Research Brief
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From Beginning to End: How Engineering Students Think and Talk About Sustainability Across the Life Cycle

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Sustainable engineering design requires not only the technical skills necessary to engineer solutions, but a broad vision of and sense of responsibility for the impacts that engineered solutions have on people and societies. ABET accreditation standards speak to this need by calling for engineering programs to provide students "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and social context." Furthermore, ABET aspires for students to develop the "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."

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Implications of Findings

Facilitating the development of self-directed learning skills and the ability to critically reflect on one's experiences may improve students' abilities to form conceptions of sustainability and incorporate them into their engineering design practices. Engineering educators and program planners should work not only to make sustainability explicit in engineering curricula, but also to provide opportunities for students to develop self-directed learning and critical reflection skills to encourage the transfer and use of knowledge about sustainable development in a variety of contexts.

Methods and Background

The Academic Pathways Study (APS) is a multi-institution, mixed-methods, longitudinal study which examines engineering students' learning and development as they move into, through, and beyond their undergraduate institutions (Atman et al., 2008; Sheppard et al., 2004). It is part of the Center for the Advancement of Engineering Education (CAEE), an NSF-funded higher education Center for Learning and Teaching (ESI-0227558).

The present study examines how students think and talk about sustainable development, as well as the extent to which they consider life cycle while engaged in engineering design. Sixty-four students across the four APS institutions completed the same engineering design task in their second and fourth years. Fifteen of those students at one of the institutions (Large Public University or LPU), participated in a semi-structured, qualitative interview in their senior year, in which they were asked to talk about sustainable development and other concepts related to engineering. Questions about sustainable development were posed to these students shortly after they had completed the engineering design task. Analysis of the students' conceptions of sustainable development was accomplished in tandem with coding of their written answers to the engineering design task.

We were interested in learning the degree to which the aspirations of policy makers had permeated the students' engineering education experience. Therefore, we asked students to respond to a quote from the *Engineer of 2020*: "It is our aspiration that engineers will continue to be leaders in the movement toward use of wise, informed, and economical sustainable development." We then asked students the following questions: (1) What do you think they mean by "sustainable development?" (2) To what extent has your education provided knowledge about sustainable development? (3) How well prepared do you feel to contribute to sustainable development? Two overarching themes dominated students' responses to questions about sustainable development, and we coded them accordingly: limited resources and life cycle. For a complete description of the methods used in this paper, please see the full paper at the link below.

To complement the interview-based understanding of how engineering students talk about sustainable development, we also analyzed data generated from students engaged in an engineering design task. Researchers collected written responses to four open-ended questions about designing a way for pedestrians to cross a busy street intersection. The street crossing design task was administered on paper with a 15-minute time limit and opened with a brief description of the problem scenario (see full paper for a complete description). The coding scheme recognizes four stages of a designed solution's lifetime, listed in chronological order: CURRENT STATE, DESIGN/CONSTRUCTION, SOLUTION IN PLACE, and MAINTENANCE/DISPOSAL.

What We Found

Students' conceptions of sustainability as an issue of limited resources ranged from very vague, arguably unlike the aspirations of policy makers for engineers in the coming decade, to rather promising in terms of exhibiting the kinds of knowledge, skills and attitudes about sustainability and sustainable development that are hoped for among the engineering education community. Their narratives suggested varying degrees of sophistication in their conceptions of sustainable development as a question of limited resources. Some students gave specific examples to illustrate the concept of limited resources. Others situated their discussion of limited resources within larger economic, environmental, global, and/or social contexts, while some students connected their discussion of limited resources with the engineering profession, specifying the work that they expected to do as engineers.

Students took sustainable development in the life cycle sense to refer to the lifetime of a product, by taking into account materials and design features that will have positive effects upon the maintenance and life of the product, as well as the world context in which the product will be used. Though the student narratives varied in detail and richness (please see the full paper for the narrative transcriptions), they tended to be more connected to the engineering design process than the limited resources narratives. Students' explanations of sustainable development in terms of life cycle analysis tended to include engineering design concepts and the design process itself. These concepts included efficient design processes, more pragmatic design decisions for the long run, and gathering information about users' priorities.

Analysis of student responses to an engineering design task showed that as second-year undergraduates, only about a quarter of the 64-student sample considered CURRENT STATE and DESIGN/CONSTRUCTION in their responses, and even fewer considered MAINTENANCE/DISPOSAL. Most of the response text described solutions in their fully constructed state and did not discuss the duration, complexity, or resource requirements of the design or construction stages in the life cycle. With respect to MAINTENANCE/DISPOSAL, few participants appeared to consider the need for physical structures such as pedestrian bridges (the most commonly proposed solution in both years) to be inspected and repaired for safety. Given the same design task two years later, the students' responses did not change significantly with respect to life cycle considerations. A modestly larger number of students considered DESIGN/ CONSTRUCTION, but none of the changes between Years 2 and 4 were statistically significant (see full paper for a complete report of coding results).

In addition to the analyses above, this paper includes summary descriptions of four students' learning experiences, conceptions of sustainable development, and their responses to the engineering design task. These student descriptions are intended to draw attention to how the variety of their individual experiences associated with an engineering education program could in some way influence their ability to respond to the engineering design task. Please see the full paper for these descriptions.

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