. The closed ended survey questions revealed that by their fourth year, students know about a certain aspect of engineering design (information gathering). The two previous lab-based design task studies revealed that fourth-year students did not always internalize this knowledge in a way that allowed them to employ it when doing design. Further research should address this gap by attempting to clarify the tacit skills and knowledge that are required in engineering design.

Methods

The research team used a multi-method approach to inquiry. The studies included in the paper employ three different methods for researching and evaluating the extent to which student designers acquire the language of engineering design and develop an ability to use this language in solving engineering design problems. These methods are closed-ended survey questions, open-ended design scenarios, and lab-based engineering design problems. These methods allow us to examine engineering design knowledge through three lenses: *select*, *generate*, and *demonstrate*:

- *Select*: As part of a survey on their perceptions and experiences of engineering education and practice, respondents are asked to select the six most important activities from a previously developed list of engineering design activities. The purpose of this data collection method is to provide a lens on how respondents prioritize design activities.
- *Generate*: As part of a classroom assessment exercise, respondents are given an engineering design scenario and are asked to describe their plans to solve the design problem. The purpose of this data collection method is to provide a lens on

respondents' engineering design knowledge as reflected in their appropriate use of engineering design language to describe a specific engineering design process.

- *Demonstrate*: This lens is multi-method in itself, as it consists of a comparison of a new data set with two previously published analyses. For the new data set, respondents select from a pre-existing list in response to a survey question about a specific design task. These data are compared to studies in which respondents were asked to "think aloud" while designing a similar specific object or system in a lab-based setting. The purpose of this multi-method analysis is to provide a lens on the extent to which respondents' selection of design language in a prioritizing task matches their approach in solving an actual design problem.

Summary of Findings

The APS students exhibited an increased understanding of engineering design as mediated by engineering design language. In comparison to their first year in engineering education, the students' engineering design activity *selections* in their fourth year more closely matched those of experts. Furthermore, taken as a whole, students' design activity priorities appeared to become more engineering-specific after they had nearly completed their engineering education. At the same time, there was variability across student groups at different APS institutions, which may reflect qualitatively different engineering cultures at those institutions. While commonalities are expected among institutions all working to produce engineers for a common national and global stage, we also should expect differences in more locally situated communities of practice that emphasize certain components of the engineering design process.

Using the classroom-based assessment method, we found that students *generated* engineering design language appropriately in response to a design scenario, as they had been taught in a freshman level introductory design course. Furthermore, this growth in engineering design knowledge as mediated by language re-oriented these students to a new way of explaining engineering design. Not only did students' language become more engineering design-specific, but the focus of their narratives shifted from an immediate solution orientation to a design process orientation.

We gained insight into students' design abilities by comparing results from a question in the survey and the lab-based design exercise that both provided a way for students to *demonstrate* an understanding of engineering design through a problem focused on a playground design. We found that after four years of engineering education, students had acquired the language of the information gathering design activity, and also had knowledge of the importance of certain kinds of information to the extent that their answers became more aligned with experts' information gathering behavior.

Despite fourth-year APS students' recognition of the importance of budget and safety information as reflected in their responses to the survey question, the actual information gathering behavior of a different sample of fourth-year students did not follow suit. Less than half the fourth-year students in this sample asked for budget and safety information during the lab-based playground design, even though the vast majority of APS students recognized the importance of budget and safety information when prompted to select from the pre-existing list. These findings suggest that although most students are able to select from a list what kind of information would be important to have while designing a playground, many of them do not actually seek it in an open response exercise.

In sum, these methods yielded a multi-faceted picture of design language, knowledge and practice. We were able to examine language choice with the *select* lens. The *generate* lens provided information about choosing and appropriately using language to express design knowledge. Finally, the *demonstrate* lens offered insight into the application of engineering design knowledge.

Author 1: Cynthia Atman; atman@u.washington.edu
Author 2: Deborah Kilgore; kilgored@u.washington.edu
Author 3: Ann McKenna; mckenna@northwestern.edu

Article Link: http://soa.asee.org/paper/jee/paper-view.cfm?pdf=992.pdf

: Back to 2009 Spring/Summer Issue Vol. 4, No. 3

: Back to List of Issues

: Back to Table of Contents