STUDENT CHEMICAL ENGINEERING REFLECTIVE ePORTFOLIOS
ChE Student Perceptions of Learning From Reflective ePortfolio Creation

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E ngineering educators and employers value and prioritize communication skills as evidenced by desired student learning outcomes and job descriptions defining new positions; however, developing and assessing such skills in an engineering program is challenging. ABET's criteria for accrediting engineering programs comprises General Criterion 3, student outcomes, including the ability to effectively communicate.[1] Effective oral and written communication outcomes frequently appear in higher education course syllabi and industry job requirements. Employer feedback, however, indicates new graduates lack communication skills.[2]

In an Association of American Colleges and Universities (AACU)-sponsored study, employers prioritized communication skills: "More than three in four employers say they want colleges to place *more emphasis* on helping students develop five key learning outcomes, including: critical thinking, complex problem solving, written and oral communication, and applied knowledge in real-world settings."[2] Furthermore, they believed company success depends on innovation and recognize that employees face increasingly complex problems requiring broader skill sets; therefore, employers prioritized "critical thinking, communication, and complex problem-solving skills . . . when making hiring decisions."

Although educators and employers value and prioritize communication skills, developing and assessing such skills in a higher education engineering course is difficult. In addition, engineering courses include rigorous science, math, and engineering curricula, but rarely require students to reflect, write, and articulate how new learning connects to prior experiences and transfers across or to new contexts.[3] Therefore, students do not connect learning from assignment to assignment,

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course to course, and course to experience, such as an internship. Even when students demonstrate communication skills through formal assessments, they may be unaware of their thought processes and unable to articulate what they know and how they solve problems, a critical engineering skill.[4,5] Incorporating technical writing into engineering courses and, more specifically, incorporating multiple reflection opportunities, enhances the student's ability to communicate within the discipline. Requiring students to go further and draw together experiences through a reflective portfolio gives them an opportunity to describe how and why they know what they know.

Reflective ePortfolios can develop students' communication skills by requiring multiple writing assignments integrated into engineering curricula.[6] Lorenzo and Ittelson defined an ePortfolio as "a digitalized collection of artifacts, resources, and accomplishments" that showcases a student's work and provides opportunities for metacognitive, reflective, critical, creative, and logical thinking.[7] In addition, ePortfolios address the six areas employers identified for higher education emphasis in student learning: critical thinking and analytical reasoning; complex problem solving and analysis; written and oral communication; knowledge and skill application in real-world settings; locating, organizing, and evaluating information from multiple sources; and innovation and creativity.[2] Furthermore, 80% of employers indicated an ePortfolio would be helpful in the hiring process to demonstrate student knowledge, skills, and experience.

The purpose of this three-year qualitative case study was to investigate the use of reflective ePortfolios in an undergraduate chemical engineering course. Three research questions guided the study: a) How do reflective ePortfolios affect chemical engineering students' perceived learning?, b) Why are chemical engineering students motivated to create reflective ePortfolios?, and c) What are chemical engineering students' preferences (likes and dislikes) in creating reflective ePortfolios?[8]

THE COURSE AND REFLECTIVE ePORTFOLIO ASSIGNMENT

To develop effective communication skills, Texas A&M University's chemical engineering department requires CHEN 301, Engineering Workplace Writing, a technical communication course (see <https://sites.google.com/site/tamuchen301/home>).[9] The instructor provided students, typically juniors and seniors, the following welcome, which connects communication learning outcomes to discipline-specific ABET outcomes and broader university undergraduate learning outcomes:

Engineering Workplace Writing integrates best-use practices of technical communication instruction including high-impact learning activities while also meeting university student learning outcomes. The course stresses the principles of rhetoric, i.e., understanding the audience and purpose of communication in different workplace contexts, in order to effectively prepare and deliver the message. You, the student, will practice the essentials of technical communication while addressing a variety of communication challenges, thus reinforcing communication, critical thinking, lifelong learning, and collaboration outcomes as stated in the TAMU Undergraduate Learning Outcomes and ABET Program Educational Outcomes.[9]

As the culminating course assignment, chemical engineering students created a ChemE-folio, hereafter referred to as a reflective ePortfolio (see <https://sites.google.com/site/chemefolioassignment/home>)[10] to house a collection of their work representing academic accomplishments as well as academic and career goals. Using an ePortfolio template (see
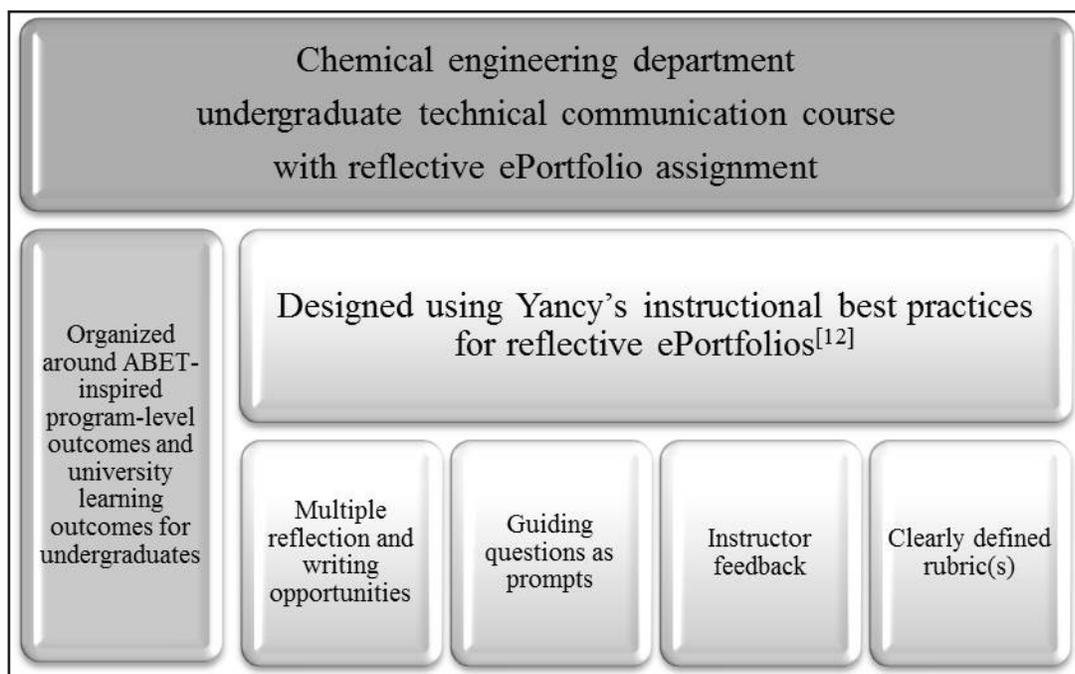

Figure 1. *CHEN 301, Engineering Workplace Writing, a technical communication course.*

<https://sites.google.com/site/chemefoliotemplatespring 2013/>),[11] students selected relevant chemical engineering outcomes and customized the reflective ePortfolio based on their unique skills and accomplishments. In addition to ABET-inspired program-level outcomes and the university's learning outcomes, Yancey's best practices for reflective ePortfolios guided the design (see Figure 1). According to Yancey, instructional best practices for reflective ePortfolios include a) multiple reflection and writing opportunities, b) guiding questions that prompt student identification of what they are learning and why it matters, c) instructor feedback on interim reflections, and d) a clearly defined rubric with specific expectations.[12]

First, this course provided multiple reflection and writing opportunities to reinforce communication competencies assessed in the final reflective ePortfolio. For example, course assignments required students to understand how rhetorical context influences the message, prepare multiple assignments addressing different workplace contexts, and reflect on how the assignment context influenced the development, organization, etc., of their created messages. Furthermore, students prepared and revised reflections demonstrating workplace writing processes (e.g., invention or defining the problem, planning, drafting, editing, revising) and writing competencies (e.g., developing logical arguments supported by adequate evidence, effective paragraph development, professional writing style, conventions, and document design).

Second, the course used guiding questions that prompted students to reflect on their broader learning across the engineering curriculum (see Table 1).[12] For example, the reflective ePortfolio assignment, organized by university and ABET learning outcomes, used guiding questions to prompt student responses demonstrating chemical engineering skills. For students to make sense of projects and experiences beyond the communication course, guiding questions scaffolded learning from lower- to higher-order thinking. Related to engineering projects, for example, lower-level thinking skill questions asked students about what they did (including when, where, and how) followed by higher-level thinking questions asking why it matters and to whom.

Third, the instructor provided feedback to students on their reflections, including written and voice comments on writing strengths and weaknesses. For example, student feedback included how effectively their reflective ePortfolios provided well-developed short essays supported by clear, substantial, relevant evidence, communicated through coherent paragraphs and a professional writing style. In addition, students received feedback in class through large group discussions on their low-stakes reflections, introducing or reinforcing key writing skills. Fourth, the instructor created clearly defined rubrics with specific expectations: to provide constructive

TABLE 1
Examples of reflective ePortfolio reflective writing prompts for chemical engineering students

What was the context?	Where, in what context, was this project completed? Was it part of a course? Internship? Co-op?
	What were the purposes of the project, as a whole?
	What was the problem or topic your project addressed? Was a project description (or problem) stated, or were you required to identify the problem and describe it yourself?
	What were you required to do to complete the project? How did you prepare for the project? What tasks or steps did you complete? Did you create a management plan?
	What did the project requirements assume that you already knew? Were there pre-requisites regarding terminology, use of equipment, safety standards, etc.?
What did you do?	Did the project require you to design something to address the problem?
	Did your recommendation, plan, or design require you to compare options?
	Did your project require you to determine the resources needed to produce a given product or service?
	Did your research require you to read, understand, and incorporate information from technical sources such as peer-reviewed journals? Which ones?
	Did your research require documentation? Did you comply with established guidelines?
	Did your research require you to use databases in your discipline? Which ones?
	Did your research require you to network with professionals whose expertise would help you solve a problem, compare options, recommend a best solution?
	Did you present any of the information in a graphical form? What was the purpose(s) of these graphics?
	Did this project require you to maintain a level of confidentiality?
What did you learn?	What did you learn (equipment, skills, safety, time management, collaboration, patience) by completing this project?
	What challenges did you face to complete the project? Did anything unexpected happen?
	How did you overcome the challenges? Provide details.
	Did you receive feedback from your instructor or supervisor? If so, what did he or she say?

feedback on essential writing competencies and to direct the development of the ePortfolio. Writing competencies addressed in the rubric included content development according to the audience, purpose, and context; organization; design; graphics; style; and convention. ePortfolio development addressed in the rubric included the required portfolio sections (*e.g.*, overview or cover letter, resume, academic interests, experiences and skills, university and ABET-related learning outcomes).

LITERATURE REVIEW

According to Davis, Davis, Leiffer, McCormack, Beyerlein, Khan, and Brackin, engineers must reflect on what they know, how they learned it, and why it matters in order to problem solve and to transfer learning to new contexts.[13] Therefore, this literature review focuses on reflection's central role in engineering students' professional skill development, professional identity development, and integrated learning. In addition, this section reviews the role of ePortfolios within integrated learning curricula and engineering education.

First, *reflection is central to professional skill development*. Research in engineering undergraduate curricula emphasizes the importance of reflection in developing professional skills, particularly in capstone courses where students complete design projects requiring skill sets they will use as practicing engineers.[13] However, students tend to focus on project completion, not on how and why they problem solve the way they do. Therefore, the National Science Foundation (NSF) funded a project to create Integrated Design Engineering Assessment and Learning System (IDEALS) modules to scaffold formative and summative reflection in a capstone course curriculum. While working on capstone projects, students moved through professional skill sets, reflecting on what works, how it works, and why it works. As a result, they made and expressed sound judgments regarding engineering standards and constraints as well as sound judgments regarding the broader impact of engineering solutions. Assessment examples from programs using the IDEALS modules "illustrate student reflection on past experiences, relating causes and effects, making decisions on actions to achieve goals, taking necessary actions, showing new understandings emerging from experiences, and taking control of thoughts in order to be more constructive."[13]

Second, *reflection is central to professional identity development*. Light, Chen, and Ittelson emphasized the importance of reflection to students' individual professional development, team contributions, and overall professional responsibility.[5] Eliot and Turns analyzed post-surveys from professional portfolio workshops to investigate engineering undergraduate identity-related impacts and processes and identified internal and external frames of reference for professional identity construction.[14] The internal frame of reference focused on students' "emerging realization of their own values and interests as professional engineers," and the external frame of reference focused on students' understanding of future employers' expectations. Last, Magolda and King as well as Light, Chen, and Ittelson advocated that self-authorship, in which students organize, connect, and evaluate information, facilitates identity development.[15,5]

Beyond making connections between information, learners also need to think through how that information helps them to know and understand the world—in other words, to understand how their existing knowledge provides a framework for their understanding, how their values shape those frameworks, and how the relationships they engage in provide alternate perspectives.[5]

Third, *reflection is central to integrated learning*. Reflection encourages students to build "across the curriculum and co-curriculum, from making simple connections among ideas and experiences to synthesizing and transferring learning to new, complex situations within and beyond the campus."[16] Based on cognitive research by Ambrose, Bridges, DiPietro, Lovett, and Norman, Brent and Felder identified five instructional strategies.[17,18] In their fourth strategy, helping students learn to function like experts, they encouraged engineering educators to require students to "reflect on what they learned and what they will do differently in the future. When you first ask them to strategize and reflect, explain why you are doing it and give several good and bad examples of both processes."[18] To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned.

In addition, *creating reflective ePortfolios supports integrated learning*. Continuing with Brent and Felder instructional strategies, engineering educators can design reflective ePortfolios with explicit learning goals, objectives, outcomes, and expectations (strategy two) and scaffold complex tasks (strategy three).[18] In addition, ePortfolios can use structured reflective pedagogy, asking students to outline their problem-solving steps, explain their thinking (metacognition), describe encountered problems, and identify most helpful learning aspects.[19]

Last, *reflective ePortfolios support engineering education*. Recent research on the use of ePortfolios in engineering education includes studies of knowledge construction, identity development, creative behaviors, prior educative experience, and lifelong learning skills awareness and development.[14,20-23] Additional research examined learning portfolios as a collaborative learning application and an assessment tool.[24-26] For example, Dunsmore, Turns, and Yellin analyzed mechanical engineering undergraduate portfolios to investigate how students construct their understanding of engineering.[20] They concluded students perceive engineering practice as real-world knowledge, but knowledge acquired through school as not integral to such practice. Rojas analyzed construction engineering and management graduate portfolios to examine collaborative learning in engineering.[24] The instructor

positively viewed the teaching and learning experience and concluded students "look at the virtual portfolio as a symbol of their achievements, and therefore, they develop a sense of pride that inspires them throughout the semester." In addition, the portfolios provided benefits to prospective students in evaluating the skill set they would learn, to incoming students in benchmarking expected work quality and scope, and to alumni in demonstrating abilities to prospective employers.

This literature review focused on reflection and ePortfolios and situated the study. The next section describes the research design.

METHODOLOGY

Based on the purpose and research questions, this study used a qualitative case study methodology. Qualitative case studies research real-life cases bounded by space and time.[27] Therefore, this study investigated the use of reflective ePortfolios in an undergraduate chemical engineering course during six semesters spanning three academic years. To achieve this purpose, we defined the case (see The Course and Reflective ePortfolio Assignment section), identified participants, and collected and analyzed data.

This study's participants included 313 mostly junior and senior students in the chemical engineering department at Texas A&M University. The students took a technical communication course, CHEN 301: Engineering Workplace Writing, and created reflective ePortfolios as the course's culminating assignment.

Data collection included anonymous post-course surveys initially comprised of seven closed- and open-ended questions (six semesters, 2011-2104, n=313), later expanded to eight questions (two semesters, 2013-2014, n=228). This study used data from four questions: a) Do you believe that reflecting (*i.e.*, writing about your knowledge, skills, and experiences) in the ChemE-folio has enhanced your learning within your degree program? If so, how?, b) What did you like most about creating your ChemE-folio?, c) What did you like least about creating your ChemE-folio?, and the question added for the final two semesters, d) What motivated you to complete your portfolio to the best of your ability (spend time on it)? Data analysis included reviewing the study's purpose and research questions and using Creswell's qualitative case study procedures (see Table 2).[27]

FINDINGS

This study investigated the use of reflective ePortfolios in an undergraduate chemical engineering course. Guided by the research questions and based on the data, this study identified themes related to chemical engineering students creating reflective ePortfolios: perceptions of learning, motivations, and preferences (see Table 3, following page). This section discusses the findings using student quotes as illustrations.

Student perceptions of learning

The first analyzed survey question asked, "Do you believe that reflecting (*i.e.*, writing about your knowledge, skills, and experiences) in the ChemE-folio has enhanced your learning within your degree program? If so, how?"

Survey responses indicated 67% of students believed reflecting very likely or likely enhanced their learning with regard to the chemical engineering program (see Table 4, following page). In addition, this analysis includes data from 13%

TABLE 2
Qualitative case study data analysis and representation applied to this study

Qualitative	Case Study	This Study
Organize data	Create and organize data files	Organized the anonymous student feedback survey responses about the reflective ePortfolio assignment by question, specifically student reflection, motivations, and combined likes/dislikes
Read and memo	Read text, make margin notes, form initial codes	Read survey responses in their entirety for an overall sense of the data
		Focusing on specific questions, read all responses
		Made notes about initial codes
Describe data using codes and themes/categories	Describe the case and context	Drafted an overview of the course and reflective ePortfolio assignment to provide context
Classify data into codes and themes/categories	Establish themes using categorical categorization	Sorted related survey question responses
		Assigned codes
		Grouped related or overlapping codes
		Established themes
		Verified each other's sorting, coding, and themes
Interpret data	Interpret data and develop generalizations of what was learned	Identified major themes, based on greatest numbers of survey responses
		Used the literature to interpret data and generalize findings
Represent data	Present case using narrative, tables, and/or figures	Presented the case
		Represented the findings using participant quotes, tables, and figure

of students who responded unsure, but narratively provided evidence of enhanced learning through reflective ePortfolios. Findings included that students a) connected reflection and learning, b) connected learning to real-world application, c) connected learning to future employability, d) learned about themselves, and e) enhanced communication skills. First, students described how they connected reflection and learning. For example, one student professed new understanding of ABET outcomes:

> "Yes! I honestly never look at ABET outcomes, but looking and reflecting on them helped me understand why professors do some of the things they do for our classes; also helped reiterate why employers ask certain questions."

Another student wrote,

> "Yes, it helped me to understand the purpose and importance of my classes."

Second, students connected the knowledge and skills they were learning to how they would apply such knowledge and skills in the real world. One student shared,

> "Writing my ChemE-folio required me to slow down and take time to reflect on my academic (and other) undergraduate experiences. This reflection has helped me to better understand where I will apply what I have learned as well as its value."

Third, students connected learning to future employability in two ways. First, reflection supported critical thinking about how classroom and work experiences connect and why resulting skills would be useful following graduation. One student summarized,

> "By reflecting on my qualities, I gained a better understanding of what values engineers should possess to succeed."

In addition, for many students, analyzing gained knowledge and skills increased confidence and reaffirmed career choice:

> "It has showed me that I have tools to succeed. It has made me more confident in my ability to excel in chemical engineering."

Second, reflection helped students prepare for interviews with potential employers. Some students used their ePortfolio reflections in job interviews, for example,

> "It made it much easier to talk about myself in my recent interview. I just mentioned each reflection point briefly."

Specifically, students thought through how specific skills relate to future work in chemical engineering and how reflecting in their ChemE-folios better prepared them for job interview questions.

Fourth, students learned more about themselves, including values, attributes, and how experiences shaped them. For example, one

TABLE 3
Major themes emerged from undergraduate chemical engineering reflective ePortfolio surveys

Survey Question	Major Themes	
Do you believe that reflecting (*i.e.*, writing about your knowledge, skills, and experiences) in the ChemE-folio has enhanced your learning within your degree program? If so, how?	Connected reflection and learning	
	Connected learning to real-world application	
	Connected learning to future employability	
	Learned about themselves	
	Enhanced communication skills	
What motivated you to complete your portfolio to the best of your ability (spend time on it)?	Extrinsic • Future • Employability • Course grade	Intrinsic • Self-reflection • Pride • Fun
What did you like most about creating your ChemE-folio?	Reflection	
	Future employability	
	Creativity or creating the deliverable	
What did you like least about creating your ChemE-folio?	Time	
	Technology or tool	

TABLE 4
Students' percentage responses to survey question: Do you believe that reflecting (*i.e.*, writing about your knowledge, skills, and experiences) in the ChemE-folio has enhanced your learning within your degree program?

Semester	Very likely	Likely	Not sure	Unlikely	Highly unlikely	Course responses
2011 Fall	10	16	9	2	1	38
2012 Spring	15	16	12	1	3	47
2012 Fall	10	16	8	1	0	35
2013 Spring	14	12	6	3	0	35
2013 Fall	20	21	9	7	5	62
2014 Spring	15	44	31	5	1	96
Total responses	84	125	75	19	10	313
	27%	40%	24%	6%	3%	100%

student described how reflection enhanced learning:

"I believe it has helped me learn about myself, and how to improve aspects about me. . . . This ultimately will help enhance learning within my degree program."

Another student responded,

"By reflecting on my qualities, I gained a better understanding of what values engineers should possess to succeed."

Last, students reported reflective ePortfolios enhanced communication skills, including effectively expressing themselves in writing. One student stated,

"My writing skills did get better, that's for sure,"

and another commented,

"I feel that I have improved my communication ability from this assignment, and I have a better grasp of new technology."

In contrast, 9% of students believed reflecting unlikely or very unlikely enhanced their learning with regard to the chemical engineering program (see Table 4). In addition, this analysis includes data from 11% of students who responded *unsure*, but narratively provided evidence of no enhanced learning through reflective ePortfolios. For example, some responses indicated students did not feel they were far enough along in their chemical engineering program and, therefore, could not see how reflection yet influenced their learning.

Student motivations

The second analyzed survey question asked, "What motivated you to complete your ChemE-folio to the best of your ability (spend time on it)?"

Students indicated extrinsic and intrinsic motivations. Extrinsically, students first identified future employability as motivation. Specifically, creating reflective ePortfolios prepared students for interviews and provided evidence of knowledge, skills, and accomplishments. For example, one student responded,

"I was motivated by the fact I could use the portfolio to help present my credentials and set myself apart from other job candidates. It was nice to have a finished product I could use after the class ended."

Second, students identified the course grade, of which the reflective ePortfolio comprised 25%, as the primary motivation. In addition to the grade, some students identified motivations prior to or during the creation of their reflective ePortfolios. One student shared,

"At first I was motivated to get a good grade, but as I went through it I began to envision seeing the folio come together."

Other students acknowledged future use,

"I wanted to be able to use the ChemE-folio in the future. I would not have spent the time if it was just for the grade,"

> *"At first I was motivated to get a good grade, but as I went through it I began to envision seeing the folio come together."*
> —Student feedback

and

"Either I was going to do a bad job and not use the ChemE-folio again, or do a really good job so I could use it. I chose the latter."

In contrast to extrinsic, student intrinsic motivations were more self-reflective. For example, one student described,

"The fact that the ChemE-folio is a direct reflection of who I am. I want it to be clear, accurate, honest, professional, and aesthetically pleasing."

Other students expressed pride in their work, especially when they saw the reflective ePortfolio coming together. For example,

"I want to be proud of my work."

and

"It looks good and felt good to see the fruits of my labor."

Last, fun motivated a few students; as one student shared,

"It was fun to do it and I was motivated to do it well since I plan on keeping it for a while."

Student preferences

The third analyzed survey question asked, "What did you like most about creating your ChemE-folio?"

Students generally liked creating reflective ePortfolios and specifically liked the reflection, preparation for future employability, and creativity or creating the deliverable. First, students most liked the reflection, and findings included closely related and overlapping aspects of reflection, such as thinking about self, reminiscing about the past, reflecting and writing about experience, thinking about learning, and learning about self. For example, students wrote,

"The ChemE-folio made me think about my experiences and how to present them," and *"It made me sit down and reflect on my past experiences, especially on how they could apply to a job application."*

Second, students most liked how reflective ePortfolios prepared them for future employability, including job inter-

views and providing a job search tool. Generally, one student acknowledged,

> "The ChemE-folio got me thinking," and asked, "What do I really have to offer employers? What can I talk about in an interview? [I] liked being able to reflect on my academic career, and what I had done at Texas A&M."

Specific to job interview preparation, one student shared,

> "I liked putting what I have [accomplished] on paper and writing it out. It made me think of what I would say instead of stuttering through an interview with only points."

Other students most liked the reflective ePortfolio as a job search tool,

> "It was like creating an online super resume and it is easy to update and track every changing experience and qualification."

Similarly,

> "I liked that it can be used for career purposes and gives me an advantage against other applicants."

Third, students most liked creating a reflective ePortfolio or using their creativity. Several students described creating reflective ePortfolios as "fun" and enjoyed the "creativity" in and "freedom" to design a visual representation of their experiences.

In contrast, the last analyzed survey question asked, "What did you like least about creating your ChemE-folio?"

Students identified time and the technology or tool as dislikes. First, many students least liked the time required to create their reflective ePortfolios, for example,

> "The heavy time commitment; To create a high quality, robust portfolio takes time," and "Very lengthy and takes a lot of time to think and write."

Second, a few students least liked the technology or tool.

Overall, chemical engineering students who created reflective ePortfolios believed such reflection enhanced their learning with regard to the chemical engineering program. They connected reflection and learning, further connected learning to real-world application and future employability, learned about themselves, and enhanced communication skills. Connection to future employability motivated students to create their reflective ePortfolios, in addition to the course grade, pride in work, and fun. Student preferences in creating their reflective ePortfolios divided into likes (reflection and future employability), and dislikes (time required to create such a large project) and, to a lesser extent, the technology or tool used for creation.

DISCUSSION OF THE FINDINGS

The purpose of this three-year qualitative case study was to investigate the use of reflective ePortfolios in an undergraduate chemical engineering course. Student motivations to create reflective ePortfolios included future employability, the course grade, pride in work, and enjoyment. Student preferences divided into likes (reflection and future employability), and dislikes (time required to create such a large project), and, to a lesser extent, the technology or tool. Influenced by such motivations and preferences, chemical engineering students created reflective ePortfolios, perceived enhanced learning, and connected their learning to job knowledge and skills, future employability, and professional identity (see Figure 2).

First, chemical engineering students connected their learning to job knowledge and skills. Creating reflective ePortfolios scaffolded student reflection on their learning, which they connected to job knowledge and skills. This finding reinforces Davis, Davis, Leiffer, McCormack, Beyerlein, Khan, and Brackin's conclusion that engineers must reflect on what they know, how they know it, and why it matters to problem solve and transfer learning to new contexts.[13] For
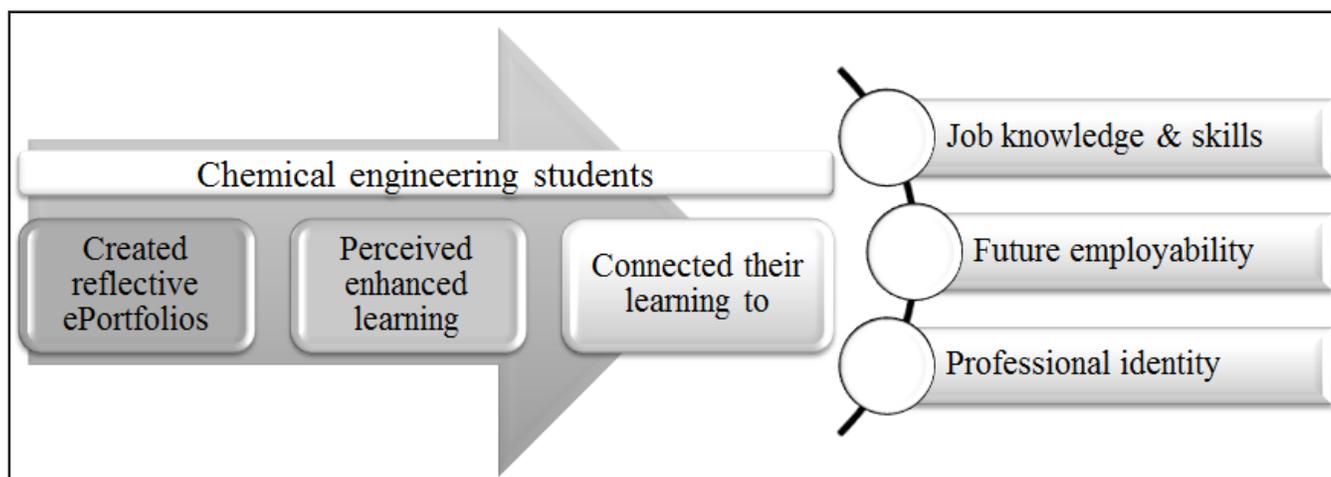
Figure 2. Study findings.

example, students connected ABET-inspired program course learning outcomes to course content and then connected these outcomes to internship experiences. Furthermore, students connected the knowledge and skills they were learning to real-world applications. As Brent and Felder concluded, to develop mastery, students must acquire component skills, practice integrating them, and know when to apply them.[18] In addition, some students enhanced communication skills through their reflections by striving to be clear and concise, yet descriptive, while demonstrating knowledge and experiences in meaningful ways.

Second, chemical engineering students connected their learning to their employability. Creating the chemical engineering reflective ePortfolios scaffolded student reflection on their learning through writing, which they connected to future employability. Students felt better prepared for job interviews because they reflected on their knowledge gained from coursework and experiences, such as capstone projects, studies abroad, or internships. Furthermore, they described how understanding course content and resulting knowledge and skills applied to future chemical engineering jobs. This finding is important because ABET student outcomes reference the ability to effectively communicate in program accreditation standards, and job descriptions often reference such standards, and employers prioritize critical thinking, problem solving, and communication skills when making hiring decisions.[1,2] In addition, students reported reflective ePortfolios provided an effective job application and interviewing tool. ePortfolios address the six areas employers identified for higher education emphasis in student learning: critical thinking and analytical reasoning; complex problem solving and analysis; written and oral communication; knowledge and skill application in real-world settings; locating, organizing, and evaluating information from multiple sources; and innovation and creativity.[3] Furthermore, 80% of employers indicated an ePortfolio would be helpful in the hiring process to demonstrate students' knowledge, skills, and experience.

Last, students connected learning to their professional identity. Creating the chemical engineering reflective ePortfolios scaffolded student reflection on their learning, which they connected to their professional identity as chemical engineers. Students learned about themselves and desired portfolios that professionally and personally reflected them. Guided reflection helped students develop self-authorship and identity by prompting them to ask what they know and how they know it.[5] Eliot and Turns found students constructed professional identities by realizing their engineering-related values and interests.[14] Last, students develop professional identity through self-authorship, by organizing, connecting, and evaluating information.[5,15]

In summary, students believed creating reflective ePortfolios enhanced their learning with regard to their chemical engineering program. Specifically, influenced by motivations and preferences, chemical engineering students created reflective ePortfolios, connecting their learning to job knowledge and skills, future employability, and professional identity.

IMPLICATIONS AND FUTURE RESEARCH

This study investigated the use of reflective ePortfolios in an undergraduate chemical engineering course and offers implications for theory, policy, and practice as well as suggestions for future research. First, the study contributes to the reflection, integrative learning, and reflective ePortfolio literature generally and within engineering and chemical engineering contexts. In addition, the findings contribute to literature on student learning, employment preparation, and professional identity both generally and in a chemical engineering context.

Second, this study contributes to higher education policy and engineering education policy. For example, ABET requirements could expand the accreditation criteria to explicitly include reflective writing and integrative learning exemplified through reflective ePortfolios. ABET reviewers could more clearly see the connection and achievement of program learning outcomes in student reflective ePortfolios. In addition, higher education institutions and engineering colleges and programs can institute cross-curricula reflective ePortfolios to enhance student job knowledge and skill acquisition, future employability, and professional identity development. Furthermore, incorporating reflection throughout engineering curricula will scaffold the development of communication skills from students' first year through their entire college careers.

Last, this study contributes to instructional practice generally in higher education and more specifically in engineering and chemical engineering. For example, instructors can integrate reflective ePortfolios in course-level instructional design to scaffold student reflection and learning and to reinforce writing skills. In addition, they can assist students in strategically selecting what artifacts to include in reflective ePortfolios and prompt reflection and learning. Furthermore, instructors can provide reflective ePortfolio feedback to motivate and support student development in writing and assist with making connections to learning in the discipline. Finally, instructors can model reflection in their teaching to exemplify and reinforce the value of reflection to students.

Based on the findings, chemical engineering students created reflective ePortfolios, perceived enhanced learning, and connected their learning to job knowledge and skills, future employability, and professional identity. For future research, we recommend adding more discipline-specific reflection questions to course components and the reflective ePortfolio assignment to enhance students' understanding and the assessment of engineering conceptual knowledge.

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