Transforming an Engineering Design Course into an Engaging Learning Experience using ePortfolios

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Nattasit Dancholvichit was born in Bangkok, Thailand in 1990. He received a B.A. degree in mechanical engineering from the University of Michigan in 2014. He received an M.S. degree in mechanical engineering from the University of Illinois Urbana-Champaign in 2017. He is currently a Ph.D. student in Mechanical Science and Engineering at the University of Illinois Urbana Champaign. He carries out research in the field of micro-manufacturing, precision control, manufacturing, and mechatronics. His research also includes control optimization and system identification. He is also a graduate teaching assistant of design for manufacturability.

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For the past 25 years, Leon Liebenberg has been engaged in engineering teaching, research, and community engagement. He was a professor of mechanical engineering at two South African universities (University of Pretoria; North West University), before becoming a higher education consultant in Switzerland where he worked with colleges of engineering and technology management. He is now a teaching associate professor at the UIUC. Leon is passionate about multidisciplinary research, particularly in the fields of energy engineering, biomedical engineering, and engineering education. His university research has focused on development of industrial energy-efficient technologies and cancer therapies using energy restriction methods. His published research works enjoy an h-index of 26. Leon' first love is however for teaching. He co-developed and taught a unique freshman course on "Innovation", where students work in so-called "whole-mind" thinking teams when addressing technological problems. These helped show that innovation for a sustainable world can be maximized by the convergence of natural sciences, engineering sciences, and the arts. pedagogies of engagement for use in the mechanical engineering curriculum. Leon is collaborating with colleagues from various disciplines in this venture. He also founded the TechnoLab technology awareness facility for junior engineering students and for school children, where the learners work in small teams to solve problems using Lego Dacta and other didactic equipment. The TechnoLab model has been adopted by several South African schools since its inception in 1997. Leon also founded the Space and Aviation Challenge for school learners in South Africa, which aimed at demystifying the aeronautical engineering profession. The Challenge was annually presented for several years in collaboration with Nasa's Dryden Lab who offered the first prize for a learner to attend Space Camp USA. Leon teaches a variety of subjects, including: Innovation; Statics; Dynamics; Thermodynamics; Fluid Mechanics; Design for Manufacturability; Machine Design; Heat Transfer; Aerodynamics; Aeronautics; and Advanced Heat and Mass Transfer. Leon holds doctoral and master's degrees from Imperial College London and from the University of Johannesburg.

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Abstract

Introduction

Employers nowadays focus less on academic achievement and more on personal attributes, experience, and skills. Engineering educators must also contend with the need to involve students at cognitive and emotional levels in authentic, meaningful, and immersive learning experiences amidst a full curriculum. Electronic portfolios (or ePortfolios), combined with a series of mini projects, have the capability to uniquely address all these needs.

ePortfolios have been shown to be effective for supporting student learning by serving as a powerful vehicle for students to display their individual competencies while also allowing faculty to provide personalized assessment. Due to the personalized nature of ePortfolios, and the engaging process of curating learning experiences and artifacts, we hypothesize that students will come to perceive their classroom learning experience as being multi-dimensional and immersive. Teaching students about meta-learning and requiring them to reflect on their learning via ePortfolios should further support a holistic learning experience. For the instructor and teaching assistants, ePortfolio-based projects will provide a good catalog of work for assessing student mastery as well as the opportunity to make meta-learning and reflective practice part of the assessment process. As students will also have the opportunity to give and receive feedback from their peers, they will have the benefit of incorporating other views and perspectives into their progress. This will help identify, strengthen, and consolidate their learning experiences.

Objectives

The primary objective of the study is to conduct a comprehensive analysis of Digication, an ePortfolio tool, by studying various aspects of its features and use within a sophomore-level Design for Manufacturability course (190 total students). Of greatest importance is the ability to customize the Digication platform for the class so that it offers students, faculty, and administrators an exacting and measurable method for streamlining and integrating the related processes of teaching, learning, and individualized assessment.

Chief among the goals of the project is to provide students with an easy-to-use tool for collecting their digital artifacts, including course assignments and other documents that will be used to display and evaluate their course competencies. Of particular interest will be the extent to which ePortfolios can be said to support and encourage student use of meta-learning and reflective practices, as demonstrated by the curation of artifacts and writing of personal reflections. We believe that by allowing students to explore and discover how their competencies are developing through their course assignments, they may also discover how *classroom* learning goals connect to *professional* learning goals drawn from the ABET quality assurance framework.

In addition to documenting ePortfolio usefulness for evaluating student achievement of *course* learning goals, this study explores the use of students' own reflective practices to measure their progress toward *program* learning goals.

Approach

We developed an ePortfolio template using the Digication platform. Students were asked to report four of their 10 mini projects using this ePortfolio tool. We then evaluated how effective the production of these ePortfolios was in engaging students on both cognitive and emotional levels. To do this, we asked participants (n = 104) to complete an online questionnaire that evaluated these engagement constructs. The completed questionnaires were evaluated using descriptive statistics and factor analysis.

Implications

Comprehensive ePortfolio platforms support and streamline student assessment in ways that enrich their learning experience while satisfying the need for institutional accountability. ePortfolios help to facilitate deeper understanding of course content, make the curriculum more relevant for students, and build connections between classroom and professional learning competencies. Of importance to this investigation is the emphasis placed on 1) personal reflection in the context of developing required competencies in engineering practice and 2) the interconnected roles of emotional engagement and cognitive engagement. Results from student evaluation questionnaires suggest that ePortfolios effectively connect teaching, learning, and individualized assessment, making them a valuable pedagogy in engineering education.

Introduction

ePortfolios

Employers nowadays focus less on academic achievement (i.e. job applicants' knowledge and scholarship) and more on experience and skills (i.e. applicants' personality and accomplishments). Kamp [1] writes that personal attributes like autonomy, organizational sensitivity and empathy are increasingly important in job applications. Portfolios, or collections of work that display an applicant's skillset and prowess, have become commonplace for job applications in many fields. Engineering educators must also contend with the need to involve students at cognitive and emotional levels [2] in authentic, meaningful, and immersive learning experiences amidst a full curriculum. ePortfolios, combined with a series of mini projects, have the capability to uniquely address these needs.

Electronic portfolios (or ePortfolios) have been shown to be effective for supporting student learning by serving as a powerful vehicle for students to display their individual competencies [3], while also allowing faculty to provide personalized assessment and providing a tool for life-long professional growth [4], [5]. Producing ePortfolios can be enjoyable for students, further encouraging them to engage in deeper learning [6]-[8]. Due to the personalized nature of ePortfolios and the process of curating their learning experiences and artifacts [9], we believe that participating students come to perceive their classroom learning experience as being multi-dimensional and immersive.

For instructors and teaching assistants, ePortfolio-based projects provide a strong catalog of work for assessing student mastery as well as the opportunity to make meta-learning and reflective practice part of the assessment process [10], [11]. Students should be brought to understand that displaying course artifacts in their ePortfolios only becomes valuable once they have effectively assimilated and evaluated the significance of the artifacts [12]. Through portfolio-based reflections, students actively appraise how their education supports their values and goals while learning how to measure their growth toward these goals. Reflections also help students to identify patterns and trends in their ways of working and learning, which fosters the development of strategies for making future choices [13]. Such reflections further assist students to contextualize their coursework with anticipated professional work and can also improve instructor evaluations [14]-[16].

ePortfolios also serve to connect the academic setting with the professional engineering environment [17], [18]. Additional value of the ePortfolio is rooted in its connective power, including its inherent ability to help students establish links among a range of experiences [10], [19]. When used for reflection, the ePortfolio can contribute to students' development of metacognitive skills that support them to transition into their future careers [20], [21]. Its use in higher education encourages proactive, student-centered learning and promotes interconnection of concepts through knowledge acquisition and greater student accountability, as well as a holistic approach to the delivery of course contents [20], [22], [23]. We hypothesize that student engagement will be further enhanced if students perceive that their ePortfolios also inform curriculum (re)design. Furthermore, we argue that ePortfolios can be used as a tool for engineering students to collate evidence that demonstrates attainment of competence against

professional accreditation domains (e.g. for educational outcomes of ABET). Providing feedback to students is important to their success as they prepare for professional engineering roles; ePortfolios provide an effective means of assessing competence while establishing accountability for both students and instructors [24].

Mini Projects

In large part due to the perceived needs of the engineering industry, design-based learning is drawn from concepts relating to problem-based and project-based learning. This begets the question of how to structure design courses that are effective in meeting both experiential and project-based learning goals. The use of mini projects constitutes one such mechanism. Mini projects present a structure in which larger projects are divided into several smaller pieces. Each of these smaller (mini) projects could either be independent from one another or scaffolded as a connected series. Lessons learned in previous mini projects could be integrated in subsequent projects. Mini projects provide an opportunity to develop competencies such as self-directed learning, autonomy, teamwork, creativity, exploration, inspiration, planning, and organization in a project of limited extent. They offer an ideal mechanism for students to demonstrate their competencies, especially when merged with comprehensive teaching-learning-assessment ePortfolios to effectively document competencies, and to enable commenting (including the use of social media). In effect, ePortfolios, combined with mini projects, offer an opportunity to transform a traditional curriculum into one comprised of a succession of learning experiences.

Objectives and significance of research

The primary objective of this study was to develop a comprehensive Teaching-Learning-Assessment (TLA) ePortfolio tool, using Digication, an ePortfolio platform [25], for the 190 engineering students in a sophomore-level Design for Manufacturability course. Of importance was the ability to customize the Digication platform for the class so that it offered students, faculty, and administrators an exacting and measurable method for streamlining and integrating the related processes of teaching, learning, and individualized assessment.

1) Developing a repository

The study aimed to provide students with an easy-to-use tool for collecting the digital artifacts linked to areas of 10 mini projects, including course assignments and other documents that were used to display and evaluate their course competencies. Of interest will be the extent to which ePortfolios can be said to support and encourage student use of meta-learning and reflective practices, as demonstrated by the curation of artifacts and writing of personal reflections. We believe that by allowing students to explore and discover how their competencies are developing through their course assignments, they may also discover how *classroom* learning goals connect to *professional* learning goals drawn from the ABET quality assurance framework.

2) Encouraging peer and instructor assessment

Evaluation of the ePortfolios included peer grading to help build a community of practice [26]. This study paper evaluates whether peer grading increases transparency, improves learning, provides more valid and reliable assessment, increases student engagement, and/or increases coherence in learning outcomes. The study included scaffolded mini projects and the delivery of

four related ePortfolios (in teams and solo) to encourage students to critically reflect on their personal, professional, departmental, and institutional learning goals. As a result of this structure, students were engaged in the process of both acquiring new skills and tracking their growth over time.

3) Fostering self-reflection

Another goal of this study was to assess whether qualitative assessment administered through ePortfolios might encourage students to view themselves as more than a letter grade, and empower them to complete the assessment cycle by making self-correcting changes to their learning practices and study techniques in order to achieve their personal and professional goals. In addition to documenting ePortfolio usefulness for evaluating student achievement of *course* learning goals, this paper will also explore the utility of students' own reflective practices to measure their progress toward *program* learning goals.

The significance of this study lies in analysis of the feasibility of using comprehensive teaching-learning-assessment (TLA) ePortfolios in a manner that would result in more engaged students and improved objective assessment of their progress that also includes individualized feedback [27]. We regard student-initiated reflection and near real-time feedback by peers and instructors as highly important. We also believe that comprehensive TLA ePortfolios can make grading much more personal. Furthermore, we hope to transform the current ePortfolio format to provide a competency profile aligned with ABET accreditation outcomes. Connecting program learning goals with general and liberal education requirements (among others) provides a framework for interdisciplinary collaboration and allows administrators to streamline departmental and institutional assessment by using evidence collected in department-based ePortfolios. Figure 1 illustrates how comprehensive teaching-learning-assessment (TLA) ePortfolios can help to link a range of different experiences that enable students with diverse perspectives to develop 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. While engaged in this type of thinking, students inherently develop their own models of understanding that could later be utilized in their professional careers.

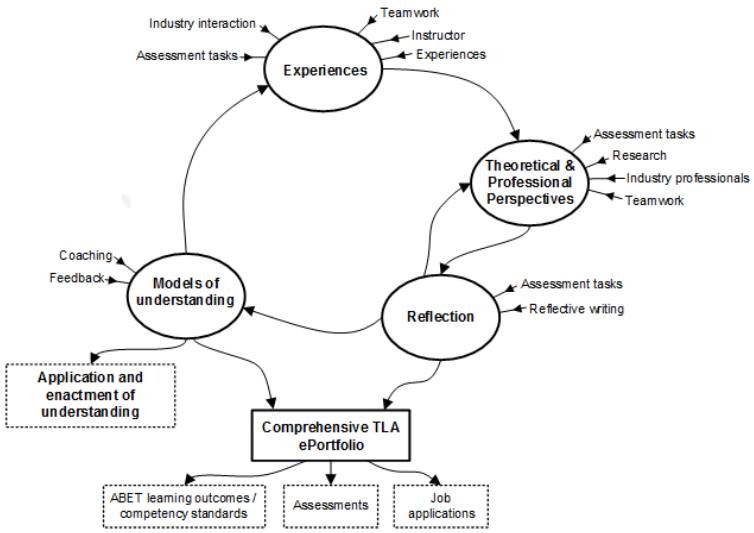

Fig. 1. Comprehensive teaching-learning-assessment (TLA) ePortfolios connected to several processes (adapted from [28])

Implementation methodology

ePortfolio Platform and Design

An effective ePortfolio platform should support portfolio scaffolding [29], digital file organizing, student reflection, and faculty and peer evaluation. The University of Illinois at Urbana-Champaign currently uses Digication as a standard platform for ePortfolios. The Digication platform had mainly been used for product/course/resource ePortfolio purposes, as opposed to comprehensive teaching-learning-assessment (program) ePortfolio purposes. We aimed to customize Digication so that it would also support comprehensive TLA ePortfolios and integrate within the University's learning management tool, Compass 2g, as well as other learning tools if necessary.

We customized the Digication platform in a manner that seamlessly integrates teaching, learning, and assessment so that students can fully participate. We expected that, through the comprehensive TLA ePortfolio, students would then be able to reflect on personal, professional, departmental, and institutional learning goals, thus taking on the role of self-directed learner while also initiating the first stage of assessment. Student progress would need to be evaluated qualitatively through further reflection and by using customized rubrics—this would help ensure that students participate more deeply in assessment by tracking growth over time. By taking ownership of the earliest stages of assessment, students become empowered to complete the assessment cycle by making changes to their learning, practicing, and studying techniques to achieve personal and professional learning goals.

ePortfolio template

We developed an ePortfolio template in Digication that was comprised of the following sections: Analysis, Design Challenge, Reflections, ABET Program Learning Goals, and Sources. Students could upload text, pictures, drawings, and videos in each of these sections to illustrate their

competencies. Student reflections were only available for viewing by the instructor and teaching assistant, while all other sections were open for viewing by teammates. Students were assisted by a research assistant who had received training pertinent to the Digication platform. In turn, the research assistant received guidance from the University's full-time Digication specialist. Figure 2 shows a page from a typical student ePortfolio with template sections (i.e. Analysis, Design Challenge, Reflections, ABET Learning Goals, Sources) that required completion and grading.

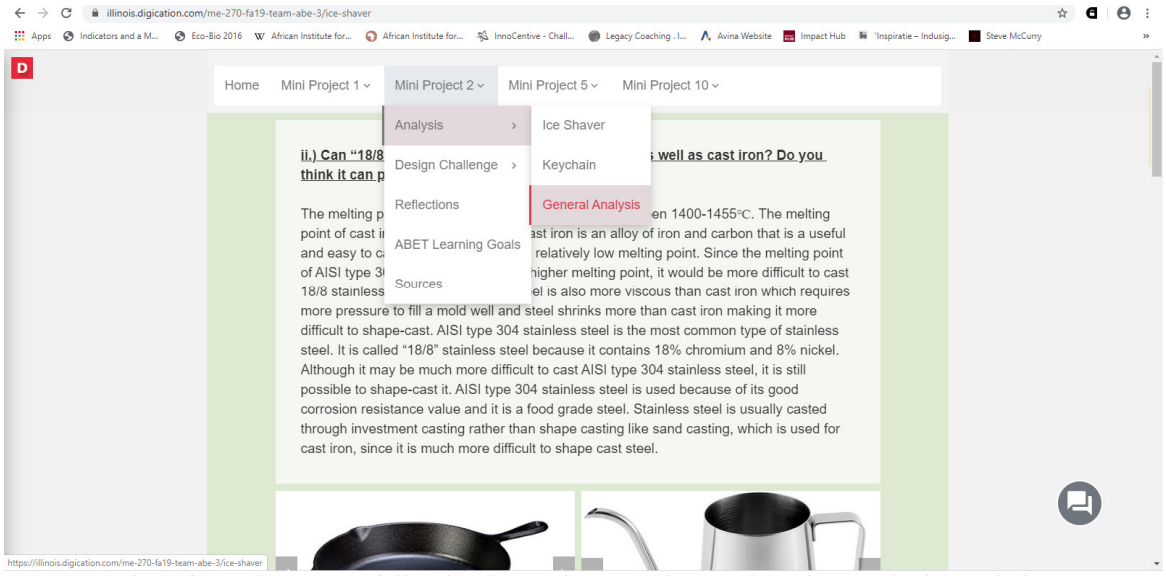

Fig. 2. Screenshot of a student's ePortfolio, showing various template sections that required completion

Customizing the platform to facilitate meta-learning

As students completed each of their 10 mini projects, they were prompted to evaluate which of several ABET (and departmental) learning objectives were met, and how. In doing so, students were engaging with competency development, creating a framework within which they could organize understanding of their emerging competency over time. Further, connecting program learning goals and general education (or ABET) requirements provides a framework for interdisciplinary collaboration and allows administrators to streamline institutional assessment (e.g. ABET accreditation visits) using evidence collected in department-based ePortfolios.

If students are not aware of their developing competency, many opportunities for learning, personal development, and professional identity development may be lost [28]. Conversely, taking an approach where students can explore, and are made explicitly aware of, their developing competencies should result in improved opportunities for learning and professional development. The use of ePortfolios benefits from this approach, as these tools can employ metacognition and reflective practices. Used in this manner, students become more aware of their motives and assume control over their learning strategy selection and deployment [30]. Further, by engaging in guided reflection throughout the course, students learn to make meaningful and productive connections between different courses and extracurricular experiences [29]; this helps build the habit of synthesizing learning across multiple domains, leading to the creation of new knowledge and new research questions [31].

Customizing the ePortfolio platform for teaching and assessment

We believe that assessments must consider the *whole* of a student and her/his education, not just the component parts [32]. The Digication platform was therefore configured to support and streamline student and program assessment in ways that enrich teaching and learning, while satisfying the need for institutional accountability via its required meeting of ABET learning outcomes. We also acknowledge that while course-based assessment tools (including student evaluation questionnaires, informal early feedbacks, etc.) evaluate student achievement of *course* learning goals, they often do little to measure student progress toward *program* learning goals. The hundreds of course assessments on a department's curriculum map do not together comprise a functional assessment program that tracks program effectiveness and student progress toward program learning goals. The customized Digication template therefore sought to address this need as a basis for implementation and evaluation in other courses in all years of undergraduate study. We believe that the customized platform will help engineering (and other) departments to shift from course-based assessments to program-based and developmental assessments, while retaining summative assessments for use at the end of the program.

Additionally, the customization process included ample time to revise and clarify learning goals and to build consensus around them. We believe that if this activity is done well, it can help achieve faculty buy-in and high adoption rates. To aid the revision process, we developed a common assessment rubric that instructors should use to evaluate student growth (or progression through the course or program). Depending on the student identifiers built into the assessment forms, students can also be tracked as cohorts from which sample populations could be constructed, allowing for relevant data assessment when necessary.

ePortfolio deliverables and grading rubrics

Students completed a series of 10 mini projects in the course, with each one addressing a different course component. The mini projects were designed to help students comprehend various modern design-for-manufacturability options, understand designer and manufacturer viewpoints, and learn how to create optimal designs based on best practices for design-for-manufacturability. The first nine mini projects, which addressed product disassembly, 3D printing, machining, casting of metals, plastic molding, joining and assembly, sheet metal forming, metal forging, and composites, respectively, were completed in teams of four to five students. The tenth mini, which focused on design for recycling, was a solo effort. These projects were reported using ePortfolios produced through the Digication platform.

The nine team-based mini projects included peer grading, with each of the 48 teams assigned to grade the ePortfolios of two other teams. The course teaching assistants and the instructor reviewed these peer-graded assignments to ensure appropriate grading practice. The tenth mini project ePortfolios were only graded by the instructor and teaching assistants. Students and teaching assistants used the same grading rubric (Fig. 3), which included indicators of a student's or team's ability to move beyond mastery of the required course concepts to the development of a unique and creative solution. Each project's rubric was customized to include supplementary material such as detailed solutions that showed typical grade allocations for each question or, for open-ended design challenges, sample problem-solving approaches.

Criteria	Ratings				
1. Analysis **_____ / 50**	Excellent solutions, with, perhaps, a minor error. Correct equations, correct implementation, brief discussion of results.	Good solutions, containing one major error or a few small errors. Correct implementation with brief discussion.	Poor solutions with two major errors or one major error and several small errors. Poor implementation with little discussion.	Very poor solutions and implementation, with minimal attempt at the solutions.	No solutions
2. Design challenge **_____ / 25**	Design concepts are novel / excellent and easy to grasp, with excellent drawings or sketches, and excellent explanatory comments. Perhaps one or two minor errors in the design or manufacturing process.	Design concepts are ordinary and not so easy to grasp; drawings or sketches are adequate, but with minimal explanatory comments. Perhaps a major error in, or improper use of, design or manufacturing process.	Design concepts are meagre and are difficult to grasp; drawings or sketches are inadequate with few or no explanatory comments. Two or more major errors (or several small errors) in the design or manufacturing process.	Design concepts are unacceptable or incomprehensible or incomplete; drawings or sketches are meagre with few or no explanatory comments. General non-adherence to basic design or manufacturing principles.	No attempt at addressing the design challenge
3. Personal reflections **_____ / 10**	Each team member provides a detailed reflection of no less than 300 words, in which the following are discussed: (i) student clearly reflects on what she/he thinks they learned in the assignment and how they learned it, (ii) how the student sees the knowledge acquired in the assignment to be applied in real-life engineering practice.	Most team members provide a detailed reflection of no less than 300 words, in which the following are discussed: (i) student reflects on what she/he thinks they learned in the assignment and how they learned it, (ii) how the student sees the knowledge acquired in the assignment to be applied in real-life engineering practice.	Most team members provide a detailed reflection of no less than 300 words, but with some team members providing inadequate reflections. In their reflections, students discuss the following in some detail, but this could much improved: (i) student reflects on what she/he thinks they learned in the assignment and how they learned it, (ii) how the student sees the knowledge acquired in the assignment to be applied in real-life engineering practice.	Few team members provide a detailed reflection of no less than 300 words, but with most team members providing inadequate or no reflections. In their reflections, students discuss the following in some detail, and poorly: (i) student reflects on what she/he thinks they learned in the assignment and how they learned it, (ii) how the student sees the knowledge acquired in the assignment to be applied in real-life engineering practice.	No attempt by any team member to provide a personal reflection
4. ABET learning goals **_____ / 5**	Clearly lists attainment of ABET learning goals. Excellent understanding of ABET learning outcomes, exemplified by good discussions.	Clearly lists attainment of ABET learning goals. Good understanding of ABET learning outcomes, but discussions could have been more detailed.	Attainment of ABET learning goals are not clearly indicated, or ABET learning goals are not understood, as exemplified by incorrect deductions.	Attainment of ABET learning goals are poorly indicated and incomplete, and ABET learning goals are not understood, as exemplified by incorrect deductions.	No attempt to interpret project activities in terms of ABET learning outcomes
5. ePortfolio (using *Digication*) **_____ / 10**	High-impact ePortfolio that clearly and effectively conveys information. Covers all mandatory sections. Ample evidence of competence in analytical, computational, drafting, and reasoning (reflection) skills. Detailed and highly appropriate discussions, suggestions, and critique, with ample contextualization.	An acceptable ePortfolio with some elements of excellence. ePortfolio clearly conveys information. Covers more than two-thirds of mandatory sections. Marginal evidence of competence in analytical, computational, drafting, and reasoning (reflection) skills. Discussions are brief but incomplete, provided critique is minimal, and suggestions are inadequate.	Low-impact ePortfolio, mediocre quality. ePortfolio poorly conveys information. Covers only about half of mandatory sections. Minimal evidence of competence in analytical, computational, drafting, and reasoning (reflection) skills. Discussions, critique, and suggestions are incomplete and inadequate, or inappropriate.	ePortfolio of very low quality with meagre impact. ePortfolio poorly conveys information. Covers less than half of mandatory sections. Meagre evidence of competence in analytical, computational, drafting, and reasoning (reflection) skills. Discussions, critique and suggestions are incomplete and inadequate.	No attempt to report work in ePortfolio format
Would you approve this assignment?	Yes			No	
What grade would you give this assignment? (i.e. Criteria 1 + 2 + 3 + 4 + 5) **_____ / 100**					
For TAs only: Did this team accurately and fairly review their peers?					
For TAs only: Final grade	**_____ / 100**				

Fig. 3. Typical grading rubric used to evaluate project deliverables and ePortfolios (supplementary material not shown)

Data Collection and Assessment Processes

The constraints of an already packed education context do not allow for any elaborate before-and-after evaluations, so we did not test students beforehand to establish a baseline against which to compare students' competence after having produced ePortfolios. Evaluation relied on the judgement of student participants, recognizing them as the experts regarding what learning had taken place.

Research participants (n = 104) were recruited from the population of students enrolled in a sophomore-level Design for Manufacturability course. All students participated in the course activities, but only research participants provided feedback via an online survey that was approved by the University's IRB. This survey was designed to measure the students' cognitive and emotional engagement when being subjected to ePortfolio pedagogy embedded in a series of mini projects. We also collected feedback from anonymous teaching evaluation questionnaires.

Student engagement was measured using a series of questions to evaluate cognitive engagement and emotional engagement, as elucidated in the Appendix. The questions were devised by following the guidelines and factor-groupings in Halverson and Graham's extensive meta-study [33]. All questions were written in such a manner that aligns high positive values with a desired agreement response.

Results and Discussion

Quantitative Results

Figure 4 summarizes the salient results captured by the evaluation questionnaires Out of the entire class population of 190 students, 104 participated.

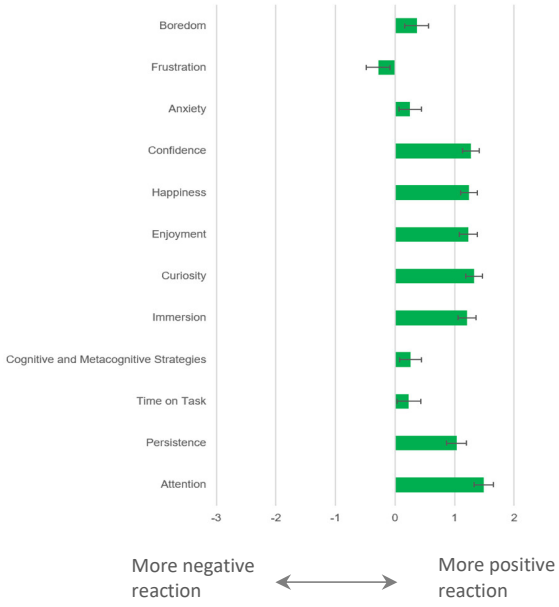

Fig. 4. Salient results of student evaluation questionnaires (n = 104)

Table 1 presents statistical data of the 32 questions grouped in 12 factors.

TABLE 1
STATISTICAL RESULTS OF QUESTIONNAIRES (N = 106)

Factor	Mean, $\bar{X}$	Standard Deviation	Standard Error
Attention	1.49	1.66	0.16
Persistence	1.03	1.69	0.17
Time on Task	0.23	2.00	0.20
Cognitive and Metacognitive Strategies	0.26	1.86	0.18
Immersion	1.21	1.56	0.15
Curiosity	1.33	1.41	0.14
Enjoyment	1.23	1.52	0.15
Happiness	1.24	1.40	0.14
Confidence	1.27	1.47	0.14
Anxiety	0.25	1.94	0.19
Frustration	-0.28	2.01	0.20
Boredom	0.36	2.07	0.20

Table 1 and Figure 4 show that participants responded overwhelmingly positive ($\bar{X} > 1.20$) for factors pertaining to attention, immersion, curiosity, enjoyment, happiness, and confidence. Also, the ePortfolio (and mini project) activities were deemed to be of lesser significance ($-0.3 < \bar{X} > 0.3$) regarding the factors of boredom, frustration, anxiety, cognitive and metacognitive strategies, and time on task.

The fact that students reported a negative reaction with the affective factor of frustration ($\bar{X} = -0.28$), bodes well for the ePortfolio type of project deliverables. The slight positive reaction with boredom ($\bar{X} = 0.36$) is however difficult to understand in the context of most other positive activating emotions enjoying positive reactions.

The positive tendency of anxiety ($\bar{X} = 0.25$) 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 [34]. Thus, anxiety may be most deleterious to emotional and cognitive energy reserves in complex learning contexts.

The factor of attention enjoys a relatively large positive reaction ($\bar{X} = 1.49$). This cognitive engagement factor is seen by many as the gatekeeper for information processing [35] 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 helped them become immersed in subject contents ($\bar{X} = 1.21$). This is indicative of students becoming deeply absorbed in the subject contents. Csikszentmihalyi described this as “a state in which people are so involved in an activity that nothing else seems to matter” [36]. This positive correlation ties in well with a similar response regarding the factor of curiosity ($\bar{X} = 1.33$). This result, when read with the qualitative results in the following section, indicates 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” [37].

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 [38]. 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 ($\bar{X} = 1.23$) activities that gave rise to feelings of happiness ($\bar{X} = 1.24$) and confidence ($\bar{X} = 1.27$).

Although enjoyment (i.e. situational interest) is deemed to be a short-lived affective state [39], it nevertheless focuses attention, enhances cognitive performance and learning, and improves integration [40]. If ePortfolios and mini projects indeed spark students' interest, it follows that students are easily engaged, and that learning may commence. In this respect, the factor of happiness is also seen as a short-lived factor, but one which may be associated with increased creativity and cognitive performance [41]. The factor of 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 [42]. Likewise, confidence can also indicate engagement, as it depends on events that occurred in solving the previous problem and not on students' incoming beliefs [43].

Overall, the quantitative results suggest that the production of ePortfolios as part of a series of mini projects increased participants' cognitive engagement (i.e. attention, immersion, curiosity) *and* emotional engagement (i.e. enjoyment, happiness, confidence) in an interconnected manner.

Qualitative results

To better interpret the quantitative results, we also reviewed qualitative feedback. It is apparent from this feedback 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' ePortfolios led to participants taking more responsibility in their own (future) ePortfolios and enhanced self-learning management.

It also appears that the 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 [44].

As students gave and received feedback from their peers, they enjoyed the benefit of incorporating other views and perspectives into their progress to help identify, strengthen, and consolidate their learning experiences.

Anonymous feedback from students (from semester-end teaching evaluation questionnaires):

> "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"

Reflective Practice

In each of the ePortfolios, 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 one of the ABET outcomes:

> "*1. 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)

The ePortfolio work seemingly perfectly complemented the series of mini projects. Overall, our participants' comments support their apparent cognitive and emotional engagement in the learning activities which featured ePortfolios as part of a series of mini projects.

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 on the Digication platform. 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 grading. 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 these comprehensive 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.

From these ePortfolio projects, it is apparent that 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 on the Digication platform. 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 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 ePortfolios lies in their capacity to build reflective ability. When used in formative and summative 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 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. Students effectively collaborated with each other on team-based ePortfolios while also producing effective individual ePortfolios. Comparison of ePortfolios for the first mini project compared to the last (tenth) mini project shows immense growth in knowledge, skills, and ability to reflect on learning. This study sheds light on innovative ways to utilize ePortfolio peer grading in order to cultivate self-directed autonomous leaders. To ensure the efficacy of a comprehensive teaching-learning-assessment ePortfolio program, the program should be carefully designed to ensure integration with degree-program learning objectives. To ensure quality of learning, ePortfolio-based teaching and learning activities must be aligned with, and supported by, authentic assessment activities.

This study revealed that comprehensive ePortfolio projects support and streamline student assessment in ways that enrich their learning experience while satisfying the need for institutional accountability (such as ABET accreditation). ePortfolios have the potential to facilitate deeper understanding of course content, make the curriculum more relevant for students, and to help build connections between classroom and professional learning competencies. 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 (among others) if 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 of related interest that will be investigated more deeply are listed below. These questions will require follow-up interviews and questionnaires.

a) What problems or limitations emerged in having students engage in ePortfolios?
b) What ePortfolio-based activities work best in different course types and sizes?
c) How do ePortfolio-based activities affect the development of student expertise over time?
d) Do e-Portfolios help students to reflect on their achievement of both *course* and *program* learning goals?

The pilot study did not feature rigorous analyses to quantify statistical significance of data. This will be done in follow-up work.

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APPENDIX:

QUESTIONS ASKED

Participants were provided an online questionnaire which contained answers on a 5-point Likert scale, and where the questions could 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].

To Evaluate 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 helped keep me engaged.

Effort and Persistence

The mini projects / ePortfolios pushed me to the limits of my skills.
The mini projects / ePortfolios Gold Awards motivated me to perform better.

Time on Task

I spent significantly more time on the mini projects / ePortfolios than on traditional non-self-directed assignments.
The mini projects / ePortfolios helped me better plan and organize my designs.
The ePortfolios helped me better manage my time and resources.

Cognitive or Metacognitive strategies

The ePortfolio reflections helped me to better understand what I learned in the mini projects.
In my ePortfolio reflections, I was able to connect what I learned in this course to knowledge from other courses, as well as to possible future applications.
My evaluation of my peers' mini projects / ePortfolios helped me develop my own design skills.

Deep concentration (absorption / immersion)

When I worked on the mini projects / ePortfolios, I devoted my full attention to my work.

Individual interest (curiosity)

I would rather work on the mini projects than do work for other classes.
When I am in class, I feel curious about what we are learning.

To Evaluate Emotional Engagement

Enjoyment (situational interest)

I enjoyed doing the mini projects and ePortfolios.
The mini projects / ePortfolios left room for me to be spontaneous and creative.
The mini projects / ePortfolios made me feel like I was discovering new things.

Happiness

I felt good when completing the mini projects / ePortfolios.
The mini projects / ePortfolios helped me understand concepts better as compared to traditional class format.

Confidence

I have a sense of achievement from the self-directed learning offered by the mini projects.
The mini projects / ePortfolios helped me to quickly connect and build relationships with fellow team members.

Anxiety

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.

Frustration

Working in a team on the mini project / ePortfolios problems frustrated me.
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.

Boredom

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

References

[1] A. Kamp, *Engineering education in the rapidly changing world: rethinking the vision for higher engineering education*. TU Delft, The Netherlands, p. 61, 2016.

[2] J. Astin and W. Alexander, "Student involvement: A developmental theory for higher education," *Journal of College Student Personnel*, vol. 25, no. 4, pp. 297-308, 1984.

[3] J. W. Gikandi, "Promoting Competence-Based Learning and Assessment Through Innovative Use of Electronic Portfolios," in *Handbook of Research on Promoting Higher-Order Skills and Global Competencies in Life and Work* (pp. 181-208). IGI Global, 2019.

[4] L. H. Bryant and J. R. Chittum, "ePortfolio Effectiveness: A(n Ill-Fated) Search for Empirical Support," *International Journal of ePortfolio*, vol. 3, no. 2, pp. 1106-198, 2013.

[5] H. L. Chen and S. J. Patel, "Using Reflection and Digital Storytelling via ePortfolios to Support the Professional Development of Engineering Graduate Students," in *2018 IEEE Frontiers in Education Conference* (FIE) (pp. 1-5). IEEE, 2018.

[6] K. Weber and K. Myrick, "Reflecting on Reflecting: Summer Undergraduate Research Students' Experiences in Developing Electronic Portfolios, a Meta-High Impact Practice," *International Journal of ePortfolio*, vol. 8, no. 1, pp. 13-25, 2018.

[7] T. Thibodeaux, C. Cummings, and D. Harapnuik, "Factors That Contribute to ePortfolio Persistence," *International Journal of ePortfolio*, vol. 7, no. 1, pp. 1-12, 2017.

[8] B. Eynon, L. M. Gambino, *Catalyst in Action. Case Studies of High-Impact ePortfolio Practice*. Sterling, Virginia: Stylus, 2017.

[9] R. LaPlante, "Assessing Language in an E-Learning Environment," In *Handbook of Research on Assessment Literacy and Teacher-Made Testing in the Language Classroom* (pp. 244-261). IGI Global, 2019.

[10] K. Scholz, C. Tse, and K. Lithgow, "Unifying Experiences: Learner and Instructor Approaches and Reactions to ePortfolio Usage in Higher Education," *International Journal of ePortfolio*, vol. 7, no. 2, pp. 139-150, 2017.

[11] C. E. Watson, G. D. Kuh, T. Rhodes, T. Penny Light, and H. L. Chen, "ePortfolios: The eleventh high impact practice," *International Journal of ePortfolio*, vol. 6, no. 2, pp. 65-69, 2016.

[12] K. Andre and M. Heartfield, *Portfolios for Health Professionals*. Elsevier Health Sciences, 2016.

[13] D. A. Schön, *Educating the Reflective Practitioner*. San Francisco: Jossey-Bass Publishers, 1987.

[14] J. L. Clarke and D. Boud, "Refocusing portfolio assessment: Curating for feedback and portrayal," *Innovations in Education and Teaching International*, vol. 55, no. 4, pp. 479-486, 2018.

[15] C. L. Cormack, E. Jensen, C. O. Durham, G. Smith, and B. Dumas, "The 360-degree evaluation model: A method for assessing competency in graduate nursing students. A pilot research study," *Nurse Education Today*, vol. 64, pp. 132-137, 2018.

[16] J. Turns, E. Cuddihy, and Z. Guan, "I thought this was going to be a waste of time: How portfolio construction can support student learning from project-based experiences," *Interdisciplinary Journal of Problem-Based Learning*, vol. 4, no. 2, 2010.

[17] K. B. Yancey, *ePortfolio as curriculum: Diverse models and practices*. Sterling, Virginia: Stylus, 2019.

[18] C. Morreale and V. Zile-Tamsen, "Thinking Skills by Design: Using a Capstone ePortfolio to Promote Reflection, Critical Thinking, and Curriculum Integration," *International Journal of ePortfolio*, vol. 7, no. 1, pp. 13-28, 2017.

[19] B. Eynon, L. M. Gambino, and J. Török, "What Difference Can ePortfolio Make? A Field Report from the Connect to Learning Project," *International Journal of ePortfolio*, vol. 4, no. 1, pp. 95-114, 2014.

[20] J. Rowley and J. Munday, "The evolved landscape of ePortfolios: Current values and purposes of academic teachers and curriculum designers," *Journal of Teaching and Learning for Graduate Employability*, vol. 9, no. 1, pp. 2-22, 2018.

[21] H. Vos and E. De Graaff, "Developing metacognition: a basis for active learning," *European Journal of Engineering Education*, vol. 29, no. 4, pp. 543-548, 2004.

[22] B. Boesch, C. Reynolds, and J. Patton, "ePortfolios as a tool for integrative learning: Building classroom practices that work," in E.A. Railean, G. Walker, A. Elci, & L. Jackson (Eds.) *Handbook of Research on Applied Learning Theory and Design in Modern Education* (pp. 439-464). Hershey, PA: IGI Global, 2016.

[23] K. A. Parkes, K. S. Dredger, and D. Hicks, "ePortfolio as a Measure of Reflective Practice," *International Journal of ePortfolio*, vol. 3, no. 2, pp. 99-115, 2013.

[24] J. A. Giering and Y. B. Firdyiwek, "E-Portfolios: Deepening Student Engagement in Learning," in *Handbook of Research on Fostering Student Engagement with Instructional Technology in Higher Education* (pp. 167-184). IGI Global, 2020.

[25] UIUC, University of Illinois Portfolio Resources, https://illinois.digication.com/portfolio/, accessed 6 March, 2019.

[26] J. Britland, "Developing Self-Directed Learners through an ePortfolio Peer Consultant Program," *International Journal of ePortfolio*, vol. 9, no. 1, pp. 45-54, 2019.

[27] A. Pagano, M. H. Goldstein, and L. Liebenberg, "Play-in-Learning: Studying the Impact of Emotion and Cognition in Undergraduate Engineering Learning," *126th ASEE Annual Progress and Exposition*, Tampa, Florida, 2019.

[28] N. Lake and J. Holt, "Designing Quality Engineering Curricula to Produce Industry Ready Graduates: A Whole Course Approach," in K. Trimmer et al. (eds.), *Ensuring Quality in Professional Education,* Vol. II, https://doi.org/10.1007/978-3-030-01084-3_8, 2019.

[29] D. Cambridge, “Layering networked and symphonic selves: A critical role for e-portfolios in employability through integrative learning,” *Campus-Wide Information Systems*, vol. 25, no. 4, pp. 244-262, 2008.

[30] J. B. Biggs, “The role of metalearning in study processes,” *British Journal of Educational Psychology*, vol. 55, no. 3, pp. 185-212, 1985.

[31] M. Van Manen, *Researching lived experience: Human science for an action sensitive pedagogy*. Routledge, 2016.

[32] L. Suskie, “Why are we assessing?” *Inside Higher Education*, Oct. 26, 2010.

[33] L. R. Halverson and C. R. Graham, “Learner Engagement in Blended Learning Environments: A Conceptual Framework,” *Online Learning*, vol. 23, no. 2, pp. 145-178, 2019.

[34] R. Pekrun, “Emotions as drivers of learning and cognitive development,” in *New perspectives on affect and learning technologies*, pp. 23-39. Springer, New York, NY, 2011.

[35] R. C. Atkinson and R. M. Shiffrin, “Human memory: A proposed system and its control processes,” in K. W. Spence and J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89-195). New York, NY: Academic Press, 1968.

[36] M. Csikszentmihalyi, “Toward a psychology of optimal experience,” in *Flow and the foundations of positive psychology*, pp. 209-226. Springer, Dordrecht, 2014.

[37] J. Dewey, *How we think*. Boston, MA: D. C. Heath, p. 567, 1910.

[38] M. H. Immordino-Yang, *Emotions, learning, and the brain: Exploring the educational implications of affective neuroscience* (the Norton series on the social neuroscience of education). WW Norton & Company, 2015.

[39] H. Jang, E. J. Kim and J. Reeve, “Why students become more engaged or more disengaged during the semester: A self-determination theory dual-process model,” *Learning and Instruction*, vol. 43, pp. 27-38, 2016.

[40] K. A. Renninger and S. Hidi, *The power of interest for motivation and engagement*. Routledge, p. 265, 2015.

[41] B. L. Fredrickson, “The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions,” *American Psychologist*, vol. 56, no. 3, p. 218, 2001.

[42] G. M. Sinatra, B. C. Heddy and D. Lombardi, “The challenges of defining and measuring student engagement in science,” *Educational Psychologist*, vol. 50, no. 1, pp. 1-13, 2015.

[43] I. Arroyo, D. G. Cooper, W. Burleson, B. P. Woolf, K. Muldner, and R. Christopherson, “Emotion sensors go to school,” *AIED*, vol. 200, pp. 17-24, 2009.

[44] O. Mirmotahari and Y. Berg, “Structured peer review using a custom assessment program for electrical engineering students,” in *2018 IEEE Global Engineering Education Conference* (EDUCON) (pp. 999-1006). IEEE, 2018.