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

In this paper, we examined undergraduate engineering students' learning over time, using a "three-dimensional" theoretical and analytical framework. The first dimension, disciplinary knowledge, is the one most traditionally associated with the concept of learning. But instead of seeing learning as the acquisition of a unified and stable body of knowledge, we viewed disciplinary knowledge as at least potentially both less unified and more variable in terms of what practitioners know and do, and sought to identify what counts as disciplinary knowledge in different situations. Our second dimension, identification, concerned how a person both identifies with engineering and is identified by others as an engineer. Our third dimension, navigation, focused on how engineers-in-the-making moved through and constructed various pathways, both personal and institutional, both official and unofficial, as they progressed through their undergraduate careers. We used ethnographic methods to observe these processes as they happened in specific sites of activity.

Our data were collected as part of a four-year study of engineering students at four schools, whom we followed from their freshman year through their senior year. Collection methods included semi-structured interviews as well as observations of and conversations with research participants in and around their routine activities. Our analytic findings were of two sorts. First, we focused comparatively on each of the three dimensions over time, both across and within schools. Second, we developed two comparative person-centered case studies in order to show how our three dimensional framework can reveal interactions among the dimensions in specific cases, so as to illuminate general theoretical issues around learning. A central finding on accountable disciplinary knowledge across the four schools was that "problems" were a key site for displaying knowledge across the four years. However, from the first to the fourth year of the curriculum, distinct and only partially relatable activities were relevant in problem-based activity. Among the shifts over this period were 1) a shift from highly structured, decontextualized problems, using "given" data, and assuming "perfect world" conditions, toward open-ended problems with self-generated data and an emphasis on "real world" conditions; 2) an increasing importance on work in teams, as opposed to individual work; 3) an increasing shift of responsibility away from the instructor and the curriculum and toward students in identifying and solving problems.

We examined two different but related aspects of identification, students' self-identifications with

engineering and their identification by others, including institutional representatives. First, students across campuses displayed similar general patterns of identification with the discipline. For instance, as they moved further into the curriculum, they demonstrated increasing solidarity with other engineering students and occupation of engineering-specific cultural spaces. At the same time, the specific circumstances of their own local situation meant that these patterns were realized in somewhat different ways, with consequences for who identified as and ultimately became an engineer. Among the most important differences regarding identification across campuses concerned the relationship between self-identification as an engineer and official institutional identification as an engineer. For example, while students at all schools experienced some degree of both ambivalence and tension about their futures as engineers, this was particularly pronounced at Large Public University, where admissions to an engineering department was competitive and in most cases was not gained until after the second year. Identification with and investment of oneself in engineering at this school, in the absence of formal recognition by the institution, was viewed as a risk. And this was a risk that not all students, even quite talented ones, were prepared to take. In contrast, at Suburban Private University, where students declared majors without undergoing a competitive admissions process, students viewed entry into engineering in terms of choice and opportunity rather that in terms of risk. Thus, these and other differences in how institutions officially identified students as engineers had profound effects on students' identification of themselves as engineers and on their futures and commitment to the field. We found the greatest differences in the dimension of navigation. Any student’s actual navigation turned out to involve a mix of official, well-marked routes—e.g., using recommended course sequences, maintaining a high GPA—and unofficial routes—e.g., taking a course at a community college rather than with a notorious professor on one’s own campus. Despite variability, though, some common themes can be discerned. One central general point involves the importance of the degree of navigational flexibility at different campuses—that is, the extent to which institutional structures—course schedules, GPA requirements for maintaining scholarships, and the like—in allowing students to develop accountable disciplinary knowledge and to maintain an identification with, and by, the discipline.

The insights gained through our three-dimensional framework are perhaps most available through detailed case studies of specific students. We developed detailed comparative case studies of two students at one school. Simon and Jill, as first year pre-engineering students, were interested in the same prestigious and competitive engineering major. Simon gained admission to that major after his second year; Jill switched majors at that point without applying to an engineering department. Simon and Jill were similar in important ways. In addition to their interest in the same major, neither was particularly distinguished in terms of displays of official disciplinary knowledge through their first two years; they had GPAs of roughly 2.9 and 2.8, respectively. Both were wavering in their identification with engineering as a major, with Simon considering a possible switch to music and Jill to business. There was a crucial difference, however. Jill relied on an official navigational route into the major and focused her efforts on her GPA. When she foundered there, she saw few other options for pursuing an engineering major and became progressively less identified with the field, eventually electing to leave. Simon, meanwhile, with the help of a family friend who was a professor in his desired engineering

department, obtained a job at a departmental testing facility. In large part as result of this position, he was able to make a case for admittance to the major, despite his lower-than-average GPA. Both students went on to be quite successful through their final two years, Simon as an engineering major and Jill as a business major. We used these cases to argue against a view of learning that is overly focused either on individual knowledge or on individual motivation. Jill could be viewed as having insufficient knowledge or motivation to succeed in engineering; Simon's success could be seen as the unfolding of the more or less straightforward trajectory of an intelligent and motivated student who followed his interests until he ultimately became recognized for his strengths. But while these understandings are possible, they are misleading in that they background the contingency of the pathways and the extensive organizing work, by Simon and Jill along with others, that shaped their careers at every point along the way.

We concluded the paper by drawing out implications for engineering education research. We suggested that the "pipeline" metaphor for engineering education, while it's been useful in showing disparities in access for underrepresented populations, might best be traded for a metaphor that foregrounds the variability and contingency of pathways into the field. We suggested that, methodologically, ethnographic and other approaches oriented toward the study of the specific details of social practice could usefully take on a more prominent role in the discipline of engineering education research.

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