Research Brief
Center for the Advancement of Engineering Education
NSF Grant ESI-0227558

Becoming an Engineer: Toward a Three Dimensional View of Engineering Learning

Authors: Stevens, Reed, Kevin O'Connor, Lari Garrison, Andrew Jocuns, and Daniel M. Amos
Source: Journal of Engineering Education, July 2008, Vol. 97(3): 355-368

In this paper, the authors develop an analytical framework referred to as "Becoming an Engineer" that focuses upon changes occurring over time as students traverse their undergraduate educations in engineering. This paper discusses three conceptual dimensions used to follow the engineering students' educational pathways: the development of *accountable disciplinary knowledge* (ADK); forming an *identity* as an engineer; and *navigating* through engineering education.

Implications of Findings

The person-centered ethnographic studies of engineering students reported in this paper demonstrate that the commonly used pipeline metaphor of generally homogeneous students (fluids) entering and exiting an engineering degree program (the pipeline) may no longer be valid. Even within most engineering education programs, and certainly in three of the four programs studied where navigational flexibility was quite limited, college students still navigated through engineering in ways that display huge and consequential variation. Students follow official routes using unofficial strategies and they also make and follow unofficial routes. There are big differences in how students navigate, and small differences, like a decision to take a more challenging course one quarter, that lead to big differences in whether a student stays or leaves engineering.

The case studies described in this paper demonstrate how the differences in students' ways of navigating their educational experiences can be consequential.

The work described in this paper leads away from a singular concern for the numbers and percentages of "types" of students who enter, stay, or leave engineering toward the qualities of experiences that students have that stay or leave, and the kinds of engineers they become. Still, this study does suggest the general importance of *identification with and by engineering*, the double-sided character of this identification, and, in ongoing work, whether these identifications vary in consequential ways by gender. This article discusses another source of cultural variation that shapes students' experiences—the institutional context through which the student navigates.

The case studies described in this paper demonstrate how the differences in students' ways of navigating their educational experiences can be consequential (see full paper to read the detailed case studies).

In general, the two issues that these cases and others in this study raise are the importance of mentors or sponsors who provide images of futures and the ways students get to those futures that are fully legitimate but do not appear in the official student guidebooks or in the recommendations of official advisors.

The three-dimensional conceptual framework discussed in this paper should be seen not primarily as offering a theory or model to be tested or validated, but rather as a set of interrelated "sensitizing

concepts" that direct attention toward aspects of learning and becoming that escape other perspectives. This research suggests that this "sensitizing framework" could be used to develop an understanding of specific dilemmas experienced by students and others in particular settings (e.g., specific universities or departments). As programmatic changes are made to what is counted as engineering knowledge, or to how navigation is organized, new opportunities and new dilemmas will emerge for students. Person-centered ethnographic methods can help identify and add understanding to the student experience.

Methods

This paper develops a framework that maps changes in three dimensions over time to describe individual persons across pathways that are partially of their own making – disciplinary knowledge, identification, and navigation. The data from which this framework was developed is longitudinal and ethnographic, based on a four-year study of engineering students who have been followed from their freshman year through their senior year. At one of the four schools involved in the study, students were accompanied on their daily round during each academic year and were interviewed regularly throughout the year. At all four schools, multi-hour ethnographic interviews were conducted with students during each of their four years. This paper draws primarily on data from Large Public University, supplemented for the sake of ethnographic generalizations by analysis of interviews conducted with students at the three other campuses. These data are part of a larger multiple methods study of engineering education called the Academic Pathways Study.

These data support a variety of comparative and case study lines of analysis. These include developmental analyses, depicting how students change over the various nested timescales of becoming an engineer, and comparative analyses, both across individual students and across the respective cultures of engineering education on the different campuses.

Background and Findings

The development of accountable disciplinary knowledge. During the last half century, much of the research on disciplinary knowledge that has informed engineering education has been conducted by cognitive scientists, whose leading conceptualization has been in terms of acquisition of disciplinary knowledge. An ethnographic approach to disciplinary knowledge makes different assumptions about how people learn and about the nature of what it means to know or practice a discipline than do the information processing tradition and the specific expert-novice paradigm. This paper draws on this ethnographic approach to disciplinary knowledge, focusing on "accountable disciplinary knowledge" (ADK). This term is used to refer to actions that when performed are counted as engineering knowledge. Changes in what counts as engineering and how students respond to these changes are important elements in understanding how they become engineers.

Forming an identity as an engineer. A fundamental issue often overlooked in studies of learning that are framed in terms of knowledge acquisition is the formation of an identity as a particular type of disciplined person. In this study, the particular types of disciplined people we are interested in are called "engineers." In this work, we are focused on two key issues: (1) how engineering identities develop over time, stabilizing within the double-sided process of specific acts of identification, and (2) how the differing forms of accountable disciplinary knowledge in engineering education position people differently in terms of their identifications with engineering.

Navigating through engineering education. Most institutions, and nearly all educational institutions, present a series of "obligatory passage points" through which people must pass in order to move toward official recognition as a particular something (e.g., engineer, doctor, married person). To become institutionally identified as an engineer, a person must, for example, be "admitted" to the college, "pass" a series of courses, and "complete" certain sets of requirements to "graduate."

Navigation is a conceptually distinct dimension and is related to identification and ADK in practice. The officially sanctioned way to navigate through higher education is by meeting some threshold on ADK, and distinction in displaying ADK nearly always means smoother navigation. Different students navigate differently through engineering and these differences can be consequential not only for where they end up, but also for the duration of their undergraduate experience, the social networks they create, and the quality and substance of their identification with engineering.

How the three dimensions interrelate. These three dimensions of "becoming an engineer," while conceptually and analytically distinct, interrelate in practice. Indeed, these relationships are the source of much of their power as analytic tools. All engineering students can be seen as moving along each dimension at all moments in their educational careers, and movement along any one dimension relative to movement in the other dimensions can become consequential to becoming an engineer.

One of the similarities across the four schools studied involved changes over the four years in the basic trajectory of what counts as disciplinary knowledge. Changes in ADK included (a) types of events for displaying knowledge (e.g., lecture, laboratory, or project), (b) types of problems to be solved, including the locus of responsibility for finding and posing those problems, and (c) students' relationships to one of the fundamental objects of engineering – data.

Changes in ADK become visible as students began taking upper-level courses in their majors. Increasingly, projects and labs became the foci of coursework, and laboratory work was no longer built upon following a recipe to reach a single, expected result. The shift to more open-ended problem solving and the accompanying shift in ADK were sources of frustration for some study participants, seeming to be both an abrupt and a radical departure from prior understandings of problem solving. The role of data in students' work also shifted in upper level classes where students were expected to generate their own data, either through research or experimentation, significantly extending the time spent completing assignments. A related issue arose from problems worked under the "perfect world" conditions of prerequisite courses that did not prepare students to deal with the more "real world" conditions they faced in senior level courses.

Other shifts in ADK in senior-level courses involved the expectation that students would augment the resources used to solve problems with resources outside the official curriculum and a more "hands off" approach of instructors in their management of student project groups.

Another type of similarity across students at the four schools involved changes in identification. Over time, students demonstrated increasing solidarity with other engineering students and increasingly reported differences between themselves and other college students. As students progressed through their engineering degrees, they reported gaining access to engineering-specific cultural spaces such as access codes to special labs and passwords for closed wireless networks in their engineering buildings.

Identity is "double sided," that is, a student's identity depends not only upon how he or she actively identifies himself or herself, but also upon how he or she is actively identified by others within the various social fields in which he or she acts.

The greatest differences in this study across students and schools were found in the dimension of navigation. The story of any student's actual navigation is of course a mix of official well-marked routes and unofficial routes. And, not only are there unofficial routes, there are unofficial strategies for making it through official routes. The differences found in navigation among students were clearly related to what might be called "navigational flexibility" on each campus.

In addition to the differences in navigation through and sometimes out of engineering among students across the four campuses, there were some similarities in how students at each of the schools navigated across the years of their undergraduate experience. At three of the four schools, students' involvement in non-official activities, even those related to engineering (e.g., Society of Automotive Engineers race car competitions and engineering clubs) decreased as students moved through their engineering educations.

This research has shed light on the variability of student pathways, but more needs to be understood about this variability before seeking general and encompassing principles of how people become engineers.

www.engr.washington.edu/caee December 2008