International Journal of ePortfolio
https://www.aacu.org/ijep

2026, Volume 16, Number 1, 113-123
ISSN 2157-622X

Asked You to Write It Down for Me: Integrating Core Knowledge and Critical Thinking Through ePortfolio in Engineering Writing

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In this study, we explore the integration of core disciplinary knowledge and critical thinking (CT) using ePortfolios in undergraduate engineering education. Leveraging a framework adapted from Pierce et al. (2014), we developed the CORE-CT Grid, an assessment matrix to guide and evaluate student learning in an undergraduate engineering course with writing-intensive and CT-based learning outcomes. Through a case study of one first-year engineering student's ePortfolio, we examined how structured reflection prompts and the CORE-CT Grid supported the development of disciplinary knowledge and CT across assignments. Two primary themes emerged, illustrating how ePortfolios can move students from personal/general engagement to relational/specific understanding.

Educators often feel caught between two seemingly mutually exclusive decisions: teach students core disciplinary knowledge, or teach them critical thinking (CT), a "cognitive skill related to rational judgment" (Tahira & Haider, 2019, p. 3) that can be demonstrated through students' faculties to "identify issues and assumptions, recognise important relationships, make correct inferences, evaluate evidence or authority, and deduce conclusions" (Tsui, 2002, p. 743). Despite such a decision feeling like a zero-sum game, research has suggested that educators can, and should, treat the decision as interdependent. For instance, scholars studying learning transfer, such as Driscoll and Wells (2012), Wardle (2007), and Yancey et al. (2014), have argued that metacognition (i.e., thinking about thinking), a foundational component of CT, facilitates the learning of disciplinary content (Flavell, 1979; Kuhn, 1999). In fact, in one writing program, instructors observed that regular reflective discussions—questions like "Why did you do this assignment?" and "How might you use this skill in other courses or beyond college?"—prompted students to make explicit links between class activities and broader learning, even sharing personal examples (Jenson, 2011, p. 54). In this study, Jenson (2011) reported that carefully designed reflection tasks helped first-year students reframe their learning: "Instead of viewing assignments in isolation, students began connecting writing strategies learned in their English course to other classes and life situations" (p. 56).

Portfolios and ePortfolios, the "digitization of print portfolios" (Torres & McKinley, 2023, p. 1), allow students to collect artifact-based evidence of their learning and organize it in a dedicated print and/or digital space (Alexiou & Paraskeva, 2019; Gearhart & Wolf, 1997; Jenson, 2011). When students assemble textual artifacts of their learning and reflect on the artifacts they assembled—why they selected specific artifacts and how those artifacts evidence their learning—they practice metacognitive awareness, offering opportunities for knowledge transfer (Yancey, 2017).

Knowledge transfer is especially vital in the engineering discipline. Engineering students must gain core disciplinary knowledge—encompassing technical competencies, theoretical foundations, and procedural fluency—and apply it at the highest level to protect human life. Eliciting core knowledge in students comes with challenges, though, as STEM faculty frequently report feeling pressure to "cover content," which can limit time spent on broader processes such as CT (Henderson & Dancy, 2007, p. 020102; Hora, 2014). Simultaneously, a growing concern exists among employers about the readiness of graduates to apply knowledge in complex, real-world scenarios (Association of American Colleges and Universities [AAC&U], 2018; National Association of Colleges and Employers [NACE], 2019). Reports from AAC&U (2018) and NACE (2019) have highlighted perceived deficits in skills that employers desire, such as CT, ethical judgment, oral communication, self-motivation, written communication, and real-world application of skills and knowledge. Internalizing such perceptions as instructors, and feeling the need to help students develop these skills, can add further pressure to faculty and curriculum designers in their quest to adhere to content coverage at the expense of CT. Given these challenges, we wondered how ePortfolios, when supported by a structured assessment matrix, could scaffold student development in both domains. More specifically, how might ePortfolios aid engineering students in metacognitive awareness and help them transfer knowledge and skills from one context to another, better preparing them for their future careers?

Pedagogical frameworks, such as Webb's (1997) Depth of Knowledge, and Fink's (2003) Taxonomy of Significant Learning, have emphasized the importance of reflection, integration, and self-awareness in achieving higher-order learning outcomes. Portfolios activate reflection to promote integrative learning and knowledge transfer (Yancey, 2017, 2023). When students assemble artifacts from diverse courses and reflect on them together, they practice making

knowledge connections. In fact, Buyarski and Landis (2014) found that in ePortfolios for a first-year seminar, students often displayed "evidence of learning meeting more than one outcome" (p. 53). Chen and Penny Light (2010) similarly argued that ePortfolios help "promote deep learning and knowledge transfer by fostering the student's ability to make connections between . . . learning experiences in a variety of classroom, workplace, and community settings" (p. 37). Consistent with this knowledge, Yancey (2023) reported that students who were asked to reflect on an internship within their portfolio explicitly noted how that experience affected multiple contexts—professional, academic, personal, and civic—and found meaning "through multiplicity" (p. 18), seeing links across classroom learning, internship tasks, and future goals. ePortfolios give students a space to assemble and compare their experiences, which research has shown strengthens transfer (Torres & McKinley, 2023; Yancey, 2017, 2023).

In this article, we explore the integration of core disciplinary knowledge and CT using ePortfolios in undergraduate engineering education. Leveraging a framework adapted from Pierce et al. (2014), we discuss the development of our assessment matrix, the CORE-CT Grid, to guide and evaluate student learning in an undergraduate engineering course with writing-intensive and CT-based learning outcomes. Through a case study of one first-year engineering student's ePortfolio, we examine how structured reflection prompts and a rubric-style matrix supported the development of disciplinary knowledge and CT across assignments. Resulting knowledge from the current study helps readers see the potential of ePortfolios and their role in facilitating growth from accurate but limited disciplinary-related reflections to sophisticated and metacognitive disciplinary insights, adding to existing literature on ePortfolios and how they aid in transfer of knowledge and skills. The following section details the framework we drew from to design and eventually assess student learning in the examined undergraduate engineering course.

Framework Development

The framework for assessment in the current study was based on the EFFECTs model, developed at the University of South Carolina (Pierce et al., 2014), which integrates technical and professional engineering skills, combining employer expectations from internship databases, ABET accreditation criteria, and evidence-based learning outcomes for CT. The adapted CORE-CT Grid (Figure 1) used in the present study defines levels of:

- Core knowledge (ranging from vague to sophisticated); and
- CT (unreflective, reflective, and metacognitive).

The EFFECTs framework was developed for use in engineering classes to "develop critical thinking skills, collaborative teamwork skills and improv[e] the transfer of core knowledge in engineering classes" (Caicedo et al., 2008, para. 1). Depth of core disciplinary knowledge and the ability to critically think about solutions tend to be related (Caicedo et al., 2008). Thus, the purpose of the EFFECTs framework is to simultaneously promote students' core disciplinary knowledge, as well as their engineering judgments.

Engineering judgment, which goes "beyond the development of a solution," is "a product of critical thinking regarding the appropriateness of the solution" (Huynh et al., 2013, p. 2); this judgment can be challenging to teach and assess. Huynh et al. (2013) suggested that engineering judgment can be promoted with clear benchmarks for how students should appraise solutions. When students direct their learning toward clear benchmarks, with a goal of self-assessment of their learning (e.g., their ability to critically think about solutions), they are engaging in co-regulatory learning, a process in which students actively seek and apply feedback to advance their learning (Andrade & Brookhart, 2021; Torres, 2022). Ample research supports the use of rubrics to facilitate co-regulatory learning, so the CORE-CT Grid extends the EFFECTs framework to support students and educators in formative assessment.

That said, rubrics certainly deserve criticism when they are used in ways that reduce teaching and learning to isolated elements, divorced from their relational meaning. What this criticism rightly points out is that learning is not just the sum of its parts. As Andrade and Brookhart (2021) contended, learning is inherently relational, which is why the authors offer co-regulatory learning as an extension of the more individualistic self-regulated learning. Rather than "teacher-centered" or "student-centered" decisions—like "content" versus "critical thinking"—we can, instead, examine the complex interactions that support learning. When rubrics are designed to reflect relational elements within a learning process, Gotch (2022) contended that they can also improve educators' assessment literacy, the ability to fluently assess student learning in various situations using a variety of available methods. Like engineering judgment, assessment literacy goes beyond instructional solutions to thinking critically about the appropriateness of a solution. Students and educators benefit from rubrics that promote co-regulatory learning and emphasize complex interactions between elements in the learning environment.

Like the EFFECTs framework, the CORE-CT Grid is centered on a driving question (i.e., a design problem) and teaches the student the core knowledge and CT necessary to create and evaluate a working solution for that design problem. In between steps, the students

Figure 1
The Adapted CORE-CT Grid

Core	CT	*Unreflective*	*Novice*	*Reflective*	*Metacognitive*
	Vague	Discusses disciplinary concepts but without specific details, terms, or connections to previous experience or evidence.	Draws a general conclusion with many misconceptions from at least one observation. Connects observation to previous experience or cited evidence.	Draws a general conclusion with many misconceptions from multiple observations. Provides valid reasoning for the conclusion. Makes multiple connections with previous experience and cited evidence.	Draws a well-supported but still general conclusion with many misconceptions from multiple observations. Explains how connections with previous experiences and cited evidence may predict future situations.
	Inaccurate	Discusses assignment-related concepts but with only one or two specific details, terms, or connections to previous experience or evidence.	Draws a general conclusion, even with more than three misconceptions, from at least one observation. Connects observation to previous experience or cited evidence.	Draws a general conclusion, even with more than three misconceptions, from multiple observations. Provides valid reasoning for the conclusion. Makes multiple connections with previous experience and cited evidence.	Draws a well-supported, but still general, conclusion with more than three misconceptions from multiple observations. Explains how connections with previous experiences and cited evidence may predict future situations.
	Accurate	Discusses instructional concepts using mostly specific details, terms, or connections to previous experience or evidence.	Draws a general conclusion, with only one or two misconceptions, from at least one observation. Connects observation to previous experience or cited evidence.	Draws a general conclusion, with only one or two misconceptions, from multiple observations. Provides valid reasoning for the conclusion. Makes multiple connections with previous experience and cited evidence.	Draws a well-supported, but still general, conclusion with only one or two misconceptions from multiple observations. Explains how connections with previous experiences and cited evidence may predict future situations.
	Sophisticated	Discusses engineering concepts using specific details, terms, or connections to previous experience or evidence.	Draws a specific conclusion from at least one observation. Connects observation to previous experience or cited evidence.	Draws a specific conclusion from multiple observations. Provides valid reasoning for the conclusion. Makes multiple connections with previous experience and cited evidence.	Draws a well-supported, specifically stated, conclusion without any misconceptions from multiple observations. Explains how connections with previous experiences and cited evidence may predict future situations.

Note. Adapted from Pierce et al. (2014).

engage in reflective journaling, in which they synthesize the material presented in the previous block of instruction and how the material affects their current solution to the design problem. EFFECTs are designed for two to five instructional periods and have been used in geotechnical, environmental, and structural engineering, among other branches. The resultant product is a final design report where students use and reflect on the experimental learning, core knowledge, and CT they have developed during the EFFECT (Huynh et al., 2013).

While the EFFECTs framework predates the widespread adoption of ePortfolios, its focus on reflective writing made the rubric developed for it a great fit, especially as improvements in effective communication were some of the principal benefits found from using the EFFECTs framework (Pierce et al., 2014). In fact, awareness and self-identification of learning were cited in one of the stated goals of the journaling, as the rubric was developed so instructors could "provide formative feedback on the worksheets

and journals" and so students could "collate [the] information into a measurement of self-learning that [was] documented in the final report" (Pierce et al., 2013, p. 289). The EFFECTs framework is consistent with Andrade's (2001) findings that "simply handing out and explaining instructional rubrics can increase students' knowledge of the criteria for writing as communicated by the rubric, but that translating that knowledge into actual writing is more demanding" (p. 8). The holistic nature of the CORE-CT Grid illustrates the importance of translating knowledge dimensions into writing.

As meaningful development in engineering judgment requires core knowledge and CT attainment (Pierce et al., 2013), the CORE-CT Grid draws from the EFFECTs framework for multilayered assessment (Facione & Facione, 1994). Each cell of the matrix contains detailed descriptors, allowing students and instructors to evaluate thinking across multiple assignments—a key reason why we chose the EFFECTs model for this study.

The next section describes the Methods applied throughout the present study to aid future researchers in replicability and/or expansion of our current work. The section also details case study research, helping to justify our decision to present an analysis of one class participant in the present study.

Methods

Study Focus, Research Questions, and Course Context

In the current study, we investigate how structured reflection prompts and the CORE-CT Grid supported engineering students in developing core knowledge and CT across assignments. We also consider how asking engineering students to create, organize, and publish ePortfolios that feature artifacts of their learning and reflective memos that speak to their learning processes might aid them in transfer. Given these foci, we posed the following research questions:

1. How might structured reflection prompts and the CORE-CT Grid support engineering students in:
    a. Developing core knowledge and CT across assignments?
    b. Transferring core knowledge and CT across assignments?
2. What can those studying the role of ePortfolios in the classroom learn about teaching and assessing the related development of core knowledge and CT?

To answer these research questions, we focused on a first-year engineering course at Quinnipiac University, The World of an Engineer (ENR 110). This course, taken by students in the fall semester, emphasizes design-based group projects, writing-intensive assignments, and team-based learning, engaging students in exercises involving CT, ethical judgment, oral communication, written communication, and real-world application of skills and knowledge.

ENR 110 also requires students to develop, revise, and publish an ePortfolio by the end of the semester; this ePortfolio includes artifactual evidence of their learning throughout the course, combined with reflective memos. To create the memos, students are instructed to reflect on how the artifacts included in their ENR 110 ePortfolio capture moments of their learning and to identify and detail disciplinary concepts that were realized by working on certain class assignments. The aim of the reflective memos is to engage students in metacognitive processes, ideally leading students to realize how what they learned and applied in ENR 110 could be called upon and used in other contexts. Given the aims of the course and the ePortfolio expectations, we felt investigating ENR 110 students' ePortfolios could offer insights about the development of students' disciplinary knowledge and CT across assignments, offering clues about potential learning transfer.

Participant Recruitment

After securing Institutional Review Board (IRB) approval to conduct the current study at Quinnipiac University, our research assistant asked students at the start of ENR 110 whether they would be interested in allowing us to examine their ePortfolios after the completion of the semester. Students were informed of the study's aims and of the significance of the ePortfolio they would create by the end of ENR 110. Students were then provided IRB-approved consent forms, where they indicated their decision to allow or not allow their ENR 110 ePortfolios to be examined by us after the semester concluded.

The Consenting Participant, Case Study Research, and Justification for a Single-Case Design

One ENR 110 student, Juliana Webster, consented to the study, offering her ePortfolio for investigation. Given that we had one consenting participant, methodologically, we settled on a case study approach. Case research, or case study, involves "a scientific method to derive explanations of organizational phenomena" (Bhattacherjee, 2012, p. 93). Explanations offered about the phenomenon of focus are rich, detailed, and contextualized, especially when exploring the phenomenon longitudinally. As argued by Bhattacherjee (2012), the case study approach is particularly well suited to:

> exploratory studies for discovering relevant constructs in areas where theory building [is] at the formative stages, for studies where the experiences of participants and context of actions are critical, and for studies aimed at understanding complex, temporal processes (why and how of a phenomenon) rather than factors or causes. (p. 94)

Additionally, a single-case design is appropriate if "the situation is unique or extreme, if it is revelatory (i.e., the situation was previously inaccessible for scientific investigation), or if it represents a critical or contrary case for testing a well-formulated theory" (Bhattacherjee, 2012, p. 94). Given the one consenting participant and our desire to work toward theory building about the development of core knowledge and CT, ePortfolios, and knowledge transfer, a case study approach was well suited for our study.

Data Collection and Analysis

At the end of the fall semester, Ms. Webster submitted her ENR 110 ePortfolio in a password-protected repository site, overseen by our research assistant. Once grades were submitted, we began reading and analyzing Ms. Webster's ePortfolio.

First, to familiarize ourselves with Ms. Webster's ePortfolio and to identify the artifacts submitted for analysis, we each read her work separately, which included:

- A reflection on disciplinary core knowledge;
- A piece exploring writing and thinking in engineering; and
- A general capstone reflection, drawing together previous insights.

After reading these artifacts, we proceeded into the next step of analysis—descriptive coding (Saldaña, 2009). To carry out this stage of analysis, we engaged in a three-part process.

Part One of Coding

Individually, we began by carefully reading the discourse found in each artifact. After reading the artifacts, we placed all discourse in a Google Drive document and, following Tesch (1990), summarized the general topics in a word or short phrase (i.e., the general topics included in the reflection on disciplinary core knowledge; the general topics exploring writing and thinking in engineering; and the general capstone reflection). Next, we read through the discourse and the summaries of each of the discourses, further summarizing the general topics included in each of the discourses. Then, the words or phrases (i.e., codes) were generated after the second examination of the discourses, which we then combined, refined, and recorded in an initial electronic codebook.

Part Two of Coding

Before manual coding commenced, we tested intercoder agreement for the coding schemes developed for each artifact. To carry out this process, we met via Zoom to discuss and clarify procedures before manually coding three randomly selected discourses from each of the artifacts (nine samples total). To randomly select each of the discourses, and to remove bias from the selection, Ari and JT collaborated, first numbering all sentences in each of the artifacts. They then used a random integer generator, random.org, to identify the samples to manually code. Once the samples were identified, Ari and JT communicated to Marissa the sentences in each sample that would need to be manually coded. Each of us exchanged copies of our initial, electronic codebook before reviewing the coding schemes together, ensuring that we understood the codes. We then discussed and agreed upon our five-step manual coding process:

1. Locating the randomly selected sentences from each of the artifacts;
2. Printing the artifacts that included the sentences;
3. Physically cutting and pasting the sentences on a poster board, placing them on the left side of the board, and grouping together and separating out the samples from each artifact;
4. Writing down in pencil the initial codes developed for all three artifacts and placing them right across from each of the artifact groupings on the right side of the board; and
5. Using multiple Crayola crayons, coding each discursive sample, highlighting passages of the data, and connecting those passages with a line to a penciled code, reflecting the general idea included in the discourse from each artifact.

Once manual coding was completed, we moved into part three of the coding process.

Part Three of Coding

We met again via Zoom to review the coding schemes, noting the total agreements and disagreements that we had when coding each of the discourses. Using the total number of agreements and disagreements, we calculated intercoder agreement for each set of sample discourses. We used the following formula to calculate intercoder agreement:

$$\text{Intercoder Agreement} = \frac{\text{Number of Agreements}}{\text{Total Number of Ratings}} \text{ x } 1000$$

We underwent two rounds of norming to further refine problematic codes, eventually obtaining intercoder agreement above our 80% target. We then recorded all revised codes in one electronic codebook before manually coding the remaining discourse in the three artifacts.

Initial codes focused on Ms. Webster's expressions of how she was learning core knowledge and CT. Descriptive codes (e.g., personalizing; relating) were organized around two distinct themes, explored below. Like the general theme of this article—that core knowledge and CT are related, rather than opposite of teaching and learning decisions—the below themes, the personal/general and the relational/specific, initially signal opposite meanings, yet they emerge as related outcomes.

Findings

Ms. Webster's experiences assembling an ePortfolio offer a useful case study in how portfolios present pedagogical opportunities to cultivate critical thinking and content knowledge. Across Ms. Webster's experiences, her reflections revealed a shift from vague or descriptive accounts of learning to increasingly sophisticated and metacognitive insights. The ePortfolio became a space where she not only documented assignments, but also reinterpreted them, gradually constructing a more integrated view of herself as an Engineer. The below narrative is articulated chronologically, but that does not mean the themes should be read as developmentally linear or causally related. We simply report them in chronological order.

The Personal/General

At the beginning of the course, Ms. Webster's reflections were tentative and general. In her first portfolio entry, she admitted, "Before coming to Quinnipiac University, I did not take any engineering courses, in fact I only took physics." This acknowledgement of her limited background framed her early attempts at connecting with engineering content. She described terms and concepts vaguely and confessed that "Some of it [the content] doesn't feel natural." Ms. Webster expressed not just a lack of confidence in what she could recall, define, or even apply, but she also expressed an uncomfortable relationship (e.g., "doesn't feel natural") with the content. Noticing Ms. Webster's position on the CORE-CT Grid, as well as her own reflections, the instructor reinforced the notion that engineering does not always have a correct answer and that uncertainty can lead to new perspectives.

While describing later projects, Ms. Webster noted that "Our app project, bridge project, and rocket project showed me new ways to think and act as an engineer," and reflected that "I found my way of critical thinking and creativity to design the app, bridge, and rocket." These statements demonstrated her enthusiasm and willingness to grow, even if they remained focused on personal impressions. The CORE-CT Grid reflected Ms. Webster's "accurate" reflections but also the limited depth of her general conclusions. The instructor encouraged Ms. Webster to connect her personal impressions with disciplinary content, encouraging co-regulatory learning with clear next steps and continued reflective practice.

By the midpoint of the course, Ms. Webster's ePortfolio showed a marked progression toward disciplinary sophistication. Her writing demonstrated awareness, not only of what she did, but of why it mattered in the field of engineering. For instance, she observed, "Writing allows the engineer to communicate their design ideas, create instructions for the user, explain test results and provide information." Here, she situated writing as a professional competency, rather than merely a classroom requirement. She also recognized the collaborative dimensions of engineering, stating, "Learning about each discipline showed me what it took to be successful with projects, writing, and teamwork." These reflections moved beyond self-discovery to articulate the functions of communication and teamwork in engineering practice. They represented a "sophisticated" grasp of core knowledge, using disciplinary terms, and linking them to authentic applications.

The Relational/Specific

Ms. Webster's thinking also became more relational and contextual at this stage. In fact, when reflecting on teamwork, Ms. Webster noted, "Working in teams helped me meet new people and expand my knowledge by listening to what my peers suggested throughout our projects." This insight highlighted her ability to integrate peer learning into her development—a shift from merely describing her experience to explaining how collaboration enhanced her understanding. Though still reflective, rather than metacognitive, her midpoint entries revealed an expanding capacity to see herself as a learner and a participant in disciplinary practices.

By the capstone reflection, Ms. Webster's ePortfolio displayed a clear metacognitive stance. She characterized writing as central to engineering identity, reflecting, "The writing for engineers is art in words. . . . Each factor of the writing produces a piece that relates to their projects." This metaphor showed a nuanced understanding of communication as technical and creative. She further explained, "Now that I understand how to go about writing in engineering, I appreciate how important it is." These comments indicated not just disciplinary knowledge, but a reflective appreciation of its role across contexts. Most tellingly, she generalized her learning to broader domains: "While writing the

assignment, I was able to think about the many things that I learned . . . which I am able to apply to software engineering, my education, and life in general." Here, she demonstrated transfer, extending insights about communication and problem-solving beyond ENR 110 and into her academic trajectory and future career.

Taken together, Ms. Webster's case illustrates how the ePortfolio facilitated growth, from accurate but limited reflections to sophisticated and metacognitive insights. Early entries emphasized discovery and personal growth; midpoint reflections, showed developing fluency in disciplinary discourse. Capstone reflections revealed an ability to generalize, predict, and transfer learning through related contexts. By assembling and reflecting on her ePortfolio, Ms. Webster transformed isolated assignments into a coherent narrative of professional identity formation, evidencing the power of purposeful ePortfolio design to foster integrative learning in engineering education.

Discussion

The structured use of the CORE-CT Grid helped scaffold Ms. Webster's ability to reflect meaningfully on course content and learning processes. By using consistent language and categories for assessment, the framework encouraged her to link learning across assignments and to articulate growth in conceptual and cognitive domains.

Recent research across higher education disciplines has shown that portfolios, electronic or otherwise, can powerfully support critical thinking and integrative learning (Jenson, 2011; Torres & McKinley, 2023; Yancey, 2017, 2023). Conceptually, a portfolio is a purposeful assemblage of student learning. In effect, assembling a portfolio is a rhetorical act: Students select, organize, and contextualize artifacts to present a persuasive narrative about their skills and understanding (Gallagher & Poklop, 2014). By planning for multiple audiences—peers, instructors, employers, or other students—learners practice key rhetorical moves, such as designing coherent structures, situating content in context, and developing a flexible use of voice to meet diverse audience expectations (Gallagher & Poklop, 2014). This rhetorical stance encourages students to think strategically about why they learn and for whom, not just what they learned.

In our study, we examine how ePortfolios function as rhetorical assemblages that foster CT about course content. CT is typically defined as an intentional, evidence-based reasoning process that is best observed using performance assessments, such as artifacts assembled in a portfolio (Braun et al., 2020, p. 2). ePortfolios foster CT skills by requiring students to reflect on their work over time and justify their learning. Our study extends results from Bowman et al. (2016), namely, that when students have a mental framework for thinking about their learning, they exhibit greater awareness of connections beyond the course and more frequently relate their learning to future personal or career goals (p. 19). Similarly, when instructors have a clear mental framework for assessment, often in the form of a rubric, they gain improved assessment literacy, helping them make more accurate and timely decisions about students' learning needs (Gotch, 2022). For students and instructors, these reflective practices cultivate metacognition and deeper learning (Flavell, 1979).

As Ms. Webster considered how she learned and why her engineering assignments mattered, she practiced co-regulation and critical analysis. Consistent with co-regulatory learning, she applied feedback she received from peers—in the form of different design ideas, comments, questions, and so forth—as well as from her teacher (Andrade & Brookhart, 2021). As her understanding of core knowledge grew, she evaluated and incorporated diverse perspectives and appraised solutions using engineering judgment.

Bowman et al. (2016) reported that ePortfolios led students to make notably more connections to career or personal goals and to view their learning as linked across disciplines (p. 21). As a result, working on an ePortfolio transformed learning into a continuous, contextualized process, rather than a set of disconnected tasks. Our research suggests that purposefully designing portfolios can advance content knowledge and CT. To implement portfolios effectively across disciplines, we offer the following recommendations.

Recommendations

The CORE-CT Grid created the structure for the portfolio. The value of the process was not so much the collection of materials that typically comprises portfolio assessment, but rather what the portfolio was designed to do, cognitively and materially. The CORE-CT Grid determined sample selection, as well as how students composed and assembled samples. It provided an illustration of metacognition.

To effectively operationalize this illustrated metacognition, educators can use the structural framework of the ePortfolio to support two primary thematic dimensions of integrative learning, in a way that aligns with Barber's (2023) tripartite model of integration: connection, application, and synthesis.

The personal/general theme captures the introductory phase of integrative learning, where students transition from tentative, highly subjective disclosures of identity to broader structural awareness of disciplinary expectations. According to Barber (2023), this initial stage relies on helping students establish connections and discover similarities between ideas and their lived

experiences, even as those ideas remain conceptually distinct from one another. Educators can structurally support this theme through targeted audience awareness, personal reflection, and scaffolded practice, connecting reflections with disciplinary knowledge.

A central consideration in effective portfolio design is clarifying purpose and audience. Students benefit from knowing not only why they are creating a portfolio but also who is expected to engage with it. Because ePortfolios often serve multiple audiences—faculty, peers, external reviewers, and the students themselves—faculty should emphasize audience awareness early in the process (Gallagher & Poklop, 2014). Helping students develop rhetorical strategies, such as structuring their portfolio coherently, contextualizing artifacts through reflective introductions, and adjusting tone for different readerships, enables them to understand the portfolio as a narrative of learning, rather than as a static collection of assignments. This structured focus helps students anchor new learning with personal connections, even as they make general conclusions that lack professional sophistication.

To help students bridge the gap between their initial personal anxieties and broad, sometimes vague, core knowledge, educators must provide explicit reflective prompts that allow them to practice disciplinary discourse. Reflection is most powerful when it is intentional and explicitly connected to other contexts (Yancey, 2017, 2023). Embedding regular prompts throughout the portfolio process encourages students to practice terms, concepts, and ideas in low-stakes, but authentic, settings. Bowman et al. (2016) and Jenson (2011) highlighted that guided reflection produces richer, more integrative thinking. These prompts should, therefore, be woven throughout the curriculum, rather than left to the final stages of portfolio assembly. Early prompts should challenge students to examine personal artifacts from their home or lived experiences and contrast them with disciplinary definitions, helping them contextualize their general impressions.

The most effective portfolios are scaffolded across time, rather than assembled in a single assignment. Sequencing portfolio tasks—beginning with basic artifact collection, moving through early reflections and peer feedback, and culminating in synthesis—ensures that students develop sophistication gradually. In the personal/general phase, early scaffolding gives students permission to document their raw impressions and limited content backgrounds, establishing a safe, developmental baseline from which their disciplinary fluency can expand.

As students progress, their learning shifts toward the relational/specific theme, marked by localized peer integration and advanced metacognitive insights regarding knowledge transfer. Structurally supporting this theme aligns with Barber's (2023) secondary and tertiary dimensions of integration: application (i.e., using knowledge from one context in another) and synthesis (i.e., creating new knowledge by unifying disparate domains). Educators can structurally drive this theme through contextualized rubrics, multi-setting artifact integration, and systemic institutional support.

To push students from general descriptions to highly specific, relational arguments, assessment must explicitly value higher order reasoning. Assessment practices should also be aligned with the dual goals of disciplinary learning and CT. As Kelly-Riley et al. (2016) noted, robust scoring frameworks incorporate rhetorical knowledge and CT as evaluative criteria. When students understand that reflective analysis, synthesis, and metacognition are valued alongside disciplinary content, they are more likely to approach the portfolio as an opportunity for higher order reasoning. Transparent rubrics emphasizing these traits can provide consistent expectations and reinforce the integrative purpose of portfolio work, holding students accountable for the specific, relational claims required in capstone reflections.

Structuring spaces for boundary-crossing artifact collection directly mirrors Barber's (2023) emphasis on breaking down the borders between academic affairs and lived experiences. Portfolios are most meaningful when students recognize their relevance beyond the classroom. Encouraging them to include artifacts from internships, co-curricular activities, or civic engagement opportunities highlights the applicability of academic skills to diverse real-world contexts. Yancey (2023) found that students often discovered the value of their learning by considering how it resonated across personal, professional, and civic dimensions. Such reflection allows students to frame their education as a holistic process with enduring impact.

The progression into deep metacognition requires a dedicated space for capstone synthesis. Morreale et al. (2017) demonstrated that capstone ePortfolios in general education contexts foster significant gains in CT and curriculum integration when they build on earlier stages of reflection. Progression is, thus, key: Students should encounter the portfolio as an evolving practice, not an isolated product. By the capstone stage, educators should shift prompts from asking students what they learned to asking how specific competencies (such as communication or peer collaboration) transfer to future professional trajectories.

To ensure both themes emerge systematically, institutions must move away from treating ePortfolios as isolated, classroom-specific tasks and, instead, establish a sustained infrastructure that mirrors Barber's (2023) holistic vision of integrated educational spaces. The successful implementation of portfolios also requires adequate support. Faculty must receive guidance on the technological platforms and pedagogical strategies that

make portfolios effective. As Yang and Wong (2024) emphasized, student-centered pedagogy, clear purposes, and examples of strong portfolios are essential for effective implementation. Without this support, faculty and students may perceive portfolios as burdensome, rather than transformative. Structured workshops, resource libraries, and peer mentoring can address this gap and build confidence.

Finally, portfolio use should be embedded in a broader culture of reflection within an institution. When reflective practices are valued across programs and reinforced at multiple points in a student's academic journey, portfolios become more than isolated assignments. Morreale et al. (2017) argued that in capstone contexts, portfolios help counteract the fragmentation of general education by underscoring connections among courses. Extending this approach institution-wide can foster coherence across disciplines and signal to students that integrative, reflective learning is central to their education.

Conclusion

When supported by clearly articulated frameworks, such as the CORE-CT Grid, ePortfolios can facilitate the integration of disciplinary knowledge and CT in engineering education. This approach offers promising implications for assessment, instructional design, and student identity development in STEM fields.

Beyond its immediate application to a first-year engineering course, the CORE-CT Grid model highlights the broader potential of integrating structured frameworks with portfolio pedagogy. By giving students consistent criteria for assessing disciplinary content and CT, educators can foster metacognition and encourage transfer across courses and contexts. This alignment is particularly important in STEM fields, where faculty often feel pressure to "cover content" at the expense of higher-order reasoning (Henderson & Dancy, 2007, p. 020102). Portfolios can serve as dynamic platforms for connecting content knowledge and CT, transforming static assignments into a rhetorical assemblage that students consciously craft, linking disparate learning experiences into an integrated whole. Empirical studies have consistently demonstrated that when portfolios require reflection on multiple contexts, students show gains in metacognition, transfer, and higher-order thinking (Bowman et al., 2016; Buyarski & Landis, 2014). By thoughtfully scaffolding portfolios—with clear audiences, reflection prompts, and assessment aligned to integrative outcomes—educators across disciplines can leverage this pedagogy to deepen student learning. With such purposeful design, portfolios become more than assessment tools; they become catalysts for students to think critically, make connections, and own their learning journey.

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Acknowledgments

This scholarship was supported by a 2020–2021 Conference on College Composition and Communication Emergent Researcher Award grant. We thank the organization for their support, along with Michelle LaFrance, for her mentorship and early feedback on this article. We would also like to thank our former research assistant, Oveen Joseph, for his time, commitment, and work in helping us prepare this text. Finally, we thank the anonymous reviewers of this journal for their time and service.

The current study received IRB approval from Quinnipiac University on August 8, 2020, and was approved under exemption from federal regulations. It satisfies the criteria for exempt category 1, "research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices" (45 CFR 46.104 [d][1]).

A pseudonym has been used so that our study participant remains anonymous. We have been given permission by our participant to quote from her written artifacts. As such, her original language has been retained, including errors.