Disciplinary Knowledge, Identity, and Navigation: The Contributions of Portfolio Construction

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Abstract: In this paper, we look at how the construction of two types of professional portfolios supports engineering student learning. To frame "engineering learning," we use the dimensions brought together by Stevens and his colleagues: disciplinary knowledge, identity, and navigation. We present data from a comparative study in which students constructed one of two types of professional portfolios and provided data through extensive questionnaires. In this analysis, we look at their answers to the first question on the questionnaire ("What did you take away from this experience") in terms of the extent to which the students reported insights about disciplinary knowledge, identity, and navigation as a result of portfolio construction activities and the nature of the insights reported.

Introduction

As with other forms of professional education, the goals for engineering education are complex and the lists of outcomes or competencies are extensive (e.g., ABET learning outcomes, conclusions from national policy reports such as ENGR 2020, Rising above the Gathering Storm, Grand Challenges). To meet the challenges of a dynamic, rapidly changing global milieu, the engineering education community has been exploring various pedagogical innovations such as problem-based learning and integrated first-year curricula, to provide students exposure to the kinds of complex, multifaceted learning experiences that more closely resemble situations they are expected to face as engineering professionals. Portfolio construction is an activity that has been advocated as valuable in supporting reflection on these and other learning experiences. While the body of work on the educational benefits of portfolio construction has been growing in other disciplines, work remains to be done to help fully understand how portfolio construction can enhance engineering learning.

In this paper, we present data from two portfolio interventions requiring different amounts of time and resources on the part of students and educators, to determine the engineering learning that might be possible given investment in such activities. To examine student learning from a perspective that complements the complex challenges of the present age to engineering education, we used a three dimensional approach proposed by Stevens and his colleagues, to include accountable disciplinary knowledge, identity, and navigation. We found this to be a useful framework for understanding what students perceived to be important benefits of portfolio development.

Portfolios in engineering education

Portfolios are frequently understood as a collection of student work with a purpose. Among the many reasons driving interest in portfolios are the following: student knowledge is represented by their own work, students can take control of gauging the quality of the work, and the processes of selecting and explaining work in a portfolio can create opportunities for reflection.

Portfolios are not new to engineering education. The various portfolio projects being reported represent goals that are diverse, implementations that range from course to institution-wide, and variation in the extent to which reflection is emphasized. For example, Eris (2007) explored the potential of portfolios to capture significant types of design knowledge, Williams (2002) focused on a systematic process for setting up a portfolio framework that is oriented toward a particular competency in engineering education and supports reflection, Campbell and Schmidt (2005) described an institution level initiative that goes beyond assessment toward career planning as a goal and has reflection as a key feature, and Knott and colleagues (2004) reported on multiple university-level portfolio initiatives along with data on student experiences in these initiatives. Such a snapshot suggests the level of interest in portfolios and the range of uses. Barrett (2007) provides useful ways of laying these uses. For example, she differentiates the idea of using portfolios for assessment *of* learning or assessment *for* learning, and she draws distinctions between a positivistic approach for using portfolios (i.e., providing documentation of true knowledge) and a constructivist approach (i.e., providing a venue for helping students construct understanding). It is not always easy to determine which paradigm is prominent in the portfolio uses in engineering education.

In our work, we are interested in what happens when creation of the portfolio is framed as construction of an argument about the ways in which one is prepared to contribute to future engineering practice, specifically the realm of engineering practice that is of personal interest. Operationally, we have students instantiate this argument in the form of a portfolio containing a professional statement and multiple annotated artifacts. We explain the professional statement as a written narrative in which students explain the ways in which they are prepared to function as an engineer and which functions as the core of the argument. Artifacts are products and by-products of experiences that support the claims made in the statement. Annotations are explanations of artifacts, the experience that gave rise to them, and the link from the artifact to one or more claims.

There are clearly many ways to think of what such a task means theoretically. For example, seen from a lens of situated learning and legitimate peripheral participation (Lave and Wenger, 1991), this notion of portfolio construction invites students to frame or reframe prior experiences as legitimate peripheral participation in the practices of engineering (e.g., linking prior communication experiences in any setting to the kinds of communication that will be required in engineering practice). Clearly such a task is likely to be easier for some experiences than others. For example, an internship at an engineering company or participation in a capstone design project is likely to have much similarity to engineering practice, and thus the portfolio activity may simply involve being able to articulate the ways in which the experience contributed to being prepared. For other experiences, such as being in a leadership role in a sorority or spending a quarter in a music appreciation class, the challenge involves better *understanding* as well as articulating the possible ways in which the experience contributed to preparation for engineering practice. While much work on education is moving toward having students have educational experience that are more "like" engineering practice, it is still important to remember that students are having lots of experiences (some we control, some we do not)—experiences that can be contributing to their preparation for engineering practice and that giving students opportunity to frame the experiences as preparation has the potential to have educational significance.

In our studies, we have been exploring such questions of educational significance as well as questions of educational feasibility (i.e., what resources are required) in relation to different instantiations of this overall idea. Different instantiations involve different ways of constraining the task and different ways of providing students with support. For example, one way of constraining or not constraining the task involves deciding the scope of experiences across which students are invited to base their argument about their preparation. This has led us to explore *cross-curricular engineering portfolios* (CCP) in which students reflect on all of their experiences to date as well as *course-based engineering portfolios* (CBP) in which students focus on how the experiences associated with a specific course have contributed to being prepared. Our program of research has focused on student construction of these two types of portfolios (e.g., Turns, Cuddihy and Guan, submitted; Eliot and Turns, accepted; Guan and Turns, 2007; Lappenbusch and Turns, 2005).

These variations clearly differ in terms of educational feasibility. For example, course-based engineering portfolio activities could be added as a required assignment to any existing course, thereby not requiring significant change to the curriculum. Incorporating a cross-curricular engineering portfolio activity into the student educational experience is not as straightforward. In addition, the larger scope of the cross-curricular engineering portfolio suggests a need for more resources. As a result of such issues, over the past six years, we have studied students constructing these types of portfolios within as well as outside classroom settings

The differential educational significance of these two framings of the portfolio is also open question. Across our studies, we have collected data via observations, interviews, and surveys and our analyses of the data have used a variety of lenses in order to fully understand the role that this intervention can have. For example, we have analyzed our data from a writing-to-learn perspective, a community of practice perspective, an epistemic space perspective, and an identity perspective. Across this work, we have consistently noted that students engaged in constructing these types of portfolios have significant educational experiences and an effort to fully understand these experiences would require a broad framework. The contribution of this paper is to apply such a broad framework to data from our newest study, a comparative study in which student participants constructed one of the two types of portfolios and then told us about their experience through an extensive, open-ended survey.

Disciplinary knowledge, Identity, and Navigation

In a recent paper, Stevens and his colleagues argued for the value of looking at three dimensions of engineering learning when thinking about the challenges of helping students become engineers (Stevens et al., 2008). These three dimensions--disciplinary knowledge, identity, and navigation--individually and in combination present a rather comprehensive view of how students conceptualize engineering knowledge and themselves as engineers, as they move into, through, and beyond their undergraduate engineering education. Stevens *et al.* present this three-dimensional model as a means for examining the experiences and development of engineering students from the analyst's perspective and illustrate the model with insights developed from ethnographic research. As we will show, the three dimensions may also provide a framework for students to reflect on and characterize *their own* experiences and development.

As Stevens and his colleagues point out, much work on disciplinary education has focused on characterizing and comparing the knowledge of disciplinary experts and student novices. In engineering, for example, researchers have focused on the critical role of design activity to engineering practice and have explored issues such as how expert engineers engage in design, how students engage in design, and how to help engineering students travel the path toward design expertise.

Stevens *et al.* take a significant turn in examining disciplinary knowledge as malleable and situational, rather than the relatively stable and progressively acquired body of knowledge assumed by expert-novice comparisons. They propose the concept of accountable disciplinary knowledge to highlight the idea that while disciplinary knowledge might be defined relative to the profession, the knowledge that is considered "accountable" or relevant changes over the course of a student's academic career. For example, while lifelong learning is considered critical to effective functioning of a professional engineer (i.e., see ABET accreditation criteria), students may not be held accountable to such a notion in the early years of their undergraduate education (or throughout their undergraduate years, for that matter) in favor of bodies of knowledge, like physics or even engineering design, that are more established in the literature and therefore easier to assess. Stevens *et al.* offer the example of engineering education in a particular large public institution that was the subject of their in-depth ethnographic inquiry. The character of knowledge for which students at this institution were accountable changed over the course of their years in college. In their first two years or so, students were assessed largely on their ability to solve discrete closed-ended textbook problems on their own, while in their upper-class years, students were assessed largely on their ability to tackle open-ended ambiguous problems while working in teams. The consequence of such a structural shift in what "counts" as knowledge, not unusual in U.S. engineering programs, is illustrated by the second-year student who found it difficult to reconcile his experiences in a research lab with what he believed would be important for his application to an engineering department.

Influenced by situated learning theory, Stevens *et al.* also assert the importance of identity in understanding engineering learning. Here, identity is not only how a person thinks of herself as an engineer, but also how a person is identified with engineering by others. Thus, identity development is an interactive process involving an individual's efforts to develop a conception of self as an engineer, and the larger community's growing recognition of the individual as an engineer (or not an engineer). As students develop a sense of what does or does not count as engineering, they develop a sense of self as more or less "engineer-like" according to how much or little they find themselves doing what they think counts as engineering. Likewise, others around them identify students as engineers more or less depending on the extent to which the student is doing what others perceive to count as engineering.

This two-sided process is illustrated by Stevens *et al.* in their observations about students at the institution in which they conducted their ethnography. For example, gaining increasing access to limited educational resources served to support the students' growing identities as engineers; while on the other hand, the competitive admissions process at the university (students have to apply to an engineering department during their sophomore or junior year) impeded students' identification as engineers, as they tended to refrain from committing to engineering until a department committed to them. One consequence of such structural conditions is that individuals' identification with the profession may weaken as they worry about admissions.

The third element of the three dimensional view, navigation "focuses on how a person moves through the personal and institutional pathways as an engineer-in-the-making to be officially recognized in one or more ways as 'an engineer,' pathways that are cut along both official and unofficial routes" (Stevens et al., 2008, pp. 356). Navigation provides "a way to talk about how other people and institutional resources play a role in a particular individual becoming an engineer or not" (Stevens et al., 2008, pp. 356). Navigation would include obligatory passage points, official routes, unofficial routes, and detours. For example, an obligatory passage point might be a particularly difficult pre-requisite course and an official route might include taking the required courses in an engineering department. At the same time, there are many unofficial pathways and detours, including internships, summer jobs, extracurricular activities, that can be the greatest sources of variation in students' experiences, engineering learning, and development. Such navigational flexibility can expand the possibilities for a student. For example, working at an engineering job gave one student access to a number of individuals who provided mentoring and additional opportunities for him, not necessarily available to other students.

Something that happens? Something you can control?

We agree with Stevens and his colleagues that these three dimensions hold great promise for thinking broadly about how engineering students become engineers. What we also wonder is the extent to which these dimensions can be used to characterize the ways in which an intervention helps students take control of their own development. The idea implicit in such a question is that these elements are not only significant for characterizing what has happened to a student along the way, but can also be variables over which a student may have some measure of control. How effectively can students think broadly about the knowledge that they possess and recognize that subsets of their knowledge are accountable for certain situations? To what extent can thinking explicitly about such an issue actually affect the state of disciplinary knowledge? To what extent can trying to explain one's preparedness to be an engineer to someone else affect one's own identification with engineering? To what extent can students effectively monitor their own pathways, making sense of where they have been and adjusting their direction as they move forward? Our experience suggests that students can have agency in these matters, and that this agency can be supported through professional portfolio development activities.

Approach

In our study, students created either a course-based professional portfolio (CBP) or a cross-curricular professional portfolio (CCP) and shared their portfolio construction experience with us via an extensive online survey. For this paper, we used the three dimensional framework introduced above as a basis for analyzing their response to the first and broadest question on the survey, "what did you take away from this experience?"

Procedure

All participants attended workshops where they were given instructions and support for creating their portfolios. Participants in the cross-curricular portfolio intervention group attended four 90-minute workshops during the fall of 2008, while participants in the course-based professional portfolio intervention group attended two 90-minute workshops during the winter of 2009. In both cases, workshops were devoted to instructions for creating a professional portfolio and opportunities to peer review one another's work. In the course-based portfolio condition, because of the timing, participants only had the opportunity to peer review the final portfolio. In contrast, participants in the cross-curricular portfolio condition had the opportunity to peer review elements of the portfolio, like the professional statement or specific annotations, as they were developed, as well as the completed portfolio as a whole. Admittedly, these two conditions differed not only in the type of portfolio being constructed, but also the "time on task" and the extent of peer review feedback. The decision to configure the two conditions in this way was based on what was deemed a minimum scale implementation of each type of portfolio as part of an effort to help the engineering community understand what could be possible with these interventions.

A single individual served as the facilitator for all sessions. In addition, to ensure consistency across the sessions, the facilitator's role in these workshops was highly scripted. In particular, the facilitator offered little or no information about the criteria for choosing portfolio content or possible future uses for the portfolio itself. Participants often asked such questions in the workshop and in these cases the facilitator was instructed to turn such questions over to the group for general discussion.

Participants

A total of 69 undergraduate engineering students participated in the study, 37 in the cross-curricular condition and 32 in the course-based condition. Collectively, the participants ranged in age from 18 to 44 years, with a median age of 21 years. There were approximately the same number of females and males in the study. Because of the relatively small number of participants, we chose to ask students whether they considered themselves underrepresented and over 50% said yes. Participants indicated that they were from a variety of engineering disciplines.

Data collection

The primary data collected in this study was in the form of extensive online questionnaires that elicited information about the students' experiences of constructing their portfolios. These questionnaires were administered during the final workshop sessions to manage the quality of the data collection. Students spent between 35 and 45 minutes completing the survey. In this exploratory paper, we focus on analyzing the students' responses to the first question—"What did you take away from this experience?" We chose this "take away" formulation rather than a formulation that asked directly about learning (e.g., "what did you learn") for a variety of reasons. Our goal with the first question was to get a sense of students' learning broadly. However, recent work on personal epistemology has helped point out that students themselves have ideas about what counts as knowledge. On our part, we have seen evidence of such issues in other students, when, for example, students described how a portfolio construction activity helped them become more aware of what they know and helped them to see the connections among their different courses and learning experiences, yet subsequently said that they "hadn't really learned anything." In our choice of asking about take-aways, we wanted to try to bypass potentially constrained ideas about what counts as knowledge and learning.

Data analysis

We used a combination of deductive and inductive analysis of the student "take-away" responses to explore a) the extent to which students reported insights related to disciplinary knowledge, identity, and navigation, b) the nature of these insights, and c) how insights reported by students differed across the two portfolio interventions.

We are using the term deductive analysis to refer to the process of filtering the data relative to each of the three dimensions from the framework introduced earlier. In addition, because initial inspection of the data suggested the prevalence of comments directly related to the portfolio, we added a fourth coding dimension.

- Disciplinary knowledge: a) literal references to "skills" or "knowledge," b) references to other terms that can be considered surrogates for skills and knowledge such as "qualifications" and "qualities"
- Identity: a) literal references to being "an engineer" either in their own eyes or in someone else's eyes, b) references to personal sense of self and "who they are"
- Navigation: a) literal references to "experience," b) references to specific types of experiences such as projects, courses, etc., c) references to accomplishments and achievements because such terms typically refer to experience delineated by a superior quality
- Portfolio: a) references to some aspect of the portfolio experience such as having the portfolio or the process of constructing the portfolio

The two first authors independently coded each student response as related or unrelated to each dimension based on the guidelines presented above. A single response could be coded for multiple dimensions. Reliability was high as measured by Cohen's kappa (0.77 for Disciplinary knowledge, 0.91 for Identity, 0.68 for Navigation, and 0.94 for Portfolio). The lowest value—the value for Navigation—was the result of one coder including mentions of specific courses as a part of navigation. This broader view was adopted for the final coding, and the remaining disagreements were resolved by the first author. Since we were interested in comparing the prevalence of these insights across the two conditions, the coding was done blind to the condition so that preconceptions about the conditions could not influence the coding outcomes.

We used an inductive analysis to characterize the nature of the insights associated with each dimension. The goal of this analysis was to identity themes in the responses coded as related to each dimension. In the results section below, we describe these themes and illustrate the themes using the students' response.

Results

As depicted in Table 1, the Navigation and Portfolio dimensions were similarly prevalent in the data—both appeared in around 65% of the *overall* set of responses. The dimensions of Identity and Disciplinary Knowledge were less prevalent but still prevalent to a notable degree (i.e., 22% and 30% respectively) in the *overall* responses. In terms of differences between conditions, the prevalence was similar for Disciplinary Knowledge and Portfolio. The CCP condition had a much higher prevalence of Identity and Navigation, while the CBP condition had a much higher prevalence of portfolio-only responses—responses that did *not* address any of the three primary areas of interest (i.e., disciplinary knowledge, identity, navigation). In the remainder of the results, we describe the themes present in responses coded within each dimension. We start with disciplinary knowledge as a category of interest that was not different across conditions, then discuss navigation since it was present but different across the conditions, and then turn to identity which was different across the conditions and almost absent in the CBP condition. We end with comments on the portfolio themes.

Table 1: The percentage (and counts) of the responses addressing each dimension (i.e., extent)

	Overall (n=69)	CCP (n=37)	CBP (n=32)	Comparison
Disciplinary knowledge	30% (21)	27% (10)	34% (11)	CCP < CBP
Identity	22% (15)	32% (12)	9% (3)	CCP >> CBP
Navigation	62% (43)	68% (25)	56% (18)	CCP >> CBP
Portfolio	65% (45)	68% (25)	63% (20)	CCP ~ CBP
---Portfolio Only	30% (21)	19% (7)	44% (14)	CCP << CBP

Disciplinary Knowledge

Three themes emerged from inductive analysis of the twenty one responses coded as related to disciplinary knowledge. First, the students' responses showed marked attention to the issue of "accountability" of their knowledge. Most frequently this took the form of identifying or thinking about the portion of their knowledge most relevant to employers or recruiters, but some students also thought about the portion of their knowledge relevant to "professional practice," to "engineering," and to their "engineering career."

- A sense of what skills and valuable experiences I have that I can bring up when talking to recruiters, interviewers, etc. to make myself a stronger candidate; A realization that these experiences/skills that make me a strong candidate are not limited to technical experiences/skills. Examples from other academic disciplines and nonacademic pursuits are also valuable, as are examples related to my major that show nontechnical skills (ability to work in a group, time management, etc.)
- I feel like I can look at a course differently now. What I mean by that is that I can look at a current class and ask myself "what marketable skills am I gaining from this class."

Second, the student responses also suggested that the activity of constructing the portfolio helped students to gain a better sense of the body of knowledge that they had been able to develop by this point in time. In some cases, this was characterized as an inventorying process, while in other cases there was an element of discovery. Such awareness creates a basis for thinking about what knowledge might be accountable to some group.

- However, my chief take-aways from this experience is my realization that I have actually produced a lot more ""artifacts"" than I had remembered. This allowed me to go back and look at the skills I've managed to develop over time. …. (Inventory with a hint of discovery)
- "Building an engineering portfolio helped me to view my completed coursework from a professional perspective as opposed to an academic one. It gave me the opportunity to rethink what I learned and added to the value of the material covered in the course… " (Discovery)

Third, students also reported insights concerning the process for doing the first two activities. Such insights included recognizing the scope of accountable knowledge and how a course can be used to demonstrate knowledge, and even a recognition of the importance taking the time to do such thinking.

- A realization that these experiences/skills that make me a strong candidate are not limited to technical experiences/skills. Examples from other academic disciplines and nonacademic pursuits are also valuable,
- I feel like I can look at a course differently now. What I mean by that is that I can look at a current class and ask myself "what marketable skills am I gaining from this class."
- I haven't really taken the time to think about what it is to be an engineer and show how I have those skills

Navigation

In the 43 responses that were coded as related to navigation across the two conditions, students 1) revisited experiences they had already had, 2) expressed that they had developed a greater appreciation for their experiences, 3) articulated a broader understanding of the experiences that are relevant to navigation through engineering, and 4) discussed plans for directing future paths. Unsurprisingly, the CBP responses were more likely to emphasize course-specific experiences, although they frequently talked about courses in generally rather than simply the course on which they had focused the portfolio, while the CCP responses emphasized experience more generally.

Several students described how the portfolio development process encouraged them to revisit their prior experiences. For one student, portfolio development simply "forced me to review all of my experiences" while another student "gained a deeper understanding of my professional experience." In addition, students said they developed greater appreciation for the experiences they had had. Some students expressed this greater appreciation in terms of realizing they had accomplished more than they thought, as with one student who wrote, "My chief take-away from this experience is my realization that I have actually produced a lot more "artifacts" than I had remembered." Another student "gained more insight into what I could prove from experiences…. I realized they showed more about me than I had realized before."

Students also described how their understanding of the relevance of their many experiences had expanded, "how everything that I have done up 'til now has some kind of value in the engineering field." This broader conception of relevant experiences, coupled with greater appreciation for such experiences, led students to consider their value: "all my experiences could potentially be documented for future benefits." In looking back at their experiences, students also were compelled to look forward, as one student who planned to continue reflecting on her learning experiences said, "I need to think about each project or assignment as something that is helping me to become a better engineer." In addition to those students who planned to continue reflecting in the future, some students planned to take greater control of their future paths. One student wrote, "I discovered that I needed more to show that I was an engineer. I will now be looking more closely at internships…" In addition to "thinking about everything I have accomplished," some students are also inclined to look forward, at "things I wish to accomplish by the time I graduate…"

Navigation, described by Stevens *et al.* as the dimension that may introduce a great deal of the variation among students' experiences, learning and development, here is shown to present opportunities for students to exert greater control over their learning. Some students say that the portfolio development activity has enabled them to re-think and organize their prior pathways, and be more intentional about those pathways they follow in the future.

Identity

Since most of the identity-related responses were associated with the CCP condition, a comparative analysis is not strongly warranted. It is possible to note, however, that the three CBP identity-related responses were quite different in emphasis and covered much of the space of the twelve identity-related CCP responses. Of the fifteen responses that were coded as related to identity, most (12) were associated with the CCP condition. Two major themes emerged from inductive analysis of the fifteen responses coded as related to identity. These themes were 1) a changed personal sense of identification with engineering and 2) a changed sense in the ability to explain one's preparedness for engineering. In the process of identifying oneself with engineering, as one student wrote, "I've had to go back and evaluate myself and what I have done as an engineer," some students gained greater identification as an engineer. This same student added, "What I'm mostly going to take out of this is what I have discovered about myself and how everything that I have done up till now has some kind of value in the engineering field." Another student wrote simply that portfolio development, "helped me define who I am as an engineer."

Furthermore, students recognized the importance of being able to explain or prove their preparedness for engineering, as one student wrote, "I have learned how to think about the things I have done in my classes in a way to present myself as an engineer. I learned how to draw on my experiences to come up with specific proofs of my qualities." Another student commented on the value of "having some basis/artifacts for the claims that I am a good engineer." The process also caused students to plan future action toward developing the ability to demonstrate their preparedness. Through reflection on their experiences, some students felt, as one expressed, "I discovered that I needed more to show that I was an engineer. I will now be looking more closely at internships and will be saving assignments." Another recognized the need to pursue "more activity that related to my career as an engineer."

Students' responses also illustrated the two-sided process of identity development as described by Stevens *et al.*, with the individual developing a sense of self as an engineer at the same time and in interaction with others forming a perception of that individual as an engineer. For example, one student wrote, "Sharing with others my experiences and their experiences helps me understand where I stand relative to other engineers in my community." Another also found value in comparisons across other engineers, "I got to look back what I have done as an engineer, and how it may differ from other engineers."

We may assume that the two-sided process of identity development described by Stevens *et al.* is always in play as students interact with their environment, and therefore it is no surprise that the process continues through portfolio development as an educational intervention. The difference here is the possibility for students to look upon their own developing professional identities as the subject of reflection, drawing connections between what they do and who they are becoming. By making sense of these relationships, students gain awareness of the control they can have over their pathways, and thus become more deliberate in developing and claiming their professional engineering identity.

Portfolio

Two major themes emerged from inductive analysis of the forty-five responses coded as related to portfolio. These themes were 1) having the portfolio and 2) having a process for creating a portfolio. First, students drew attention to the simple fact that they gained from the experience a physical portfolio. Some students went even further and described the portfolio as an organizing tool, and sometimes even specifically to share with others (e.g., "A portfolio that I can present to future employers and academic admissions boards"). The students also students reported gaining knowledge about the "fundamentals of how to build a portfolio" and a sense of how creating a portfolio is related to other types of writing they have learned about (e.g., "Creating a portfolio is quite similar to any other paper I've been writing. You make an argument--Professional statement, annotations--and you support your argument--artifacts"). Some students linked the process of creating a portfolio with having one, by describing the portfolio they created as a starting point for developing future portfolios such as in the following quote: "I am taking away a foundation for a future engineering portfolio if I wanted to start one, as this one is a solid foundation then only polishing would be needed at this point." It was interesting to note the number of portfolio-only responses associated with the CBP condition.

Discussion and Concluding remarks

In this paper, we showed how the three dimensions of disciplinary knowledge, identity, and navigation can be used to make sense of what students reported taking away from two types of portfolio construction activities. We were able to code much of the data using these dimensions and then identify themes within each dimension. For example, students reported greater awareness of their own knowledge and how to think about what is accountable at any point, stronger identification with engineering, and a broadened sense of what could be included in the engineering pathway to date and ideas about how to manage the pathway in the future. These results suggest that portfolios can help students take greater responsibility for their education. The relatively small scale of these interventions (particularly when compared to large scale curricular change) makes these results even more compelling. The comparative emphasis of this study is intended to provide information for creating portfolio assignments that meet available resource requirements (i.e., the amount of time available) and also help students focus on important learning goals. In our work, the results suggest that educators who are interested in helping students think directly about identity issues should consider the cross-curricular portfolio over the course-based portfolio.

We believe the results presented here may underestimate the extent to which students had insights relative to each dimension since we analyzed only a small amount of information from each student. Because our questionnaire was more extensive, we will be able to explore this conjecture in future analyses. What we will not be able to explore directly is whether students would have had these insights without the portfolio intervention. While it does seem plausible that some students would have such insights eventually, it nevertheless seems valuable to know that portfolio construction can help students along in this process. This work contributes to the scholarship on portfolios as an educational intervention, efforts to understand engineering learning broadly, and, of particular importance, efforts to help empower engineering students to take charge of their education.

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Acknowledgments

This work has been supported by the National Science Foundation through grant REC-0238392. The authors wish to thank the students who participated in this study and shared their experiences with us. The authors wish to thank Matt Eliot and Cindy Atman for their contributions to this work.