WIP: Transforming an Engineering Design Course into an Engaging Learning Experience using a Series of Self-Directed Mini Projects and ePortfolios

Abstract

Contemporary educational challenges have become amplified through the adoption of online-only modes of instruction due to the Covid-19 pandemic. When planning and delivering online instruction, even more than when delivering face-to-face instruction, engineering educators need to involve students at cognitive and emotional levels that encourage authentic, meaningful, and immersive learning experiences. During traditional online learning, students often feel disconnected from their learning communities. They also report a lack of motivation. Emotional engagement is therefore a necessary complement to cognitive engagement and can further help to facilitate intrinsic motivation and feelings of delight, surprise, understanding, empathy, and trust. This study analyzes the use of scaffolded mini-projects (complex design projects divided into smaller segments) combined with comprehensive electronic portfolios (ePortfolios) in a sophomore-level Design for Manufacturability course. By emphasizing progressively more complex learning experiences and pairing these with electronic portfolios, students may become more attuned to cognitive learning processes such as effective planning and communication of complex ideas. We also hypothesize that they may develop awareness of, and competency in, skills with an emotional component including self-directed learning, autonomous exploration, and creative inspiration.

For the purposes of this investigation, mini-projects may be independent from one another or connected as a series. Lessons from previous mini-projects are built into subsequent projects, and each offers loosely-defined analytical questions and open-ended design questions that require independent research. The unfolding of scaffolded mini-projects offers an orderly mechanism for students to grow and demonstrate important engineering competencies, especially when offered in tandem with teaching-learning-assessments via ePortfolios. ePortfolios have been shown to be effective in documenting learning competencies, enabling meta-analysis and personal reflection, and improving skills in the use of social media to communicate ideas. In effect, mini-projects combined with ePortfolios may help to facilitate deeper understanding of course content, make the curriculum more relevant for students, and build connections between classroom and professional learning competencies.

This study offers a comparative analysis evaluating the efficacy of using mini-projects and ePortfolios in a face-to-face learning environment (Fall 2019) and in an online-only learning environment (Fall 2020). Participants in the face-to-face Fall 2019 (n = 104) course completed a questionnaire that evaluated specific engagement constructs. The completed questionnaires were evaluated using descriptive statistics and factor analysis. Data from the Fall 2020 (n = 62) course were evaluated using the same assessment methodology. It is hoped that findings from this work may contribute to the development of self-directed learning strategies that enhance students’ cognitive and emotional engagement in their learning during online-only and face-to-face instruction.
Introduction

Undergraduate students today are experiencing significant challenges as they are forced to adjust to online learning. The competitive, autonomous nature of contemporary engineering education further challenges them to take responsibility for their learning to succeed. Learning to become an engineer has always been rigorous, but the added stress of learning online has increased the need for students to develop self-regulation skills that enable them to understand and manage various facets of their learning such as motivation, organization, and time management [1], [2]. Development of self-regulation skills includes learning practices like goal setting, self-evaluation, reviewing answers to previous work, and other self-regulating strategies that require students to act of their own volition during the learning process. The development and enhancement of self-directed learning skills are not only crucial for self-regulation, but also help strengthen students’ ability to navigate learning online. This is especially pertinent in light of the tendency of online learning environments to rely on students’ autonomy by requiring them to initiate the bulk of their learning activities themselves (e.g. viewing pre-recorded lecture videos, participating in online discussions, and managing group work remotely) [3].

For most students, self-directed learning skills are not inherent but instead must be fostered through both the development of agency, or awareness of one’s own competence, and effective coaching in productivity and teamwork. Both modes of development come together in the practice of design thinking (or human-centered design), now widely employed by engineering educators [4], [5]. Incorporating the design thinking process into engineering courses helps students learn the values of empathizing with end-users and co-creating solutions. Yet while engineering instructors are typically able to teach students how to develop empathy for others, they often neglect to empathize with the learning needs of their students.

One way of showing empathy for student learning needs could be to offer them opportunities to make autonomous discoveries in team-based design projects. Another might be to recognize that engineering students, who are taught to communicate design decisions through technical tools and software, often struggle to describe complex information effectively to a lay public. These subtle but important considerations in becoming empathetic to the needs of engineering students make up an important component of effective teaching. It follows that implementing this type of consideration in engineering curricula is necessary for preparing students for a modern-day workforce that is less focused on academic achievement (knowledge and scholarship) and more on emotional intelligence and skills like personality, independent thinking, and ability to work effectively in teams. Indeed, Kamp [6] writes that personal attributes like autonomy, organizational sensitivity, and empathy are increasingly important in job applications.

Developing such a skillset requires that students master the ability to make emotional connections among theoretical concepts [7]. This means that engineering educators need to involve students at cognitive and emotional levels in authentic, meaningful, and immersive learning experiences amidst a full curriculum. This study, which uses mixed methods to compare data from two semesters (one face to face, one online only) of the same Design for Manufacturability course, seeks to address this need by investigating the following broad research question: How might engineering educators leverage pedagogies of cognitive and emotional engagement to support the development of students’ self-directed learning skills?
Background

Overview of mini-projects
Per mini-project structure, course material is divided into “bite-size” chunks, with each chunk representing a core aspect of the syllabus. These chunks are then crafted into a series of mini-projects, usually between five and eight, that are offered as team-based or solo assignments. These projects made up the bulk (60%) of formative assessments in the evaluated Design for Manufacturability course, thereby shifting the focus from high-stakes exam performance to lower-stakes project performance. The decision to assess student performance on mini-projects was intentional, signaling to students that they would be assessed on both technical skill development and the acquisition of knowledge necessary to understand, utilize, create, and communicate their ideas. This assessment method also adapts well to both face-to-face and online course settings, making it both a practical pedagogical strategy and one that allows for comparative data collection on student learning experiences in-class and online.

It is important to note that the series of mini-projects offered to students is not simply a collection of discrete learning units, but rather a scaffolded learning platform that is flexible enough to accommodate the individual needs and desires of students. The use of such a platform aims not to simply cede control of the learning process to the student, but to intentionally add a degree of freedom and flexibility often missing from academic coursework. Allowing students some ability to shape their learning experience enables them to advance their personal skill set and interests in new and constructive ways. Pedagogically, the mini-projects aim to move students from a simple to a complex level of understanding; for example, moving beyond simply grasping how a tool is employed to understanding its purpose, the need(s) it addresses, and the expectations surrounding its use. In short, students learn how to think about tools and operations that are viable, feasible, and desirable. Adding opportunities for flexibility in pursuing some of their own interests can further challenge students to look beyond the tools employed in the engineering profession and recognize the fundamental relationships between acquiring foundational knowledge and developing personal expertise.

Supporting self-direction through mini-projects
As students progress through the sequence of mini-projects, their tasks become more complex and ill-defined to require independent research. The value of allowing students to engage with an ill-defined problem space, especially before they have obtained much of the knowledge necessary for analysis and design, is that doing so can lead them into a state of productive struggle that can foster a capacity to identify and take responsibility for their own knowledge needs. Self-directed learning also fosters personal autonomy and student agency, which can positively influence their ability to form individual academic identities. In this manner, learning becomes more about the individual and less about the course.

Strategic scaffolding in mini-projects
The first mini-project in a series is typically team-based and meant to build confidence in foundational concepts. Each subsequent project builds on the previous, eventually culminating in students performing solo-based mini projects. The projects begin with well-defined tasks and progress to open-ended design tasks with ill-defined questions. The removal of scaffolds over time relies on the assumption that students are adapting to, and developing strategies for, these tasks, meaning that as they develop as designers, they are more capable of exploring and
planning within an open-ended space. Indeed, students seem to derive a sense of personal accomplishment from doing this work, which may provide further motivation and contribute to their ongoing maturation in insight and work quality [8].

**Analysis, design, and reflection in mini-projects**

In each mini-project, students are tasked with solving both well-defined analytical problems and open-ended design problems that require guided, self-directed learning. While some questions contain background theory and hints, the tasks are intentionally designed to require students to perform rigorous research to identify theory-backed solution techniques. Students are also prompted to reflect specifically on how their learning meets ABET accreditation outcomes. These reflections, which are incorporated into students’ ePortfolios, provide instructors with personalized insight into students’ experiences [13].

Indeed, using ePortfolios to support student reflection practices can be beneficial in many ways. Through the process of reflecting, students combine “how to” with “why” questions and learn to form individualized value judgments. Reflective exercises also activate emotional awareness which can lead to students “knowing that they know something” [14], [15]. Furthermore, the use of ePortfolios for self-assessment fosters the process of developing and mastering personal and professional competency in that the emotional associations students forge with course content (and with the instructor) can further prompt cognitive processes [16]. Reflective work also helps students to identify patterns and trends in the ways they work and learn, thereby composing a repertoire of strategies they might use for making future choices in contextualizing coursework and professional work [17].

**Peer learning in mini-projects**

The mini projects are peer-graded by other teams (and checked by teaching assistants) so that students can learn from one another’s work and reflections. This process helps students to 1) develop confidence in sharing knowledge and learning from others and 2) strengthen and defines their own areas of expertise, which in turn helps to support future problem solving and knowledge-making [18]. To facilitate effective peer grading, teams are provided with detailed grading keys and grading rubrics—where teams are asked to comment on each question instead of only providing a score. This ensures that an expected level of rigor is maintained while promoting curiosity and critical evaluation of peer approaches. Students and teaching assistants are further required to provide feedback specifically designed to help their peers to improve their “thinking” and “feeling” competencies. For ease of workflow, peer grading is performed on the Google Forms platform.

**Overview of ePortfolios**

Students report their mini-project work (analysis, design, and reflections) in comprehensive teaching-learning-assessment (TLA) ePortfolios. The ePortfolio format allows all students to present their findings in an efficient and accessible manner. ePortfolios also help to link a range of individualized learning experiences with diverse learning perspectives that help them build upon competencies that will be relevant to both their current studies and their future professional careers, including applying for a job by citing a link in a program or course ePortfolio [19], [20]. While engaged in this type of thinking, students inherently develop their own models of understanding that could later be utilized in their professional careers [21].
The adaptable nature of ePortfolios (Fig. 1) also allows them to incorporate a wide variety of project formats, such as PDF-type reports, augmented reality apps, or graphic novels [8].

![Figure 1. Screenshot of a student’s ePortfolio, showing various template sections that required completion.](image)

**Methodology**

**Design**

This study is part of an ongoing exploration of pedagogies of engagement that aims to evaluate the efficacy of several pertinent pedagogies (i.e. mini projects, ePortfolios, guided self-directed learning, peer learning, analysis & design) in a sophomore-level Design for Manufacturability course [8].

**Participants**

All undergraduate engineering students enrolled in a sophomore-level Design for Manufacturability course in the Fall 2019 (face-to-face) and Fall 2020 (fully online) terms were sent a survey designed to measure their cognitive and emotional engagement as they experienced the use of ePortfolios embedded in a series of mini projects. All content and assessments were identical in both terms, and all students were required to participate in the course activities. No incentive or other enticement was offered for participating in the survey. Survey participants were assured that their responses would be fully anonymized. Data from anonymous teaching evaluation questionnaires was also collected. Of the 160 of surveys sent each semester, there were 104 respondents from the Fall 2019 term, and 62 respondents from the Fall 2020 term. The
disparity between 2020 and 2019 participants is most likely influenced by factors related to the pandemic, which impacted students’ ability and willingness to participate.

**Analysis**
Student engagement was measured using a series of questions to evaluate cognitive engagement and emotional engagement that were devised by following the guidelines and factor-groupings in Halverson and Graham’s extensive meta-study [22]. All questions were written in such a manner that aligns high positive values with a desired agreement response. Response options corresponded to the following Likert scale: strongly disagree, disagree, slightly disagree, slightly agree, agree, strongly agree. Questions were preassigned to the following 13 factors: attention, comfort with ambiguity, creativity, curiosity, willingness to embrace risk, empathy, enjoyment, lack of anxiety, lack of boredom, lack of frustration, optimism, teamwork, and (conceptual) understanding. All responses were coded numerically to indicate positive and negative tendencies; “strongly disagree” corresponded to -3, “disagree” to -2, “strongly agree” to 3, and so on. Factor analysis was used to measure the playfulness of students’ responses to task-related experiences.

**Results**

**Quantitative**
Questionnaire prompts were grouped according to the above factors. Figure 2 summarizes the salient results captured by the questionnaires for both face-to-face instruction (Fall 2019, \( n = 104 \)) and online-only instruction (Fall 2020, \( n = 62 \)). A tendency toward the positive x-axis indicates a more positive response to the factor captured by the questionnaire prompt; in other words, a higher value means that students on average tended to more strongly agree/identify with the prompt. A negative value indicates that students on average tended to disagree or did not identify with the prompt.

![Figure 2. Salient results of student evaluation questionnaires from face-to-face instruction (Fall 2019) and online-only instruction (Fall 2020).](image)

Table 1 presents statistical data of the 32 questions grouped into 13 factors.
Table 1. Statistical Results of Questionnaires for Face-to-Face (Fall 2019) and Online-Only (Fall 2020) Instruction

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean, $\bar{X}$</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td>1.439</td>
<td>1.489</td>
<td>1.665</td>
</tr>
<tr>
<td>Comfortable with Ambiguity</td>
<td>1.223</td>
<td>1.769</td>
<td>1.437</td>
</tr>
<tr>
<td>Creativity</td>
<td>1.515</td>
<td>1.185</td>
<td>1.284</td>
</tr>
<tr>
<td>Curiosity</td>
<td>1.328</td>
<td>1.301</td>
<td>1.412</td>
</tr>
<tr>
<td>Embracing Risk</td>
<td>-0.223</td>
<td>0.656</td>
<td>2.005</td>
</tr>
<tr>
<td>Empathy</td>
<td>1.097</td>
<td>0.839</td>
<td>1.517</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>1.233</td>
<td>0.790</td>
<td>1.518</td>
</tr>
<tr>
<td>Lack of Anxiety</td>
<td>-0.252</td>
<td>-0.460</td>
<td>1.939</td>
</tr>
<tr>
<td>Lack of Boredom</td>
<td>-0.364</td>
<td>2.048</td>
<td>2.066</td>
</tr>
<tr>
<td>Lack of Frustration</td>
<td>0.282</td>
<td>1.184</td>
<td>2.013</td>
</tr>
<tr>
<td>Optimism</td>
<td>1.602</td>
<td>0.870</td>
<td>1.218</td>
</tr>
<tr>
<td>Teamwork</td>
<td>2.289</td>
<td>1.337</td>
<td>0.828</td>
</tr>
<tr>
<td>(Conceptual) Understanding</td>
<td>1.073</td>
<td>1.057</td>
<td>1.806</td>
</tr>
</tbody>
</table>

Table 1 and Figure 2 show that participants responded positively (averaging responses of at least “Slightly Agree” on a six-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree,” $\bar{X} > 1.000$) for factors pertaining to attention, comfort with ambiguity, creativity, curiosity, empathy, enjoyment, optimism, teamwork, and conceptual understanding for face-to-face instruction. Participants responded positively for factors pertaining to attention, comfort with ambiguity, creativity, curiosity, lack of boredom, lack of frustration, teamwork, and conceptual understanding for online-only instruction. Factors pertaining to attention, curiosity, and conceptual understanding received the same responses across both conditions to within one decimal place. Participants responded slightly in the negative (averaging responses less than “slightly disagree”) to lack of anxiety, with a slightly higher negative value in Fall 2020 than Fall 2019. For the face-to-face condition, teamwork received the most playful response; this was the only factor to receive responses averaging at least “Agree” on the Likert scale. For the online-only condition, lack of boredom received the most playful response; this was the only factor to receive responses averaging at least “Agree” on the scale.

**Qualitative**

ePortfolio reflections

In each of the ePortfolios that accompanied the mini projects, students had to reflect (independently) in no less than 300 words on her / his learning experience on specific mini projects. Below is a sample of excerpts from students’ reflections (names have been changed):

“I’ve found that my strengths include formulating processes to be more efficient and that my ability to create diagrams for explanations is better than I thought. However, when it comes to weaknesses, I am terrible at time management. Mini Project 10 was the most...”
planned-out project I have ever done, and even on the last day I was still cramming in work.” (Susan)

“I enjoyed working in the team because of how well we were able to delegate work – although we were together for the entirety of the project, we still managed to all work on separate things when it was required, allowing us to finish our ePortfolio efficiently while still covering all of the necessary content.” (Jermaine)

“Supplementing mini projects with the in-class lectures helped me get a much better understanding of design for manufacturing as opposed to just sitting down in class and taking notes. The mini projects and ePortfolios completed throughout the semester allowed me to improve my critical and creative thinking skills while learning valuable knowledge outside of the classroom. The most beneficial part of the mini projects and ePortfolios was that we had the opportunity to solve the problems being presented in our own fashion.” (Tony)

“If I had to highlight any aspect of ME 270, it would be the mini projects and ePortfolios. It was the part of the course that I spent more time working on. The fact that it was based on a research activity taught me where to look for reliable information. It was a challenge to give the best of me in order to not fail my team.” (Francine)

“The first Mini Project we were assigned, we quickly gained skills in reverse engineering a product and, much to my surprise, honed skills in communicating our ideas in a formal report format. It is my belief that this first task was integral to our success in the course as it formed the foundation for skills and thought processes that were later relied on heavily as the course proceeded.” (Sirius)

ABET program learning goals
Teams were asked to discuss each ABET program learning goal. All teams and individuals performed this activity in detail, indicative of their interest to learn how they are learning and how their learning addresses ABET learning outcomes. Below is an extract from one team’s answer regarding the following ABET learning outcome: “An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.”

“Mini-Projects: The mini projects in this course challenged our team to analyze complex engineering problems from various perspectives, and in some cases tasked us with ideating unique design solutions. In the analysis portion of the mini project, we were frequently tasked with formulating solutions by researching and applying equations and principles from authoritative engineering textbooks. In the design portion, we were given the open-ended task of identifying problems from inefficiencies in design, to possible reasons products were discarded. The design portion also challenged us to solve these perceived shortcomings through simple design solutions, such as reducing the number of parts in an assembly or choosing a more durable material.

Homework/quizzes: The homework and quizzes met this learning target by ensuring we could rigorously apply mathematical equations and insights in the appropriate contexts.
Labs: Many of the labs provided us with a solid framework to analyze and solve engineering challenges. For example, in the design of experiments lab, we used an extensive statistical analysis to gain insights into the effects of factors on a given response - a process which is very applicable in many areas of engineering.

Lectures: Though we did not typically need to apply our knowledge in lecture, we gained the knowledge we needed to identify engineering problems.

Independent learning of modules: Independent learning was crucial to solving the engineering problems faced in the mini projects for this course. Using credible online resources, textbooks and journal articles proved vital to understanding and applying the principles needed to solve engineering challenges” (Alison, Robert, Jackson, and Michelle).

Open-ended feedback
Students also had the opportunity to provide open-ended anonymous feedback in end-of-semester teaching evaluation questionnaires. A sampling of their responses is provided below:

“I enjoyed the mini projects and the ePortfolios. Very interesting + learnt a lot”
“Using ePortfolios helped me distill my thoughts”
“More ePortfolio work, please, from freshman year to senior year”
“Self-directed learning is not my preferred style of learning, but it fosters a responsibility for oneself”
“The projects and ePortfolios helped me to strongly connect with the various topics”
“The ePortfolios forced me to work better, as others in class could see my work”
“Producing the portfolios made me feel more like a student engineer than an engineering student. I loved it!”
“I had a blast working on mini project 10 as there was very little structure forced on us and we could do our own thing, and then display it all with our ePortfolios”

Our participants’ comments in each of these formats support their apparent cognitive and emotional engagement in the learning activities which featured ePortfolios as part of a series of mini projects.

Discussion
Quantitative
For the face-to-face condition, lack of anxiety, willingness to embrace risk, and lack of frustration were deemed to be of lesser importance ($-0.3 < \bar{X} > 0.3$). In comparison, all factors except lack of anxiety received positive responses ($\bar{X} > 0.3$) for the online-only condition. The negative tendency for lack of anxiety during both modes of instruction ($\bar{X} = -0.25$, face-to-face; -.46, online-only) can be deemed as having positive or negative attributes. Pekrun noted that on simple tasks anxiety does not affect, or may even enhance, performance; however, learning may
become impaired on complex or difficult tasks that demand cognitive resources [23]. Thus, anxiety may be deleterious to emotional and cognitive energy reserves in complex learning contexts. However, considering the pandemic and its impact on students’ overall quality of life, it is to be expected that higher anxiety would be reported during the 2020 semester. Future work can investigate strategies for mitigating anxiety during mini-project work.

The factor of attention enjoys a relatively large positive reaction ($X_{MEAN} = 1.489$ for face-to-face instruction and $1.439$ for online-only instruction). This cognitive engagement factor is seen by many as the gatekeeper for information processing [24] and is therefore one of the basic indicators that students are engaging mental effort in the learning process. Participants also report that the ePortfolio-based activities supported their conceptual understanding become immersed in subject contents ($\bar{X} = 1.073; 1.057$). This is indicative of students becoming more deeply absorbed in the subject contents, which may be a sign of deeper flow, which is described by Csikszentmihalyi as “a state in which people are so involved in an activity that nothing else seems to matter” [25]. Students’ potential engagement with subject content is further supported by a similarly positive response for curiosity ($\bar{X} = 1.328; 1.301$). When combined with the qualitative results in the following section, these findings indicate that students perceived the mini-projects and ePortfolios to be personally relevant. As Dewey noted, “situational interest may develop into individual interest, which is characterized by curiosity and self-guided exploration” [26]. Furthermore, the online-only mode evoked a more playful response to embracing risk, indicating that the virtual collaboration experience not only helped students to immerse in the tasks but also supported their willingness to take risks in their work.

It is now accepted that emotions cannot be separated from thinking in guiding rational behavior, memory retrieval, decision-making, problem solving, and creativity, among others [27]. As it follows that positive emotions assist learning, it is heartening to see that the participants experienced the series of mini-projects and related ePortfolio assignments as enjoyable ($\bar{X} = 1.233$ for face-to-face instruction; $0.790$ for online-only instruction). Although enjoyment (i.e. situational interest) is deemed to be a short-lived affective state [28], it nevertheless focuses attention, enhances cognitive performance and learning, and improves integration [29]. If mini-projects and ePortfolios indeed spark students’ interest, it follows that students are better engaged. In this respect, the factor of enjoyment is also seen as a short-lived factor, but one which may be associated with increased creativity and cognitive performance [30]. The factor of optimism, which can be considered like a sense of a confidence, may precede and facilitate engagement, as students are more likely to exert effort in tasks if they believe that they have the capacity to succeed [31]. Likewise, this attitude can also indicate engagement, as it depends on events that occurred in solving the previous problem and not on students’ incoming beliefs [32].

Overall, the quantitative results suggest that the production of ePortfolios as part of a series of mini-projects increased participants’ cognitive engagement (e.g. attention, curiosity, teamwork) and emotional engagement (e.g. enjoyment, lack of frustration, optimism) in an interconnected manner for both modes of instruction. Regarding the most playful factors for each mode, teamwork’s importance in Fall 2019 is heartening because it reflects the students’ positive experiences working collaboratively with their peers in person. The playful “lack of boredom” response for online-only instruction is especially meaningful, as this suggests that the
mini-project/ePortfolio format provided interest and engagement for students during an especially challenging semester.

Qualitative
From reviewing students’ comments across opportunities for both self-reflection and course evaluation, findings indicate that students not only enjoyed a meaningful and deep learning experience but also had fun in the process. Students reported that involvement in assessment of their peers’ mini projects led to them taking more responsibility in their own (future) mini projects and enhanced self-learning management.

Results also suggest that students’ awareness of peer assessment improved their activation more than the quality of the feedback itself. Peer grading further helped students to understand what elements are appreciated in an answer and to identify common mistakes or deficiencies. This insight provided students with a meta-perspective on their own understanding and learning; other research substantiates this finding [33]. As students gave and received feedback from their peers, they enjoyed the benefits of incorporating other views and perspectives into their progress to help identify, strengthen, and consolidate their learning experiences.

Conclusion
A sophomore-level Design for Manufacturability course was transformed using a series of 10 self-directed mini-projects in which students worked in teams (for the first nine projects) or alone (for the tenth project) and reported their work using ePortfolios. Working in this way provided a scaffolded course that incorporated authentic projects, real-world products, self-assessment, competency showcasing, and reflective practice, all underpinned by peer grading to enhance conventional evaluation. Of importance to this investigation was the emphasis placed on 1) personal reflection in the context of developing required competencies in engineering practice and 2) the intertwined connections of cognitive and emotional engagement.

Preliminary results suggest that mini-projects and ePortfolios help foster self-directed learning, as well as enhance self-awareness, by providing students with valuable insight into their own learning styles. The awareness gained from this process in turn helps students to regulate, change, and improve learning behavior, while also fostering the development of critical thinking skills by prompting students to conceptualize and articulate their thinking in a disciplinary context.

Our findings indicate that, during the online-only semester, students took ownership of their learning through reflective engagement and were able to create compelling product (or process) ePortfolios with minimal faculty intervention. The students also enjoyed crafting their ePortfolios and sharing them with other users. They took charge of their learning in realms outside of the lecture room and laboratory and became responsible for their individual knowledge and skills. Prompted by the mini-projects, students acquired most of their course-related knowledge and skills independently and with minimal guidance. They also effectively reflected on their learning experiences and on meeting ABET program goals, further suggesting meaningful and self-directed learning.
The strength of mini-projects and ePortfolios lies in their capacity to build reflective ability. When used in formative assessment formats, feedback from peers, instructors, and teaching assistants helps students to identify their strengths and stimulates the development of future learning goals and strategies. Successful ePortfolio-based projects require unambiguous and detailed grading rubrics, which provide students with well-defined objectives and explicit assessment criteria. The use of comprehensive grading rubrics also supports faculty and teaching assistants in providing feedback to support student learning and progression. In this study, students effectively collaborated with each other on team-based mini-projects while also producing meaningful individual mini-projects. Comparison of ePortfolios for the first mini-project compared to the last mini-project shows immense growth in knowledge, skills, and reflection.

This study sheds light on innovative ways to utilize mini-projects and teamwork to help cultivate self-directed autonomous leaders. Our investigation has revealed that mini-projects and comprehensive ePortfolios support and streamline student assessment in ways that enrich their learning experience while satisfying the need for institutional accountability (such as ABET accreditation). Mini-projects and ePortfolios have the potential to facilitate deeper understanding of course content, make the curriculum more relevant for students, and help build connections between classroom and professional learning competencies. To ensure quality of learning, mini project-based teaching and learning activities must be aligned with, and supported by, authentic assessment activities. The successful integration of ePortfolios with project-based learning (such as a series of mini-projects) enables a course to be transformed into a series of engaging learning experiences.

**Future Work**

Although the findings of this study have been overwhelmingly positive, there are areas that merit further investigation. In future work, student performance in final exams will be collected for documentation and comparison to determine whether ABET and other learning outcomes achieved through creation of ePortfolios are similar or different to those achieved through traditional instructional and assessment methods. Other questions for future investigation, which will require follow-up interviews and questionnaires, are listed below:

1) How do mini project and Portfolio-based activities affect the development of student expertise over time?
2) Do e-Portfolios help students to reflect on their achievement of both course and program learning goals?

This study does not include rigorous analyses to quantify statistical significance of data. This will be done in follow-up work.
Appendix: Questionnaires
Participants were provided an online questionnaire with questions that could later be ordered in terms of (a) cognitive engagement and (b) emotional engagement. These questions and their ordering into factors are based on the extensive meta-study reported in [33]. All questions were answered on a 6-point Likert scale.

A) Cognitive Engagement

Attention
- The mini projects / ePortfolios focused my attention on specific topics.
- The variety of design challenges and research work in the mini projects / ePortfolios kept my attention.
- When I worked on the mini projects / ePortfolios, I devoted my full attention to my work.

Curiosity
- When I am in class, I feel curious about what we are learning.
- The mini projects made me feel like I was discovering new things.
- I feel safe taking risks with my team.

Creativity
- The mini projects helped me use my creativity to effectively solve complicated problems.
- The mini projects encouraged me to be creative.
- My evaluation of my peers’ mini projects / ePortfolios helped me develop my own design skills.

Embracing Risk
- The open-endedness of the mini project tasks made me more comfortable with taking risks.
- I feel safe making mistakes with my team.
- I feel safe taking risks with my team.

Teamwork
- I would prefer to work in a team than alone on the mini projects.
- I feel that every individual team member makes a difference in my team’s work.
- The mini projects helped me to quickly connect and build relationships with fellow team members.
- I feel free to introduce new or different ideas for my team’s projects.
In my team, the work is divided evenly over the team members.

Understanding

In my reflections, I was able to connect what I learned in this course to knowledge from other courses as well as to possible future applications. The reflection tasks helped me to better understand what I learned in the mini projects.

Doing the mini projects increased my understanding of design for manufacturability.

The mini projects helped me understand concepts better as compared to traditional class format.

B) Emotional Engagement

Anxiety (translated on graph)

Working on the mini projects / ePortfolios caused me to feel anxious.
Working on the mini projects / ePortfolios took more time than I wanted to spend.

Boredom (translated on graph)

I was bored when doing the mini projects / ePortfolios.
Working in a team on the mini projects was boring to me.

Comfortable with Ambiguity

I feel comfortable interacting with my team members.
I felt comfortable sharing my knowledge with my mini project teammates.
I feel comfortable asking the team for help when I do not understand something
I feel safe discussing tough project issues with my team.
I feel comfortable learning new things with my team.
I am comfortable working with people who have different perspectives and abilities from mine.

Empathy

The mini projects helped me to empathize with the concerns of other people.
Working in a team on the mini projects / ePortfolios was boring to me.

Enjoyment (situational interest)

I would rather work on the mini projects / ePortfolios than do work for other classes.
I enjoyed the fact that a solution to a mini project problem could result from an unexpected direction.
I enjoyed doing the mini projects.

_Frustration (translated on graph)_

Working in a team on the mini project problems frustrated me.
I feel my effort is undermined by others in my team.
In my team, the work is done by a small minority of team members.
I was dissatisfied with the open-endedness of some of the mini project tasks.
The real-world scenarios in the mini projects were frustrating to me.

_Optimism_

The mini projects / ePortfolios helped me realize that I desire to have an impact on people around me.

Working on the mini projects / ePortfolios caused me to see myself in a positive light.

My experience working on the mini projects showed me that I can overcome difficult challenges.
References


