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I thought this was going to be a waste of time:How portfolio construction can support student learning from project-based experiences

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I Thought This Was Going To Be a Waste of Time: Using Portfolio Construction To Support Reflection on Project-based Experiences

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Abstract

In this work, we sought to understand ways that students experienced a small-scale portfolio assignment provided to them as an opportunity to reflect on their experiences in a project-based class. This work was motivated by research in various instructional contexts showing that portfolio construction results in important learning outcomes. We wanted to see if such findings would extend to project-based learning situations in engineering. In addition, our research was motivated by the need to better understand specific portfolio assignments in terms of the effort required of students, the extent to which students value such assignments, and the ways in which students' overall experiences differ in terms of learning, effort, and value. To address these issues, we interviewed thirteen students who completed a portfolio assignment as a culminating activity for a project-based manufacturing class. We selected these students because their individual responses to a screening survey suggested that they had very different experiences with the portfolio assignment. We then conducted open-ended interviews with the students in order to better understand their experiences. In this paper, we show how the themes of *epistemically different, manageably effortful*, and *ultimately valuable* can be used to understand three ways of experiencing the assignment (as a significant experience, a muted experience, and a limited experience). This work provides practical information to educators interested in supporting reflection while also contributing to the scholarship on how portfolios support learning from experience.
Keywords: Portfolio, Project-based learning, Manufacturing, Preparedness

Introduction

In this paper, we explore the potential for portfolio construction to be used as an activity to enhance student learning from project-based experiences. In this work, we were motivated by theories of learning that emphasize the importance of experience and reflection

on experience (Dewey, 1916; Jarvis, 2004; Kolb, 1984; Mezirow, 1998; Kegan, 2000) as well as the acknowledged importance of reflection for problem-based learning (PBL). Savery (2006) highlights the importance of reflection for PBL: "a closing analysis of what has been learned from work with the problem and a discussion of what concepts and principles have been learned are essential" (p. 14). We were also motivated by open questions about how to effectively support such reflection. As such, our work complements other efforts to enhance PBL experiences (Hmelo-Silver & Barrows [2006] on facilitation; Jonassen & Hung [2008] and Hung [2006] on problem selection).

Portfolios can be understood as a collection of one's work that makes an argument about knowing or learning (Barrett, 2007). For example, a professional portfolio is typically understood to be an argument about one's preparedness to practice in a particular profession, while a learning portfolio would be an argument about what one has learned. While much attention to student portfolios in education has emphasized their value for assessment and has sought to address issues in this area (e.g., Scott & Plumb, 1999), it is the connection between portfolio construction, reflection, and learning that is of interest to our study.

Recent research sheds light on the ways in which portfolio construction supports learning. This research provides evidence that portfolio construction may enhance student performance on standardized achievement tests. For example, Bartoochi & Keshavarz (2002) found that high school students who constructed portfolios related to their foreign language study scored higher on standardized achievement tests than students who did not construct such portfolios. Of more interest here is the evidence provided by recent research about other types of contributions made by portfolio construction, contributions that deal with broader issues of learning and knowing. For example, using interviews with adult learners who had developed experiential learning portfolios, Brown (2002) identified the following benefits of portfolio construction: "(a) marked increase in the participants' self knowledge after portfolio development; (b) a greater recognition of the value of learning from work and from mentors; and (c) improved communication and organization skills and greater appreciation of the role of reflection in recognizing learning" (p. 234). Klenowski (2000) discovered through surveys and interviews that portfolio development helped preservice teachers integrate their learning, understand applications of their knowledge to teaching, and develop confidence as teachers and learners. Eliot and Turns (2009) used undergraduate engineering students' open-ended survey responses to characterize the many ways in which portfolio development activities contributed to professional identity development. Scholes et al. (2004) found that portfolio construction led some nursing students to build their own theories of practice.

The emerging body of research linking portfolio construction and learning has begun to document the profound types of knowing that can result from portfolio construction. However, the contextual features of these studies limit their generalizability, making it

difficult to determine the extent to which these results transfer to various PBL situations. For example, these studies differ in terms of the scope of the portfolios (e.g., the amount of information in the portfolios, the scale of the portfolio assignments) and in terms of the domain (e.g., portfolios are common in nursing and education but are less common in engineering). Therefore, research on how portfolios support learning in PBL situations with specific populations and specific portfolio implementations is needed.

The body of research linking portfolio construction and learning also provides other dimensions to consider when thinking about the potential for portfolio construction to support PBL. In particular, the studies suggest that it is important to characterize not only the benefits to learning provided by portfolio construction, but also to document *who* experiences the various learning benefits, what *effort* is required to experience those benefits, the *extent* to which the portfolio construction activity is valued, and the trajectory for these elements over *time*.

In terms of who experiences learning benefits, Brown (2002), after profiling dimensions of learning, observed that "not everyone experiences the same degree of learning" (p. 241). Cambridge (2008) also highlighted the issue of who learns with his finding that only 18 percent of active users of a Minnesota-based portfolio tool reported a substantial amount of learning as a result of their activity—a finding that raises questions about the amount of learning experienced by other participants. In terms of effort, Scholes et al. (2004) emphasized the kinds of effort associated with constructing portfolios for nursing certification in the UK, looking in particular at the significant challenges and complexities of matching experiences to specific portfolios requirements. Although not an identified theme in Klenowski's (2000) paper, student perceptions of the effort involved in the portfolio activities appear in several student quotes: for example, one participant refers to the portfolio activity as "harsh work" (p. 229). Finally, with regard to value, studies provide evidence that, while the work might be effortful, there is also evidence that participants ascribe value to the portfolio activities even though such value may be realized over time. For example, Brown (2002) observes that "the outcomes described by the participants are unexpected and welcomed results" (p. 241). Cambridge's (2008) entire analysis is focused on people who are voluntarily creating personal portfolios using a portfolio tool provided free to Minnesota citizens; such voluntary use suggests that the users are valuing some aspect of the portfolio activity.

Information on how portfolio assignments are experienced by students in terms of learning, effort, and value, including information on who benefits from portfolios, will be important, not just in terms of furthering research in this area, but also more immediately for educators seeking to implement a portfolio assignment. Such information will help educators have calibrated expectations about how a portfolio assignment might transpire in a PBL situation, as well as anticipate and respond to challenges.

We were guided by these ideas as we explored student experiences with a specific portfolio assignment as a culminating component of a required, project-based mechanical engineering course. In particular, we asked students to construct a portfolio representing an argument about the ways in which the experiences in this project-based course had prepared them for future mechanical engineering activity. In terms of structure, we asked each student to prepare a portfolio with three required components: a written statement about how the course had contributed to his or her preparedness to function as an engineer, a collection of three (or more) artifacts from the course that supported the claims made in his or her statement, and a written annotation for each artifact that explained how the artifact supported one of the claims. Students had access to a web-based portfolio construction tool provided by their university, and they used this tool to compile and submit their statements, artifacts, and annotations. Unlike some of the portfolio activities reported in the literature, our portfolio assignment represented a small-scale intervention (worth only 5% of their grade).

Our research questions reflect the ideas presented above. Specifically, we were interested in 1) how students perceived the kinds of knowing and learning that occur when creating a course-based portfolio, 2) how students perceived the effort required to create such a portfolio, 3) how students valued the act of creating such a portfolio, and 4) how the individual students' information along these dimensions vary and could be used to categorize the students' overall experiences. In the next section, we present a conceptual framework for addressing these questions.

Conceptual Framework

This section provides the theoretical foundations that we used to situate our research questions, guide the development of our data collection protocol, and provide sensitizing ideas for analyzing and interpreting the data. These foundations include issues related to knowing and learning, value, effort, and phenomenography.

Knowing and Learning: An Epistemic Dimension

Given that learning involves changes in knowing, it is relevant and important to examine the epistemic issue of the types of knowing that are affected during portfolio construction. The studies linking portfolio construction and learning suggest the relevance of not only the types of knowing often central to education (e.g., conceptual understanding and skill refinement), but also the types of knowing that relate to issues such as identification and identity, the integratedness of knowledge, and self-awareness.

Portfolio construction affords students the opportunity to emphasize and discuss specific concepts understood or skills refined, which can lead them to report improved understandings in such areas. At the same time, portfolio construction requires that

students decide what parts of their knowledge to focus on and, further, that students communicate their knowledge clearly. This process can help increase students' awareness of what they know and of how aspects of their knowing might be integrated. Such issues of self awareness and metacognition are considered important for self-directed learning, and integrated knowledge is generally considered a hallmark of expertise (Bransford, Brown, & Cocking1999).

Issues of identity and identification are part of a movement in education to think more broadly about education (Gee, 2001). In the context of portfolio activities that call upon students to make arguments about their preparedness for professional activity, it seems possible that engagement in such argumentation will lead some students to report changes in their sense of identification with their profession. Also, making arguments about the ways in which educational experiences contribute to one's preparation for future activity may lead to critical reflection of one's fundamental assumptions about the world (Mezirow, 1998). In the present study, these assumptions might include what it means to be an engineer, who gets to be an engineer, and what counts as being prepared for engineering.

Taking a broad perspective on knowing, such as suggested above, creates challenges for data collection because students have varied ideas about what counts as learning and what kinds of knowing are worthy of attention. The idea that students differ in terms of their beliefs about knowing is reflected in scholarship on intellectual development, such as work by Perry, Belenky, and Kitchner and King (see chapters by each author in the volume by Hofer & Pintrich, 2002). Students may also differ in their ideas about what counts as knowledge and learning as a result of socialization within disciplines as well as institutions. Individual differences between students on issues such as those described above suggest the importance of asking questions using straightforward language that makes it possible for students to have the greatest chance of sharing relevant information.

In our study, we asked students questions related to learning, but we used everyday language (e.g., rather than "what did you learn," we asked "what did you take away"). In addition, we also asked students questions about dimensions of the experiences that are linked to learning. For example, given the significance of time on task to learning (Bransford, Brown, and Cocking, 1999) and the role of dissonance and disjuncture in learning (Jarvis, 2004), we asked students about how they spent their time and about difficulties that they encountered.

Expectancy-Value Theory: The Value and Effort Dimensions

The ways in which students value an activity and the effort associated with that activity are instructionally significant—they contribute to the sustainability of an instructional activity. For example, an activity that results in significant learning yet is very effortful for students and is not valued by them may ultimately be difficult to sustain. In our study,

we situate these concepts in expectancy-value theories of motivation. Expectancy-value theories posit that learners will persist in, perform better on, and even choose to engage in, activities they consider valuable and achievable (Eccles & Wigfield, 2002; Svinicki, 2004).

Research into student motivation suggests that students' expectations of their ability to succeed (i.e., their sense of self-efficacy) play a central role in motivation. However, there is no clear consensus in this research on the specific dimensions of student expectations that are of primary importance across all tasks and all student populations. For example, Eccles and Wigfield (2002) emphasized "individuals' beliefs about how well they will do on an upcoming task, either in the immediate or longer-term future" (p. 119). A potential complication for efficacy judgments is distinguishing a judgment of whether one can do a task in the abstract as opposed to in one's current circumstances (e.g., I can do it, but not right now). Other theorists have ways of discussing efficacy that capture such situated ideas. For example, one model focuses on four types of expectancies: "situation outcome (subjective probability of attaining an outcome in a specific situation without acting), action-outcome (subjective probability of attaining an outcome by one's actions), action-by-situation outcome (subjective probability that situational factors facilitate or impede one's action-outcome expectancy), and outcome-consequence (subjective probability of an outcome to be associated with a specific consequence)" (Eccles & Wigfield, 2002, p. 121).

When students have limited understanding of a task and what exactly is entailed in the task (e.g., what difficulties exist and whether one has the capacity to overcome those difficulties), their judgments about their ability to succeed may be compromised. This observation suggests that explorations related to expectancy consider students' initial understandings of the types of effort a task will entail as well as how these understandings may change over time.

Research into student motivation also emphasizes the importance of considering what students value in relation to learning activities. For example, Eccles and Wigfield (2002) have posited the importance of attainment value, intrinsic value, utility value, and cost. Attainment value refers to the "value of the personal importance of doing well on the task" and is linked to "the relevance of engaging in a task for confirming or disconfirming salient aspects of one's self schema" (Eccles & Wigfield, 2002, p. 119). Intrinsic value refers to the "enjoyment the individual gets from performing the activity or the subjective interest the individual has in the subject" (p. 120). Utility value refers to "how well a task relates to current and future goals, such as career goals" (p. 120). Finally, cost has to do with negative aspects of a task, such as performance anxiety and fear of failure.

Portfolio construction has great potential for being perceived as valuable along one or more of these value dimensions. The dimensions are interesting when considered relative to a task such as constructing a portfolio that is centered on the self. In such a case, it seems possible for the types of value to start to overlap. For example, attainment value

and utility value are highly linked when the task is to explain the relevance of current learning for future career activities. At the same time, the cost of a task, linked above to performance anxiety and fear of failure, could be potentially significant in the case of a portfolio construction activity where the activity is centered on oneself.

While some of the emphasis in expectancy-value theory has been on seeing the contribution of the two dimensions (value and effort) to issues of choice, persistence, and performance, other research has shown how these dimensions affect each other (Eccles & Wigfield, 2002). Further, as discussed above, there is reason to believe that unfamiliarity with a task will affect initial efficacy and value judgments—judgments that would get updated as the task becomes better understood. In the context of the portfolio activity, if a student is unfamiliar with the portfolio activity, the initial judgments of value and efficacy would be poorly calibrated and could be expected to change. Such change over time is what Brown (2002) seems to have hinted at with her comments about the portfolio experience being "unexpected and welcome" for the students (p. 241).

Variation across Students

Given observations that students experience portfolio activities in different ways, a phenomenographic approach represents an appropriate way to proceed (Richardson, 1999). In the phenomenographic tradition, the emphasis is on identifying various ways that individuals experience a phenomenon (in our case, different ways of experiencing the portfolio assignment). In phenomenographic work, the researcher identifies a set of participants who are likely to have had different experiences with the phenomena of interest and then uses interviews with participants to understand their experience with the phenomena. Subsequent analysis of the interviews seeks to identify a small set of categories representing the patterns in the experiences.

This Study

We interviewed thirteen students with the aim of describing commonalities and variations in their experiences when completing a required portfolio assignment at the end of a college course that was structured around project-based learning. These thirteen students were purposefully sampled from the thirty-five students enrolled in this required upper-level engineering course.

Context and Procedure

We conducted our study in an upper-level undergraduate Mechanical Engineering class (ME355: Introduction to Manufacturing Processes) taught at a major research university during the winter of 2006. Students participated in a term-long project, designing and manufacturing a working Stirling engine. To support the various course goals (e.g., system

integration, tolerances, communication), each student team designed and manufactured only one component of the Stirling engine. At the end of the term, the teams assembled these components into a working engine. Students spent a significant portion of their class time in the manufacturing lab, learning to use the equipment and manufacturing the engine's components. Lectures supported the project requirements and provided relevant theory about manufacturing (e.g., the importance and structure of process plans, issues related to tolerances).

The course syllabus indicated that each student would be required to submit a portfolio at the end of the eleven-week term. During the third week of the term, the students received an instruction sheet for the portfolio assignment (see Appendix A). During the eighth week of the term, a member of the research team visited the class and led a 90-minute workshop that explained the assignment's requirements and demonstrated an electronic portfolio tool provided by the university. During this workshop, students engaged in small group brainstorming sessions that helped them identify potential themes for their portfolio's professional statements and select potential artifacts to include. The students were told that the portfolios would be graded only on completeness (i.e., whether the portfolio contained all of the required components), quality of the writing, and whether or not the portfolio made sense as a whole. Students were given full credit as long as their portfolio satisfied each of these criteria, and most students received full credit. Figure 1 shows the professional statement page (left side of the figure) and one annotated artifact page (right side of the figure) from a typical four-page portfolio.

Figure 1. Two pages from a portfolio completed by a study participant.
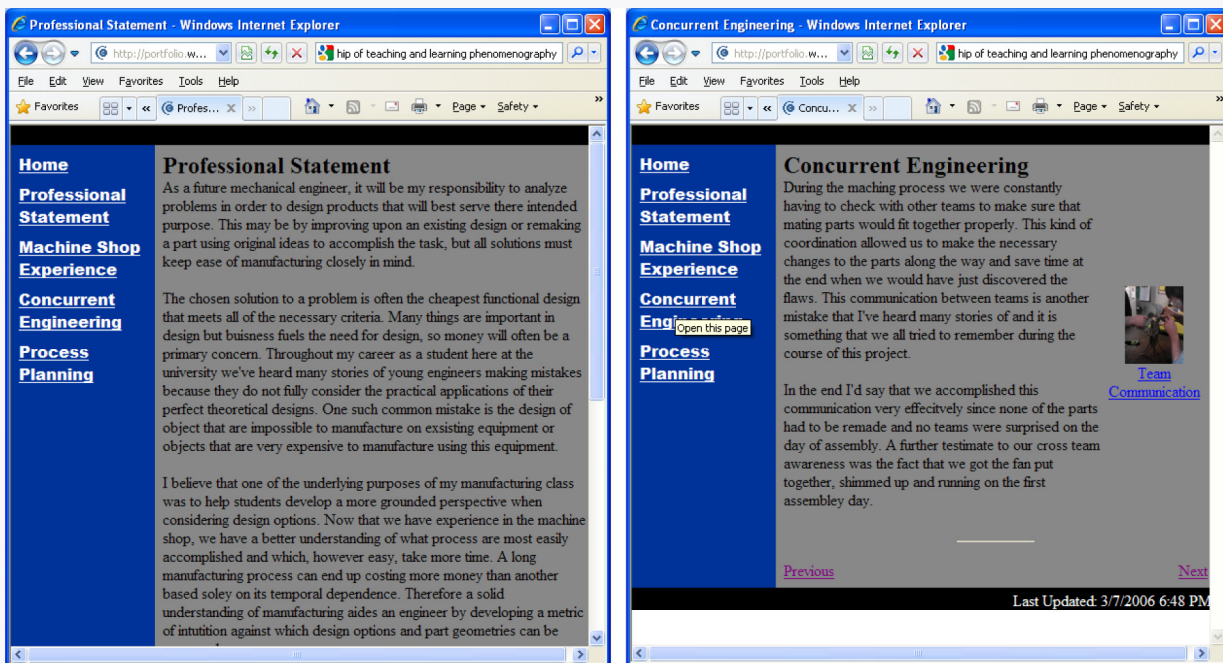
Thirty-five students who were in their junior or senior year completed the portfolio assignment. After submitting their portfolios online, students were directed to a screening survey. This survey asked students for their level of agreement or disagreement with various statements concerning their impressions of the impact of the portfolio construction activity on their understanding of mechanical engineering, their educational trajectories, and the relationships between course topics. Survey results were analyzed to determine trends of variability in the students' answers. Thirteen students were selected for interviews based on their responses across the survey questions—we selected students who agreed with most statements, who disagreed with most statements, who were neutral for most statements, and also students who had quite disparate reactions across the statements.

Data Collection

The open-ended interviews were conducted approximately one to two months after the students received their final grades for the class. The interviewer began by asking the students how they had decided to go into their engineering discipline, whether or not they had prior work experience, and if they had made portfolios for other classes. Next, the interviewer asked several "grand tour" questions (Spradley 1979), eliciting information on how students had built their portfolios, their feelings toward creating a portfolio and how those feelings changed throughout the course, and their perceptions of the impacts of making a portfolio. The interviewer then turned to more general questions about the students' college study (Spradley, 1979) and their perceptions of their learning style and writing ability. Audio recordings were made of the interviews.

In order to reduce potential bias caused by the interviewing context, a research associate who was unaffiliated with the course, and who was not a member of the Mechanical Engineering Department, conducted all thirteen interviews. It is difficult to imagine that the students perceived the interviewer as someone they needed to please. In fact, the students consistently shared both positive and negative experiences.

We have reason to believe that the students' accounts were genuine and provided in good faith. The students spoke with emotion, they often worked to articulate their stories, they hesitated and restated what they were trying to say, and they often used general words like "stuff" until they narrowed down to more exacting terms. Additionally, they provided many specific, concrete examples, and they created imaginative metaphors that attempted to capture their experiences.

Data Analysis

We analyzed the interviews in three stages. For the first stage, we characterized the students' experiences in terms of three dimensions: knowing, effort, and value. Regarding the epistemic dimension (i.e., knowing), we were interested in understanding the students' relationship with their knowledge while constructing their portfolios. In terms of effort,

we were interested in better understanding the time and difficulties that were involved in portfolio construction. Finally, in terms of value, we were interested in the extent to which students valued the portfolio construction activity. During this first stage, every turn-taking event in the interviews was independently coded by two of the researchers. Codes were generated inductively, and all coding disagreements were negotiated until consensus was reached.

In the second stage of analysis, we looked across the results for each dimension and sought to identify a dominant theme to capture the results of each dimension. In particular, we looked to identify what was significant to students about the kinds of knowing involved in portfolio construction, the kinds of effort involved in portfolio construction, and the ways in which they valued portfolio construction.

The third stage of analysis involved the development of a classification scheme for grouping the students' overall experiences, based on the dominant theme identified during the second stage. Like the first stage, both the second and third stages of analysis involved resolving all disagreements until consensus was reached.

For transparency, we created a matrix representation of our results (after Miles and Huberman, 1994). This matrix (see table 1) shows results from all three stages of the analysis. Note that, although a "Y" in the table indicates that a student mentioned a particular epistemic dimension at least once, an absence of a "Y" does not necessarily mean that the student never experienced or thought about the dimension, but only that the interview transcript showed no positive evidence confirming that.

Results

The students' experiences can be understood in relation to the themes of *epistemically different*, *manageably effortful*, and *ultimately valuable*. Epistemically different captures the comments made by participants about the ways in which the dominant types of knowing involved in portfolio construction—externalized, integrated, and subjective— are different than the types of knowing involved in what many participants referred to as "normal" school. Manageably effortful captures the idea that, although the assignment was found to be effortful, no student found the effort to be unmanageable. When asked in the interview about difficulties, students reported difficulties in understanding the assignment, choosing the topic and artifacts, and writing. Ultimately valuable captures the idea that, while many participants were ultimately able to ascribe value to the assignment, their final sense of value represented a change from their initial perception.

While all of the students' experiences can be understood in relation to these themes, the students' experiences were far from uniform. Table 1 provides information on the experiences of each of the participants in relation to each of the themes. To character- ize the range of student experiences with the portfolio construction activity, we defined

Table 1. Summary of results with participants grouped by their overall experience with the portfolio assignment. Grey squares indicate that the participant did not provide information on the dimension of inquiry. The absence of information in the interview data does not necessarily indicate that the participant did not experience the dimension.

	Significant Experiences (1=Soren, 2=Sebastian, 3=Sam, 4=Scott, 5=Shane)					Muted Experiences (1 = Max, 2 Mercer, 3 = Miles, 4 = Mitchell, 5 = Monroe)					Limited Experiences (1=Leanne, 2=Laura, 3=Louis)		
	1	2	3	4	5	1	2	3	4	5	1	2	3
SURPRISINGLY VALUABLE (L = Low, N = Neutral, H = High. Y = Participant provided at least one example. A dash indicates interviewer failed to ask question or participants' failed to provide a clear response.)													
Initial Value	L	L	L	L	L	N	L	L	N	*easy*	L	L	L
Final Value	H	H	H	H	H	H	N	H	N	-	H	N	H
Imagined: use for interview	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	
Imagined: additional uses	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
EPISTEMICALLY DIFFERENT (Y = Participant provided at least one example.)													
Making an argument	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Metacognitive awareness	Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y
Integrated	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Subjective	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Different from school	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	
Different from new learning		Y			Y	Y	Y		Y		Y	Y	
Different from what wanted	Y	Y	Y			Y	Y	Y	Y		Y		Y
MANAGEABLE EFFORTFUL (H = Hard, NH = Not hard. A = Artifacts, W = Writing. Y = Participant provided at least one example. A dash indicates interviewer failed to ask question or participants' failed to provide a clear response.)													
Perceived time spent (hrs)	8	2	-	-	4	6	8-10	4	6-8	4-6	6	8-10	6.5
Hard to find/choose artifacts	H	H	H	H	H	H	NH	H	NH	NH	H	H	H
Hard to get ideas into words	NH	NH	-	H	H	H	NH	-	NH	NH	NH	-	NH
Most time spent on	A	-	-	W	W	W	W	-	W	-	A	W	-
Was easier than expected		Y			Y			Y					Y
Effort was manageable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
CONTRIBUTING FACTORS (B = Likes building things, W = Prior related work experience, A = Social advice, L = Linked interest. NEG = Negative, POS = Positive, *easy* = Thought course was "easy." H = High level of writing ability, M = Mid level of writing ability, L = Low level of writing ability. Job offer = Recently received a job/internship offer. Mil = Prior military experience. Job = Prior professional experience. A dash indicates interviewer failed to ask question or participants' failed to provide a clear response.)													
Reason to major in ME	B	B	B	W	B	B	B,W	B	L	B	-	A	W
Attitude toward course	NEG	NEG	-	-	-	-	-	*easy*	NEG	POS	*easy*	NEG	POS
Portfolio experience	N	N	Y	N	-	N	N	N	N	Y	Y	N	N
Writing ability	H	H	M	M	H	L	L	M	M	M	H	L	L
Workshop perception	-	POS	-	-	POS	POS	POS	-	-	POS	NEG	POS	POS
Prior professional experience	job offer	job offer		mil, job			job offer	job offer	mil	job		job	mil

and named three clusters: the five students who found the assignment to be a significant experience, the five students who had a more muted experience, and the three students whose experience was characterized by a particular limitation. Below, we use the opening discussion of the significant experience cluster to unpack the three themes, and then we discuss the experiences of the other two clusters relative to the significant experience cluster. Names of students in the significant experience cluster are coded with pseudonyms that begin with the letter S. Pseudonyms begin with M for the students in the muted experience cluster, and with L for the limited experience cluster (see table 1).

Significant Experience

The students in the significant experience cluster reported uniformly that they strongly valued the experience of making a portfolio, and, as seen in table 1, all of them reported a significant change in the value ascribed, from before the exercise to after. Scott is illustrative of this change. His first impression of the portfolio was "oh, my god, here's another project I have to get done, but I think it's—I think it's a useful—definitely a useful idea and useful project, and I think it's probably a good thing for engineers to have." He also reported how the portfolio helped improve his opinion of the course once the portfolio helped him see connections between the course materials and their practical application: "I think the portfolio made me think the classes were better because of the laboratory and realizing what I could take out of that class and how they apply when I leave . . . school." (Scott). Quotes like this were common among the students in the significant experience cluster. Further, the data seem to suggest a strong interplay between the types of knowing associated with the assignment (externalized, integrated, and subjective knowing), the reasonableness of the effort, and the initial reactions to the assignment (even the strong negative ones).

Epistemically different: Externalized knowing

Getting knowledge out of the head and into an externalized form was a significant aspect of the portfolio activity, as evidenced by the quote below. This externalization involved students telling others what they knew but also becoming more aware of their own knowledge.

"[The goal of the portfolio activity is] to show the student that you have learned something and that you do have something to show for it. Because for most classes, everything you learn you keep in here. Yeah, in your head, and there's no way you can show that unless they give you a problem and you solve it. But this class shows you that you can actually take pictures and have something concrete and specific to show here, this is why I like." (Sebastian)

Unsurprisingly, given the nature of the portfolio task, participants spoke about the kinds of knowledge involved in making an argument to others, in particular an argument

about their own knowledge that uses evidence from their course experience and is targeted for an audience beyond the local context. All thirteen students made at least one substantial comment in this area although there was significant variation in the extent to which they elaborated on this issue.

The most prevalent theme in this area included issues related to the complexities of using artifacts to show and prove one's knowledge in a portfolio. For example, one student mused on the difficulties of showing evidence of theoretical knowledge: "And then I did think about theory, but that was beyond . . . how am I going to show that I know," (Sebastian). Three students commented on the difficulty of showing evidence of teamwork skills: "a lot of stuff in the class was like learning teamwork and stuff and there wasn't really the best way to put that in like an artifact and talk about it" (Sam); "like teamwork, okay, well, what can I say? How do you represent that, you know?" (Scott); and "to pick an artifact for teamwork, something can't really show, yeah, that's a picture" (Shane). Students mused over the strengths of various artifacts: "Some of them weren't as strong as another" (Soren); "I am not so sure how valuable midterms and tests are, um, relating to what you really learn" (Soren); and "I don't think an employer would care that you got seven out of seven on the homework" (Sebastian).

A little less self-evident, but of interest, were the number of allusions to issues of gaining and maintaining awareness of one's own knowledge as a result of working on the portfolio task. Such self-awareness, often termed metacognitive awareness, was mentioned in some form by all of the participants. Specifically, participants talked of gaining awareness of aspects of their knowledge, but also of the more mundane issues of remembering and preventing future forgetting.

All participants in the significant experience cluster made comments about gaining awareness as a result of portfolio activities. For example, Shane said that "having to put it down in words helped me like—like crystallize in my mind like having an actual almost feeling of what I learned or what I gained in class"; and Soren mentioned that you can "actually see . . . the maturity level—everything—everything is kind of getting better." Participants in the significant cluster mentioned gaining awareness of "what was learned" (Shane); "the maturity level" (Scott); "what I've done" (Soren); and "what I have now that I didn't have before" (Scott).

While gaining awareness was a key aspect of their experiences, students also talked about remembering and preventing future forgetting. For example, Shane described the assignment as "having to look back at the last three months of scramble, big blur of assignments and exams and stuff, and having to remember what you did and why you did it." Sebastian considered this remembering to be quite significant: "I mean if it wasn't for the portfolio, I would have completely forgotten about it." Sebastian's comment also introduces a particularly interesting role that the students saw for the portfolio, that of helping them maintain or recover the awareness of what they know. Soren explained it

as "the portfolio, it's easier to remember what you've done . . . it's almost like a thought . . . records your thought process . . . then you can do what you've done before again" and "it prevents you from forgetting what you've done." Sebastian actually experienced this function of the portfolio during the interview: "Oh, I did do a process plan, I didn't remember that. Oh, yeah, see, I didn't remember anymore."

These issues of argumentation and metacognitive knowledge both involved externalization of knowledge. The externalization in the former case was for an external audience, and in the latter case, for the student him or herself. Some students found these two to be related. For example, Sebastian commented on the interrelationship this way: "when I did the portfolio, sat down and tried to convince others of what I don't even believe myself, it made me realize that the class is useful and that I do need to learn it."

Several of these types of comments underscored the significance of the externalized knowing associated with the portfolio construction activity. In particular, the participants spoke of normal school activity as being about knowledge that resides in the head rather than being documented (Sebastian), about artifacts as a means to an end rather than something to be gathered (Sam), about not having a central location (Scott), and about forgetting (Soren).

Epistemically different: Integrated knowing

The portfolio assignment asked the students to make claims about their preparedness for engineering and to provide evidence using three artifacts from their class. As their comments illustrated, the thinking that went into their choices and their explanations helped them integrate knowledge from a variety of areas.

For example, most of the students in the significant experience cluster (Soren, Sam, Scott, Shane) discussed their portfolio as an opportunity to see larger connections across the entire class or to look at the class as a whole. Shane said that the portfolio brought the "whole concept of the class . . . to the forefront." One student (Soren) described the portfolio as not just giving him a "broader view of what . . . the course was offering," but as an exercise that helped him understand "the reasons why they structure a course in a certain way."

The portfolio assignment asked students to connect their ideas from the class to their overall engineering discipline. Most students in the significant cluster (Soren, Sebastian, Sam, Shane) indicated that they thought about these connections and why some of the topics they learned were important in the larger context of mechanical engineering, although they were not specific during their interview about how they saw these connections or what connections they made. For example, Sam commented that the portfolio made him think about how the class "put everything in the context of mechanical engineering."

Although the portfolio assignment was course-based rather than curriculum-based, all of the significant experience students nonetheless reported that they explicitly thought about connection with material from other classes. Sebastian noted how "the stress theory that [he] had learned in ME354 was really related to ME355." Sam said that his "mind kept bouncing to . . . other courses" as he made his portfolio. Shane talked about how it made him think of "other projects . . . filtered through the lens of ME355." Thus, it is important to note that even though the assignment asked the students to create a course-based portfolio, several students found opportunities to draw connections between concepts across their curricula.

All students in the significant experience cluster also reported how they thought about connections between their current work in ME355, their past work experiences, and their future career goals. Students came into the course with different levels of work experience, and a few talked about how the portfolio exercise made them remember specific prior experiences and how those experiences connected to topics they wrote about in their course-based portfolio. All students in the significant experience cluster discussed the ways in which they thought about how their artifacts—their evidence of learning in ME355—related to their future career goals. For Sam, the portfolio provided him a chance to see that he was "a lot closer than he thought" to becoming a professional engineer.

A key opportunity of this integration process was the chance to think about what was "important," and all participants described the contents of their portfolio as emphasizing the most important topics in the class or the most important things that the student had accomplished in class. For example, Sam talked about how the portfolio helped him "understand the importance of particular material." Yet, students recognized the incomplete picture that their portfolios provided. The portfolio required students to make choices about what to highlight, and some students mentioned additional topics from the class that they believed to be important but, due to difficulties in representing the topic with an artifact or merely because they were asked to limit their selections, they chose to leave the topic out. One student (Sebastian) stated that the portfolio helped him see the importance of the class: he said that he "hated the class," that he "didn't want to learn [the material]," and that he "didn't see how [the class] was related to anything." Yet, when he made his portfolio and "tried to convince other people what [he] didn't even believe [himself], it made [him] realize that the class is useful." In his case, it appears that the act of selecting three topics from the class and describing their importance partially mitigated a negative experience with the class.

In contrasting the integrated knowing of portfolio construction with normal school, Sam became quite metaphorical and spoke of normal school as being about information that stays inside of bubbles.

Epistemically different: Subjective knowing

The types of thinking and knowing involved in the portfolio activity went beyond types with objective qualities, into a more subjective personal realm. Sebastian introduced the idea of subjectivity: "The main things you learned during the class, um it's pretty subjective in the sense that it's your opinion what you think that you learn and that's more important."

Subjective knowing complements the other forms of knowing involved in the portfolio construction process and can be highlighted in contrast to those forms. While externalized knowing involves good evidence (for an external audience) or good calibration (for oneself), and integrated knowing involves breadth and alignment, subjective knowing involves being true to self. Subjective knowing was frequently revealed through the use of possessive statements (my) and reflexive statements (to me).

All participants in the significant experience cluster made comments related to the subjective knowing theme. These participants spoke of working with, and articulating, personal understandings of engineering and of the importance of such personal interpretations—"what engineering means to me" (Sam), "my viewpoint of engineering and stuff" (Sam), and "what everything means to you in ME and you should know what everything means to you in ME" (Sam). The participants spoke of thinking about their feelings concerning the subject matter—"write what you felt about the things you've done" (Soren), and one student spoke of feeling good when he started to really see what he learned—"It makes you feel really like good about everything I learned" (Sam). Students spoke of thinking about their interests, "what I am starting to get a passion for" (Scott), and about their aspirations, "I want to be able to make something out of my career" (Soren), and "your whole goal of being a mechanical engineer professionally" (Shane).

One particular element of subjectivity that stood out in a few participants' accounts was their subjective experience with the class and they way that the portfolio construction activity helped them think about this experience. In particular, four of the five students who reported a notably positive experience with the portfolio assignment mentioned how the assignment improved their motivation in the course or helped them have a more positive attitude toward a course that they did not like as much as their other courses.

Sebastian said that "[the portfolio] helped me not be so biased against the course" and that "it made me realize that whether I like it or not, manufacturing is a key step, because, you know, I can design the best engine in the world, but if nobody can make it at an affordable price, then it's useless. So [the portfolio] did help. It helped a lot. . . . Those two hours showed me to care more about the class, so it's definitely worth it." Scott expressed a similar feeling, saying, "I think the portfolio made me think the classes were better because of the laboratory and realizing what I could take out of that class and how they apply when I leave, when I leave school."

Sam discussed a larger problem he had been having with motivation. He said, "[the portfolio] kind of like motivated me more to . . . understand the stuff I was learning and to appreciate the stuff I was learning. . . . It put everything into a view like – what I'm doing now is actually stuff . . . that I'm going to need as an engineer, that I'm going to be using. And so it just motivated me to like—you know, to keep this stuff in mind . . . versus before I was just like sometimes I felt like, oh, as long as I go out and get my . . . BSME, then I'll be fine, and then I can learn all I need to know, but it's like this is actually stuff that I'm going to need to know in engineering . . . and so it kind of just motivated me. . . . Yeah, [it] made me feel like I wanted to actually do better in the course than I was motivated to do before . . . this kind of made me think, you know, if I don't learn it now, I'm going to have to do a lot of re-learning later . . . ."

Soren described his experience like this: "If it was a course you didn't like, it's something you suffer through and you go, oh, I don't want to do this homework anymore, but when it's done, it's like a relief, and you think about what you have just accomplished, and you get this whole different view of it, and I think the portfolio kind of summarizes that, the difference between . . . thinking about the class during the class and thinking about it after you get out."

Participants in the significant experience cluster made many comments that concerned the objectivity and depersonalization of "normal school." Participants spoke of normal school as being about not thinking about "what it all is going to mean to you in the long run" (Sam), about learning yet "not knowing what it means" (Sam), about emphasizing the "stuff you just have to learn" (Sam), about "one more homework" (Sebastian), about "crunching numbers" (Sebastian), about "going through the motions" (Sam), and about "thinking about some things randomly" (Scott). Participants also highlighted their observation that school is normally about grades.

Manageably effortful

The participants in the significant experience cluster reported that the portfolio assignment was effortful, yet these students did not report having concerns about their ability to successfully complete the assignment, and no student reported encountering obstacles that were insurmountable. In terms of effort, the students reported varied amounts of time to complete the assignment, as well as variation in when they started the assignment. Several put it off until the week before it was due. Multiple members in this cluster reported that they did not initially understand the assignment (e.g., Sebastian said he had "no clue"). Students had mixed feelings about whether or not the writing required by in the assignment was difficult.

A striking feature of this cluster was that all members reported difficulties in choosing topics and artifacts. During the interviews, students did not consistently differentiate between the acts of choosing three topics that would comprise the focus of their

portfolio versus choosing artifacts that illustrate the chosen topics. For this reason, it was sometimes difficult to tease out in the interviews where the difficulties lay for them. Difficulties included finding artifacts that were meaningful to them and finding artifacts that concretely illustrated what they had learned and accomplished. Some students had difficulty choosing three artifacts from many possible examples. Others felt that they had very little to show and needed to select the best three artifacts that they had. Soren stated that the act of selecting artifacts took a longer period of time than writing the annotations and professional statement.

Ultimately valuable

Ultimately, each of the participants in the significant experience cluster reported that the assignment had value for them. For example, students commented that "[the portfolio assignment] should probably be required . . . definitely worth doing" (Soren), "I think the portfolio is really interesting" (Sebastian), "It is really helpful" (Sebastian), "I got something out of it" (Sebastian), "I thought it worthwhile" (Sam), "this is a good assignment" (Sam), "it was a pretty good idea to do the portfolio" (Scott), "It is a useful project" (Scott), and "It was just actually like a valuable assignment to do" (Shane)

A striking feature of this cluster was the distinctly negative initial impressions of the portfolio assignment. For example, Sebastian stated that his initial reaction to the port-folio assignment was, "Well, this is going to be a pain," and "I can't believe they are going to make us do it. It's a waste of time. I don't want to do it." Similarly, Soren said that his first impression was "oh, it's another thing we have to do, because . . . we're all busy," that he "wasn't all that excited about it," and that "it was hard to understand why we were doing it at first, because . . . it was something extra we had to do." Given the distinctly negative initial impressions, the ultimate discovery of the assignment having value represents a significant change.

Muted Experiences

An additional five students reported experiences that shared qualities with the student experiences reported by the significant experience cluster, yet the students in this cluster were distinctly less effusive about their experiences.

Epistemically different: Externalized knowing

While participants in the muted experience cluster did emphasize the complexities of choosing artifacts, for example, finding things where you can "see what you are talking about with it" (Mercer) and finding "something unique" (Mercer), they were more likely to emphasize the value of being able to show one's knowledge and appreciation of the portfolio tool as a useful tool for providing evidence of knowledge. Mercer spoke of hav-ing a friend who got hired because he could provide evidence of his knowledge in an

interview. Miles also spoke of recognizing the value of being able to provide evidence, although his sense of value came after the portfolio assignment was completed (discussed more in the section on value below). Max made the most specific comments about the portfolio as a useful tool for demonstrating knowledge: "I think what I really got from the portfolio more is how to do the portfolio and how that might help later on as opposed to getting a deeper understanding from the course work . . . But, yeah, I think it's just a good way to present information and it's a good skill to have . . . it would be something good to give to an employer. I think they'd really like to see exactly what you've done, kind of how you went about doing that, what you've learned."

Comments about gaining awareness also came up in the muted experience cluster, but to a lesser degree. For example, Mercer said that "thinking about that stuff and being able to write it down helps you . . . clarify it in your head even." Participants in this cluster mentioned gaining awareness of "the experiences you had" (Mercer), "what I took out of the class" (Monroe), and "what you like to do" (Max). Participants in this cluster also commented on the remembering function (Miles defined the assignment in terms of remembering—"remembering things that you learned through the course") and the preventing forgetting function (Monroe referred to this function: "It's something that will stick with you").

The participants in the muted experience cluster had less to say than the participants in the significant experience cluster about the lack of emphasis on externalized knowing in normal school. Nevertheless, they did talk about school in terms of forgetting (Monroe) and moving on (Monroe).

Epistemically different: Integrated knowing

Like the students in the significant experience cluster, most of the students in the muted experience cluster (Mercer, Miles, Mitchell, Monroe) spoke about their portfolios as an opportunity to see larger connections across the entire class or to look at the class as a whole. Monroe spoke about the portfolio activity as an exercise that allowed him "to reflect upon all the work as a whole, as opposed to picking out key topics." Mercer and Mitchell talked about how the portfolios allowed them to organize the ideas they encountered in the class. Similarly, most students in this cluster (Mercer, Miles, Mitchell, Monroe), like the students in the significant experience cluster, mentioned that they thought about connections between the class and the overall engineering discipline and why some of the topics they learned were important in the larger context of mechanical engineering. At the same time, the students in this cluster were typically not specific during their interviews about the ways in which they saw these connections or what connections they made. For example, Mitchell commented that the portfolio made him think about how the class "related to the engineering discipline in general" (Mitchell).

Three participants in the muted experience cluster spoke of thinking about what was important when constructing their portfolios (Max, Mercer, Monroe). One of these students stated that the portfolio "actually kind of forces you to think what you learned during a class and why that class is or is not important" (Monroe). Participants in this cluster also made comments about the ways in which the integrated type of knowing associated with portfolio construction is different than "normal school." For example, Mitchell spoke of never really having anything that related coursework to doing engineering, and that the portfolio assignment helped him think "a little bit broader than normal classroom work, where instead of just doing an assignment without thinking about what—how it applies, you know, normally just trying to get an assignment done and a grade for it, and this is trying to get them to think on a little broader scale."

Unlike the significant experience cluster, where all of the participants reported thinking about connections to other classes, only two students in the muted experience cluster had such comments (Miles, Mitchell). Miles chose to talk about failure analysis in his portfolio because it was "based off of a class [he] had before." In contrast, at least one student in this cluster did not feel empowered to include those connections given the assignment's requirements—Mercer wanted to connect ideas discussed in his portfolio with specific ideas from other classes, but he did not feel that the requirements of the assignment allowed him to do this. Rather, students focused on how the portfolio activity would be improved if connecting to other experiences were a stated part of the activity. For example, Mercer and Mitchell stated that the portfolio assignment had the potential for greater benefit if it drew upon multiple classes or was incrementally expanded each academic quarter. Mercer specifically wanted to "bring in different projects that [he'd] worked on." Mitchell said that "[he] just like[d] the idea of connecting different classes to other classes and to the discipline in general." While one participant in the significant experience cluster commented on such extensions, it was not a dominant theme for that cluster: Soren saw the potential for "a comprehensive collection of everything inside of mechanical engineering" and that, when "arranging [the artifacts], it will be easier to see how things fit from other classes."

Also unlike the participants in the significant experience cluster, where everyone spoke of connections between class, past work experience, and future goals, only one participant in this cluster spoke of this. Mitchell, who had set himself apart from some of his classmates by describing himself as a "renewable energy major," spoke about how the portfolio made him look for connections between topics in the manufacturing course and his intended career plans.

Epistemically different: Subjective knowing

Like the participants in the significant experience cluster, all participants in this cluster made comments related to the subjective knowing theme. For example, Max described

the assignment as "kind of an honest tell us how you feel"; Monroe spoke about getting to think about what was "fun"; Mercer got to think about what "fires me up;" Miles got to think about "what I liked the most"; and Mitchell got to think about issues of identity: "people like me who are majoring in energy." Unlike the participants in the significant experience cluster, no participant in this cluster reported a subjective experience with the class that was particularly related to their experience with the portfolio assignment. While the participants in this cluster also made comments that contrasted normal school with the subjective knowing of the portfolio, these statements were less emphatic than those of students in the significant experience cluster. For example, students in this cluster talked about normal school as involving "no form of reflection" (Monroe) and as always having "something that you've got to work hard on and get homework done" (Miles).

Manageably effortful

Overall, the participants in this cluster, like those in the significant experience cluster, reported a similar effort profile: initial expectations of success; varied, but reasonable, amounts of time required for completing the assignment; and difficulties in completing the assignment that were not insurmountable.

Overall, however, the comments of the participants in the muted experience cluster indicate a different level of challenge and engagement than comments from those in the significant experience cluster. Strikingly, multiple participants in the muted experience cluster reported not finding the selection of artifacts to be difficult. For example, Monroe had spent time thinking about what to include in his portfolio before sitting down to write and assemble it. Mitchell indicated that he chose the first three artifacts he could find. Another student in this cluster, Max, provided an overall description suggesting limited challenge: "I pretty much started thinking about [the portfolio] when I heard about the assignment . . . and then if I had a spot to fill, I just kind of waited out to see what there was to put in there." By the time Max sat down to write and assemble his portfolio, "[he] had a pretty good idea of . . . what [he] wanted to do."

It is interesting that the level of engagement of students in this cluster may have been associated with their initial impressions of the portfolio assignment. For example, three of the students in this cluster did not think the assignment was going to be particularly difficult or overly time consuming. Max stated, "I didn't have too strong an opinion on it when I first heard about it. . . . I didn't think it was going to be that hard, really," and Monroe said, "I thought it was going to be pretty simple." Mitchell stated that "It sounds like a couple of hours of work that I have to do" [*laughter*]. Further, for at least one student, getting it done quickly was a goal. Mitchell spoke about how his "number one criteria" when creating his portfolio was to "get it done as quickly as possible [by] find[ing] the three easiest [artifacts] to do."

Ultimately valuable

Ultimately, no participant in the muted experience cluster ended with a negative impression of the assignment. However, in general, the participants in this cluster neither started with as negative of initial impressions of the portfolio activity as the students in the significant experience cluster nor ended with strongly positive impressions. Additionally, the students in the muted cluster were more likely to report unchanged perceptions about the assignment or about feeling unable to assess the value of the assignment at that point in their academic career.

For example, Mitchell appeared to have approached the portfolio assignment with a neutral value and remained neutral after completing the assignment. As stated above, Mitchell's initial impression of the assignment was that "It sounds like a couple of hours of work that I have to do." When prompted in the interview to discuss if the portfolio had an effect on him and his learning, he said, "I think there's some value to [the portfolio assignment]" and "I think it slightly adds to the value of the class, but not significant." Mitchell experienced the activity as an opportunity to engage in the natural (to him) and not overly difficult (to him) process of connecting.

Mercer was more direct about what kept him from appreciating the assignment, reporting that he was not very excited about the assignment when it was first introduced in class. "I had a lot of homework and a lot of other things going on, so it was kind of overwhelming at first. . . . I was like, oh, man, I don't know, I don't know whether this is—I wasn't very excited when I first heard about it." During the interview, he offered very little unprompted indication that he valued the assignment. When he was directly asked by the interviewer what he thought the value of his portfolio was, he said, "I haven't gotten to—I think I could probably answer that question better once I've tried—once I'm like out trying to show companies what I am capable of doing, and when I'm out in the job field. Right now there's not really—I can't use it for anything when I'm still in school, kind of just going through classes and stuff." Mercer experienced the activity as reasonable, but maybe more valuable for those who had prior experience with job interviews.

Miles was on a similar path as Mercer, but he ultimately had a job interview experience that helped him see things more clearly. Miles said that he initially thought the assignment would be a waste of time—"[I] didn't think it was going to be all that fun at all. I thought it was going to be a waste of time, actually, completely honest with you." Although he was able to successfully complete the assignment within the expected amount of time without difficulty, he indicated in the interview that he did not value the experience until well after the class was over. He stated that he did not find the portfolio "important" until after he had gone to a series of job interviews without having anything to show employers as he spoke about what he had done. Miles then said that a teaching assistant for another course recommended that he "bring something to show" potential

employers during interviews. Miles created a small portfolio that reused materials from the portfolio he made as a part of this study. He reported that "it really helped, because I got the internship. They liked what they saw." Once seeing the portfolio's value, he stated in the interview that it was useful for demonstrating his knowledge to other people. In a sense, he leveraged his ME355 portfolio experience in his own later activities.

Limited experiences

The final three participants refrained from describing the assignment as particularly valuable for them in their current situation, each based on a different limitation. Yet each was able to imagine situations in which such an assignment or a slightly changed version of the assignment would be potentially valuable to them. Features of their stories help to further clarify the themes of epistemically different, manageably effortful, and ultimately valuable.

Leanne: Portfolio not different from normal school

While many of Leanne's comments concerning the types of knowing and effort associated with the portfolio assignment resembled other comments captured above, her overarching story was about the assignment not being particularly valuable to her because of her familiarity with such activities, but also about how a slightly revised assignment could be immensely valuable. In terms of her reported experience with the assignment, she did speak of the role of subjective knowing in the assignment (e.g., thinking about what was "very very important to me"); the role of integrated knowing in the assignment (she described the portfolio as "connect[ing] everything together better"); the role of externalized knowing in the assignment (the portfolio as a "useful tool to keep track of work you are doing"); her concerns about the limited role of externalized knowing in normal school (she spoke of school activity as wasteful, not typically about documenting, lacking evidence and products, and forgetting); and the effort of finding artifacts to represent abstract ideas like teamwork (she fell back on including a picture of her, her lab partner, and the fan that they built) and artifacts that were clearly her work (she initially included some lecture notes in her portfolio but then decided that "Professor x's work wasn't my work").

Nevertheless, Leanne was not very pleased with the assignment. She reported initially thinking that the assignment was "paternalistic . . . geared more toward students who had difficulty writing and . . . presenting their work," and "a remedial thing as opposed to something that helps you synthesize your work." In terms of value, Leanne linked her comments and experience with the portfolio to having been "raised on the idea that you have to show what you've been doing, and you have to show what you're capable of doing." Further, she reported that as an interdisciplinary major who had to create a portfolio to get into the interdisciplinary program, the task was relatively familiar to her.

As she worked on the assignment, she was able to identify variations in the assignment that she said would be "very valuable . . . a very good idea" (Leanne). In particular, she stated that the portfolio assignment had the potential for greater benefit if it drew on multiple classes or was incrementally expanded each academic quarter. Leanne said that this would "make your whole college career . . . a little bit more integrated" and that "if you have . . . this central place where all your work is going, then it . . . helps focus on what you are doing."

Louis: Portfolio not valuable for future career

Unlike Leanne who was actually quite critical of the assignment, Louis was able to ascribe value to the assignment: "I'm glad I did it. . . . It was a good assignment to have." Moreover, Louis' comments about effort included an observation that the assignment took less time than he expected and that the in-class workshop helped clear up any confusion or misunderstandings about the assignment ("I think a whole lot of us learned exactly what was expected, and we got a lot out of that. So we knew exactly what was required of us, so that made the assignment really understandable"). But, his comments about the kind of knowing involved in the assignment were minimal—he talked about the portfolio as useful to help "stick [the knowledge] in your mind," which he seemed to think was perhaps the primary value ("I don't think it had an impact of understanding it, just kind of reminding me what did I learn").

What is unique about Louis' experience is that he chose to target his portfolio at future ME355 students, while other students chose to target employers or recruiters or, on the other hand, say little about their target audience. Louis explained that he chose this audience because he believed that when he returns to his pre-existing appointment in the military, no one will particularly care about his degree. So, whereas other participants sought to find artifacts to interest employers, Louis was interested in choosing "something that would be applicable to a large majority of mechanical engineering students." In other words, while Louis engaged in a potentially significant activity, he set up a situation that distanced him from the subjective dimension of knowing that seems to have been important for other students. It is interesting to contemplate what would have happened if he had been able to find meaning in connecting his experiences to his own future.

Laura: Portfolio construction overly effortful

Laura's experience stood out among the participants in that she expressed the most negative statements about the portfolio assignment. For example, she stated that "after [the portfolio] was done, I probably still wouldn't choose it if it was an option," that "it seemed kind of repetitive," that she "was just kind of angry about it because I found it as extra work," and that she "didn't take much out of this portfolio assignment." Yet, at the end of

the interview she did say that the portfolio assignment was "a good idea" and that "[she doesn't] think it is a complete waste of time."

In some ways, Laura experienced the assignment, as other students had: as a subjective type of knowing ("be true to what we learned" and an invitation to think about "what kind of person I am, what kind of worker I am, what kind of engineer I am"); as an externalized type of knowing (thinking about "something that I would want to show"); and as an integrated type of knowing (the act of creating a portfolio made her think about how her current studies "apply to the real world").

Yet, the dominant themes of her interview were the ways in which the portfolio construction helped her understand what she had not learned in the engineering course, and the distinct amount of frustration this created for her. She spent a lot of time during the interview talking about how the assignment made her "grumpy" and "angry" because she could not find artifacts from the class that she wanted to show to anyone during an interview. Ultimately, the work on the portfolio helped her gain awareness, but the awareness she gained had to do with a lack of learning: "the portfolio just made it more obvious that I wasn't learning anything in the class." In particular, she admitted that some of her negativity was tied to her very poor experience with the ME355 lecture. Further, she explained that she felt as if she did not learn anything in ME355 and that, if the portfolio was supposed to be something you would talk about during a job interview, there was nothing that she would want to show. She already had an internship and was working as an intern during the quarter she took ME335. She felt that the projects from her internship were much more important and served as much better evidence of her qualifications. Ironically, while other students reported experiencing the assignment as an opportunity to make connections to experiences like internships, Laura reported that she did not think about her internship or attempt to integrate ideas from her internship into her portfolio. She seemed to believe that she was not supposed to make connections to outside-of-the-class experiences.

Discussion

In our study, we were interested in characterizing and classifying students' experiences with a specific portfolio assignment in terms of learning, effort, and value. In terms of learning, we found that the potential of the portfolio assignment could be understood in relation to the notions of externalized knowing, integrated knowing, and subjective knowing. These three dimensions of knowing, which are well aligned with the results of previous research (e.g., Brown, 2002; Klenowski, 2002), are particularly informative to researchers interested in linking portfolio construction and learning because of the ways in which students identified the types of knowing and thinking involved in portfolio activities as different from what they experienced as being necessary in "normal school."

Thus, the unique contribution of a portfolio assignment such as ours is to provide students with an opportunity to engage in types of thinking and knowing that may receive little attention in normal school activity.

In terms of effort, educators should find comfort in the fact that our results demonstrate that the portfolio assignment was experienced as manageable even though it was found to have particularly challenging dimensions. It is important to recall here that the portfolio assignment in our study was much smaller in scale than many of the assignments reported in the literature (e.g., the student portfolios in our study typically consisted of four relatively short web pages, while Brown's (2002) study involved portfolios with 75 pages or more of text) and that our assignment had significantly lower stakes (the portfolio assignment in our study was worth 5% of the students' course grade and was assessed primarily on compliance with the requirements of the assignment in contrast to the Scholes et al. [2004] portfolio activity which was associated with professional certification). As such, it is possible that one would expect our assignment to have been considered manageable. Of import is that our research provides confirmation of the manageability of the portfolio activity across different students.

The results concerning value, particularly the sometimes extreme changes in value reported by participants, deserve attention from researchers interested in linking portfolio construction and learning. Because the interviews were conducted one to two months after the portfolios were completed and submitted, it is not easy to know with certainty at what point in time changes in reported value occurred. In other words, we do not always know if the change in value occurred during the act of making the portfolio, shortly after turning it in, during the period of time between the assignment and the interview, or during the interview itself. Student comments do suggest that their initial perceptions of value were related to not understanding what to expect in terms of the types of thinking and the amount of effort that would be involved in the portfolio activity. Working through the activity helped students refine their expectations. That many students valued the assignment in the end suggests that educators should neither underestimate students in terms of their ability to appreciate this type of reflection opportunity nor overinterpret a lack of such reflective behavior in existing student activity. In other words, these results suggest that students' lack of engagement in reflective activity may be as related to (or more related to) lack of time and skill than to an ability to appreciate such thinking.

Finally, a particularly significant contribution of this work is the characterization of the different ways that the students experienced the activity—the significant experience, the muted experience, and the limited experience. The results of our study provide a basis for future researchers to investigate individual differences that could predict which students are likely to have which experiences. These results can also help educators anticipate the kinds of experiences that students will have and make sense of how students are responding to assignments in real time. Because we included students who had a variety

of experiences in our study, there is good reason to believe that the types of experiences we documented in this study will be encountered in future educational contexts where portfolios might be assigned.

Future Research

Additional research on this type of portfolio activity would be valuable in order to address the limitations of this study and explore additional variations. For example, what would be the result if students did such a portfolio assignment multiple times? Would the experience become more valuable, as students really start to understand the portfolio medium and to think in a forward way about collecting artifacts and making arguments about their preparedness for engineering activity? Or, would the experience become less valuable as students become able to think about these issues without the portfolio assignment as a forcing function? Also, what is the interplay of this type of activity and other reflective, sense-making activities such as having students write learning essays, prepare minute papers, or share posters about their experiences? Still other questions include the following: Does it matter if the portfolio is electronic? What would happen if the portfolios were shared with other students? Are there any negative side effects of having students construct such portfolios? What would happen if portfolios included a larger role for instructors?

Concluding Remarks

This work contributes to discussions of reflection in project-based learning, including ways to think about reflection, ways to support reflection, and the role of portfolio construction in supporting reflection. This work also contributes to the growing body of research concerning portfolios in education. The results of this study demonstrate that the portfolio construction we studied not only engages students in ways of knowing that complement what is often emphasized by existing instruction (or "normal school"), but also accomplishes this engagement with relatively few resources. The results also suggest some potential complications—that not all students will have an equally significant experience, that there may be initial negativity, and that some students may not even think of the experience as significant at the end. Instructors could enhance students' experiences with portfolio construction in a number of ways: providing support for finding artifacts (something our participants reported to be effortful), giving students the opportunity to see portfolios being created by their peers (something other researchers report as effective), or even sharing with students the types of experiences that they might have, given the results of this research study.

Portfolio construction is a valuable, and often distinct, educational activity that engages students with ways of knowing (i.e., externalized knowing, integrated knowing,

subjective knowing) that are not necessarily involved in traditional instructional experiences. Moreover, even in situations where students have had exceptional experiences (as is the case with many problem-based and project-based learning experiences), students will have had experiences that are different from one another and the overall meaning of their experiences may still be in flux.

Acknowledgement

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Appendix A

ME355: Professional Portfolio Assignment

Overview

We want you to create a course-based portfolio consisting of a statement, three or more artifacts, and annotations for each artifact. The purpose of this exercise is to review the knowledge taught in the course. Creating this portfolio should strengthen your under-standing of the class, your understanding of your engineering discipline in general, and your sense of how the class is helping you become better prepared to practice as an engineer. Specifically, you will demonstrate what you learned in the class, and how the learning contributes to your understanding of your engineering discipline and leads you to becoming a better prepared professional engineer.

Assignment

Your portfolio will consist of the following components. Figure 1 is a schematic diagram of the function and structure of your portfolio and its components. An example of a course-based portfolio may be found at http://portfolio.washington.edu/jsmartin/eng-course-portfolio/.
[*Note.* The online example used by students is no longer available.]

I. STATEMENT: How does the course relate to your preparedness to function as an engineer? Prepare a 400-500 word statement describing your understanding of your engineering discipline, of the course and course knowledge, and the connection between the two. This statement brings together your understanding of the course, your conception of en-gineering as a discipline, and your skills and knowledge. This statement is the backbone of your portfolio and is your opportunity to showcase and sell your knowledge and skills – you will link everything else in your portfolio to this statement. You might think of this statement as the cover letter to your portfolio.

II. ARTIFACTS: What examples of work did you produce in this course? Review the work you did in this course. Identify three or more pieces of work (knowledge/concept/topic) that you think are important to the course, your engineering discipline, and the points you made in the statement.

III. ANNOTATIONS to above artifacts: Explain the significance of the artifacts (knowledge) in light of the statement you prepared. For each artifact, write 100-250 words that explain its value and connections to the ideas in the statement.

Figure 1. Schematic diagram of the function and structure of your portfolio.