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Integrating Multidisciplinary Project-Based and Experiential Learning in a First-Year Engineering Course to Strengthen Design Thinking and Professional Identity

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Abstract

This Complete Evidence-Based Practice paper presents the design, implementation, and assessment of a multidisciplinary, project-based learning framework embedded within a first-year Introduction to Engineering course. The study examines how structured experiential learning combined with reflective digital portfolios enhances student engagement, communication skills, professional identity formation, and perceived connections to authentic engineering practice during the critical first year of engineering education.

Motivation: Under ABET 2024 standards emphasizing teamwork and professional communication, this study investigates whether combining project-based learning with structured digital portfolios yields measurable gains in first-year students' ability to articulate engineering practice, communicate technical ideas, and develop an emerging professional identity.

Background: Informed by constructivist and situated learning theories, the redesigned curriculum bridges traditional instruction and authentic engineering practice through four sequenced, hands-on projects: civil engineering design-build, environmental sustainability, robotics-based mechanical/electrical challenges, and developing-world engineering design. Structured reflection, team collaboration, and digital portfolio documentation guide progressive skill building aligned to ABET learning outcomes.

Methods and Assessment: A mixed-methods approach combined pre- and post-course surveys (n = 10 matched pairs; n = 12 post-only respondents) measuring self-efficacy, engineering identity, and teamwork confidence, with qualitative evidence from reflective journals, portfolio artifacts, and instructor observations. Rubric-based assessment aligned deliverables to ABET outcomes for design, teamwork, and communication.

Results: Matched pre/post analysis revealed moderate gains in students' perceived connection to real-world engineering practice (dz = 0.55), comfort writing technical reports (dz = 0.50), and preparedness to discuss technical work (dz = 0.35). Post-survey data indicated that digital portfolios effectively supported reflection (75% favorable), professional articulation (75%), and emerging engineering identity (67%).

Implications and Future Work: This study demonstrates that integrating project-based learning with reflective digital portfolios promotes deeper connections to engineering practice and supports professional identity formation in the first year. The findings provide evidence-based justification for portfolio-enhanced first-year curricula and align directly with ASEE priorities in experiential learning and student success. Future work includes longitudinal tracking and dissemination of replicable resources (rubrics, project templates, reflection scaffolds) to facilitate adoption across institutions.

Keywords: *Project-based learning, Experiential learning, Engineering identity, Digital portfolios, Reflection, Teamwork, First-year engineering*

1. Introduction

The first year of engineering education plays a critical role in shaping students' academic success, professional identity, and persistence in the major. Yet many first-year engineering programs struggle with helping students meaningfully connect foundational coursework to authentic engineering practice [1], [2], [3]. Traditional introductory courses emphasize exposure to disciplines and basic technical skills but provide limited opportunities for students to integrate experiences, reflect on learning, or articulate how engineering knowledge applies to real-world problems [1], [3], [4].

Research emphasizes experiential learning, project-based curricula, and early professional identity formation as drivers of student engagement and retention [1], [5], [6]. In parallel, ePortfolio studies highlight their value for reflection, self-regulation, and evidence of learning across contexts [7], [4], [8]. Authentic design experiences and teamwork improve motivation and self-efficacy, particularly when students perceive relevance beyond the classroom. However, while many programs have successfully adopted hands-on projects, fewer have systematically integrated structured reflection and synthesis mechanisms, particularly digital portfolios, that support metacognition, communication, and coherent identity development [2] , [3], [4], [7], [8], [9].

Digital portfolios function as integrative learning tools that connect projects, field experiences, and professional skills through documentation and reflection [3], [4], [9]. While portfolios have supported assessment, professional communication, and career preparation in advanced engineering and professional communication courses [3], [9], [10], their intentional integration into first-year, project-based curricula remains comparatively underexplored in the broader higher-education ePortfolio literature [4], [7], [11]. Although empirical studies have examined ePortfolios as tools for professional identity development [3], teamwork and collaboration in engineering [12], enhanced learning experiences and entrepreneurial skills [13], and improved technical writing performance and attitudes [14], fewer studies investigate their intentional embedding within multidisciplinary, first-year engineering design experiences aimed at articulating engineering practice.

This paper presents a Complete Evidence-Based Practice examining the integration of a digital engineering portfolio within a multidisciplinary, project-based first-year Introduction to Engineering course. The instructional model positions the portfolio as a central integrative scaffold linking projects, field experiences, and reflection, not as an add-on assessment artifact. Using matched pre/post survey data, post-only portfolio indicators, and effect size estimates, this study evaluates effectiveness in supporting students' development of (1) connections between coursework and real-world engineering practice, (2) technical and professional communication skills, (3) reflective learning habits, and (4) emerging engineering identity.

This work addresses First-Year Programs Division themes of projects, experiential learning, learning technologies, assessment, and engineering mindset by presenting empirical evidence, using pre/post survey data, effect size estimates, and portfolio indicators, demonstrating how structured reflection and documentation enhance students' connections to engineering practice, communication skills, and professional identity development, and responding to calls for context-sensitive, pedagogically embedded ePortfolio implementations in STEM programs [4], [7], [11]. The paper offers a replicable instructional and assessment model aligned with ABET continuous improvement processes, making it particularly relevant for programs seeking scalable, high-impact strategies to strengthen first-year engagement, integration, and persistence [2], [7], [10], [11], [15].

2. Literature Review

2.1 Project-Based and Experiential Learning in First-Year Engineering

Project-based learning (PBL) and experiential learning are now recognized as cornerstone pedagogies in first-year engineering education, particularly for improving student engagement, retention, and professional skill development. Recent empirical studies demonstrate significant gains in student motivation, engineering skill development, and retention across cohorts, highlighting that hands-on, team-based design experiences sustain student engagement even amid instructional modality changes [1]. Systematic reviews confirm that PBL supports development of professional competencies, including teamwork, communication, problem solving, and systems thinking, when implemented with sufficient curricular coherence and instructional support [16], [17].

In first-year contexts, design-focused experiences help students move beyond abstract representations of engineering toward authentic understandings of engineering practice. Empirical studies show that early design projects positively influence students' perceptions of what engineers do and help students begin forming professional role conceptions [5], [18]. Multidisciplinary models further broaden these perceptions by exposing students to diverse engineering roles, stakeholder perspectives, and societal contexts [19], [20], [21].

Despite strong evidence for PBL effectiveness, recent reviews caution that many implementations emphasize project completion over reflective integration, limiting deeper learning outcomes [2], [16]. Without explicit structures for reflection, sense-making, and synthesis, first-year students struggle to connect individual project experiences to longer-term learning trajectories or professional identity development.

2.2 Reflection, Self-Regulated Learning, and Professional Identity

Experiential learning theory positions reflection as essential for transforming experience into learning [22]. Engineering education research reinforces this position, linking structured reflection to improved self-regulated learning, motivation, and persistence in foundational courses [23], [24].

Professional identity development has emerged as a particularly important outcome of first-year experiences. Identity-focused models emphasize that students' sense of "becoming an engineer" is shaped not only by technical competence but also by recognition, self-efficacy, and opportunities to articulate professional meaning [25]. Project-based environments can serve as powerful identity-forming spaces when students are encouraged to reflect on their roles, decisions, and values [6], [26].

Recent studies suggest that identity development does not occur automatically through participation in projects alone. Without guided reflection and narrative articulation, students may complete projects without internalizing their professional significance [6], [17]. This highlights the need for instructional mechanisms that explicitly support identity sense-making alongside experiential activity.

2.3 Digital Portfolios as Integrative Learning Tools

Digital portfolios have been increasingly adopted in engineering education as tools for reflection, assessment, and professional communication. Research indicates that portfolios support deep learning by enabling students to curate artifacts, construct narratives, and make learning visible across time and context [9], [27]. In engineering programs, portfolios have supported accreditation documentation and career readiness.

Recent scholarship emphasizes the tension between portfolios as learning tools and portfolios as assessment repositories. When portfolios are implemented primarily for compliance or grading, their potential to support reflection and integration is diminished [15]. Conversely, portfolios designed as narrative and sense-making spaces foster professional identity development and metacognitive awareness [9].

Advances in digital learning ecosystems further position portfolios as central tools for integrating experiential learning, digital literacy, and professional formation [10]. Yet empirical studies examining the intentional embedding of digital portfolios within first-year, project-based engineering courses remain limited.

2.4 Multidisciplinary, Ethical, and Societal Dimensions of Early Engineering Education

Modern engineering practice increasingly requires graduates to operate within multidisciplinary, ethical, and global contexts. First-year interdisciplinary projects improve students' understanding of engineering's societal role and enhance their ability to collaborate across disciplinary boundaries [1],[20], [21], [28].

Early engagement with ethical and societal considerations broadens students' understanding of engineering responsibility beyond technical problem solving [12], [29]. When paired with reflective documentation, these experiences contribute to more durable and transferable learning outcomes.

2.5 Identified Gap and Research Contribution

Collectively, literature establishes the effectiveness of project-based learning, reflection, and digital portfolios as independent pedagogical strategies. However, a persistent gap remains in understanding how these approaches can be intentionally integrated within first-year engineering curricula [2], [15].

This study addresses this gap by examining a digitally scaffolded engineering portfolio embedded within a multidisciplinary, project-based first-year engineering course. By positioning the portfolio as a central mechanism for reflection, synthesis, and professional narrative construction across multiple projects, this work contributes evidence-based insights into how portfolios can enhance experiential learning, support early professional identity development, and generate actionable assessment data aligned with ABET continuous improvement processes [30]. In addition, this work situates its assessment and continuous improvement approach within established ABET Criterion 4 guidance, drawing on models that emphasize scheduled outcome cycles, documented faculty reflection, stakeholder engagement, and data-driven action planning [31], [32], [33], [34].

3. Methods

3.1 Research Design

This study employed a mixed-methods, evidence-based practice design to evaluate the educational impact of integrating a digital engineering portfolio within a multidisciplinary, project-based first-year engineering course. Quantitative data were collected through matched pre- and post-course student surveys to assess changes in perceptions related to communication, professional identity, teamwork, and connections to engineering practice. Qualitative data were obtained from open-ended survey responses, portfolio artifacts, and instructor observations to contextualize and triangulate quantitative findings. This design aligns with best practices for evaluating instructional innovations in authentic classroom settings while prioritizing practical significance over experimental control.

3.2 Course Context, Instructional Intervention, and Resources

The study was conducted in a required first-year *Introduction to Engineering* course at a small, teaching-focused institution offering a general engineering degree. The 16-week semester course met twice weekly for 60-minute lectures and once weekly for a three-hour laboratory session in a engineering classroom-laboratory space. The course targets first-year and transfer students across multiple disciplines and emphasizes project-based assignments that develop problem solving, teamwork, and written and oral communication aligned with stated learning outcomes.

Multidisciplinary Project Sequence and Learning Outcomes:

The curriculum is organized around four multidisciplinary design experiences, each including a discipline-specific instructional module (lecture plus industry or discipline overview), targeted homework with foundational analytical problems, team-based design-and-build components, in-class technical presentations, and documentation within the digital portfolio.

1. *Civil Engineering Design-Build Project.* Students complete a structured design-build assignment introducing basic civil engineering principles through scaled drawings, introductory AutoCAD use, and woodworking (e.g., birdhouse/bridge-style structures). Expected learning outcomes include the ability to interpret and produce basic technical drawings, apply measurement and material-selection principles, use shop tools safely and effectively, and communicate design intent visually and orally. Instructional materials comprise AutoCAD tutorials, instructor-provided design exemplars, formal shop-safety training, and a rubric emphasizing design feasibility and communication clarity.

2. *Environmental/Sustainability Project.* Students address reuse, sustainability, or resource-constrained design problems grounded in introductory environmental or systems concepts. Prior to design work, students complete homework on fundamental environmental or systems-based engineering problems. Learning outcomes include explaining core environmental engineering principles, evaluating sustainability trade-offs, applying systems thinking to realistic constraints, and presenting environmental impacts in technical reports. Field trips to regional facilities and guest speakers from engineering and manufacturing organizations provide authentic context that students later document in their portfolios.

3. *Mechanical/Electrical (Robotics) Project.* Students are introduced to basic robotics, sensors, and coding logic through team-based design challenges such as clawbot construction, climbing robots, and simple sensor integration. Learning outcomes include demonstrating introductory programming logic, integrating mechanical assemblies with electrical components, troubleshooting iterative design failures, and delivering structured technical presentations. Instructional supports include starter code templates, wiring diagrams, live lab demonstrations, and TA-supported debugging sessions.
4. *Engineering in the Developing World Project.* The final project foregrounds global context, resource constraints, and metalworking skills through tasks such as designing and fabricating efficient rocket stoves for low-resource environments. Students are expected to evaluate engineering problems in sociotechnical context, incorporate affordability and local manufacturability constraints, demonstrate safe use of metalworking tools, and reflect on professional responsibility and societal impact.

Digital Engineering Portfolio:

Throughout the semester, a web-based digital engineering portfolio serves as the integrative scaffold linking projects, field experiences, and reflective writing. Required components include a professional homepage, "About" page (background, goals, optional résumé), project pages with artifacts and technical summaries, blog-style reflections on field trips and guest speakers, and an end-of-term reflective essay on engineering identity. The final essay prompts students to describe how they became interested in engineering, which discipline they are considering, and the type of work they hope to pursue, directly supporting identity-focused outcomes. The portfolio accounted for approximately 16% of the total course grade and was assessed using a rubric emphasizing technical clarity, reflection depth, organization, and professional communication.

To position the portfolio as a professional rather than purely academic artifact, instructors introduce examples of public-facing engineering portfolios and project sites from practicing engineers and recent program alumni. These examples highlight clear problem statements, design rationales, visuals, and concise narratives of outcomes, and are discussed explicitly in class as models for how engineers communicate their work to employers, clients, and broader audiences. First-year students are encouraged to view their own portfolio as an initial version of this kind of professional presence that they will continue to refine in subsequent courses.

Faculty, Staffing, and Laboratory Resources:

The course is taught by a single faculty member with support from one undergraduate teaching assistant; no graduate TAs are assigned. The TA assists with lab supervision during build sessions, robotics debugging, shop-safety monitoring, and preliminary portfolio reviews. Students work in a general engineering lab with worktables, woodworking tools (saws, drills, clamps), basic metalworking tools, robotics kits and microcontrollers, and computers equipped with AutoCAD.

Replicability for Other Programs:

The projects were intentionally scoped to be feasible with modest resources: they rely on accessible materials, common robotics kits, and widely available software rather than specialized industrial equipment. Because the model operates successfully with a single faculty member and one undergraduate TA, other institutions can adopt it incrementally, beginning with one project and associated portfolio components and scaling up as space, staffing, and equipment allow.

3.3 Multi-Year Portfolio Integration Across the Curriculum

The digital engineering portfolio introduced in the first-year course is intentionally designed as the starting point of a multi-year professional practice rather than a stand-alone assignment. After completing the Introduction to Engineering course, students continue to maintain and extend the same portfolio in a sophomore project course, a junior-level design course, and the senior capstone design sequence. In these subsequent courses, the portfolio shifts from a focus on learning to document and reflect, toward a more professional representation of engineering work, including problem definition, design justification, testing results, and articulated impact for external audiences such as internship supervisors and potential employers.

In the sophomore project course, students use the portfolio to document early team design experiences, including problem statements, sketches or models, and reflections on team processes and emerging professional roles. At the junior level, portfolio expectations emphasize more formal technical reporting, integration of discipline-specific analysis, and communication with stakeholders. In the capstone sequence, students create professional-quality project pages that synthesize requirements, design decisions, verification and validation results, and reflections on ethical, societal, and career implications. Across these courses, instructors use the portfolio as a common platform for providing feedback on communication, professionalism, and design process, and as a convenient source of indirect evidence for program-level assessment.

3.4 Participants

Participants included students enrolled in the course. Matched pre- and post-survey data were obtained from $n = 10$ students, enabling paired analysis. The post survey included $n = 12$ respondents and was used to report portfolio-specific outcomes not measured at baseline. Participation in the surveys was voluntary and did not affect course grades. Survey responses were anonymized prior to analysis.

3.5 Data Collection Instruments

Pre- and Post-Course Surveys

Surveys included Likert-scale items (5-point scale: 1 = Strongly Disagree to 5 = Strongly Agree) measuring student perceptions of:

- Connections between coursework and real-world engineering practice
- Technical and professional communication confidence
- Teamwork and feedback processes
- Motivation and engineering identity

Survey items were adapted from established first-year engineering and identity-related instruments reported in the ASEE literature and aligned with ABET student outcomes. The post survey included additional items specifically targeting the perceived impact of the digital portfolio on reflection, identity, and professional communication.

Portfolio Artifacts and Completion Data

Portfolio completion data documented implementation fidelity and student engagement. Required sections included homepage, project pages, reflection entries, and contact page, with optional documentation of field experiences. Instructors reviewed portfolio artifacts to identify representative examples of reflection depth and integration.

Qualitative Data Sources

Open-ended survey responses and instructor field notes captured evidence of student learning, mindset development, and engagement. Responses were analyzed using descriptive thematic coding to identify recurring patterns related to reflection, communication, and professional identity.

3.6 Data Analysis

Quantitative survey data were analyzed using descriptive statistics (means and percentages of favorable responses: Agree/Strongly Agree). For matched pre/post items, paired standardized mean change effect sizes (Cohen's *dz*) were estimated to assess practical significance. Cohen's *d*z is calculated as the standardized difference between pre- and post-means, where values of approximately 0.2, 0.5, and 0.8 represent small, medium, and large effects, respectively. Effect sizes were reported to emphasize practical significance rather than inferential claims, consistent with ASEE evidence-based practice reporting conventions.

Qualitative data were coded inductively to identify themes related to integration of learning, communication practices, and perceptions of engineering practice. Quantitative and qualitative findings were triangulated to strengthen interpretation validity.

3.7 Ethical Considerations

The study protocol was submitted to the university's Institutional Review Board and determined to be exempt from further review as minimal-risk classroom-based educational research. All student participation was voluntary, responses were anonymized, and findings are reported in aggregate to protect confidentiality in accordance with institutional guidelines.

3.8 Validity, Reliability, and Continuous Improvement Alignment

To strengthen validity and reliability, this study employed multiple strategies consistent with best practices in engineering education research and ABET continuous improvement processes. Construct validity was supported by aligning survey items and portfolio rubrics with clearly defined instructional objectives and ABET Student Outcomes related to problem solving, communication, teamwork, ethics, and professional responsibility. Content validity was strengthened by adapting items from established first-year engineering and engineering identity instruments reported in prior ASEE literature.

Triangulation across data sources, including pre/post surveys, portfolio artifacts, completion data, and instructor observations, enhanced internal validity by corroborating findings across independent measures. While formal reliability coefficients were not calculated due to small sample size, procedural reliability was strengthened through consistent survey administration, stable Likert-scale response formats, and uniform application of portfolio rubrics.

Importantly, the assessment design aligns directly with ABET Criterion 4 (Continuous Improvement), which emphasizes documented processes for assessing student outcomes and systematically using results to inform program changes [31], [32]. Pre/post survey instruments and portfolio evaluations serve as recurring assessment tools providing actionable evidence of student learning, consistent with recommended use of mixed direct and indirect measures in continuous improvement cycles [31], [34]. Results were reviewed by course instructors to identify strengths and refinement opportunities, such as the need for additional scaffolding of field-experience reflections, which informed targeted curricular adjustments in subsequent offerings, mirroring published models that stress closing the loop through documented action items, stakeholder input, and curriculum revision [31], [32] [33].

4. Results

4.1 Participants and Analysis Approach

Matched pre- and post-survey responses were available for *n* = 10 first-year engineering students, enabling paired comparisons across constructs shared between surveys. The post survey included *n* = 12 respondents and was used to report digital-portfolio-specific indicators not measured at baseline. Table 1 summarizes the results reported as means, percentages of favorable responses (Agree/Strongly Agree), and paired standardized mean change (Cohen's *dz*) where applicable.

Table 1: Pre/Post Outcomes and Post-Only Digital Portfolio Indicators

Outcome/Indicator	Pre Mean	Post Mean	Δ Mean	Cohen's d_z	% Favorable
Connection to real-world engineering practice	3.70	4.20	+0.50	0.55	100%
Comfort writing technical reports	3.00	3.50	+0.50	0.50	40%
Prepared to discuss technical work	3.35	3.70	+0.35	0.35	80%
Comfort giving presentations	3.45	3.70	+0.25	0.25	70%
Ability to give/receive feedback	4.00	4.20	+0.20	0.20	90%
Motivation to pursue engineering	4.30	4.00	−0.30	−0.30	80%
Post-only Indicators	---	---	---	---	---
Portfolio identified strengths/growth	---	3.58	---	---	75%
Portfolio strengthened practice connections	---	3.75	---	---	75%
Increased confidence with digital tools	---	3.83	---	---	67%
Portfolio supported engineering identity	---	3.67	---	---	67%

Note. Cohen's *dz* values represent paired standardized mean changes on 5-point scales. Favorable responses indicate Agree or Strongly Agree. Ceiling effects (pre-means of 4.0 or higher) are noted for teamwork and motivation constructs.

4.2 Pre/Post Outcomes Aligned with Course Objectives

Across all shared constructs, the overall mean increased from 3.67 (pre) to 3.76 (post), reflecting consistent improvement. The largest gains occurred in constructs explicitly targeted by the instructional design.

Connection to Real-World Engineering Practice: Students' perception that course activities connected to authentic engineering work increased from 3.70 (pre) to 4.20 (post), with favorable responses rising from 50% to 100%. This moderate effect ($dz = 0.55$) represents a half-point gain per student, a substantial practical improvement.

Technical Communication: Comfort writing technical reports increased from 3.00 to 3.50 ($\Delta = +0.50$; $dz = 0.50$), with favorable responses rising from 40%. Preparedness to discuss technical work with peers and faculty increased from 3.35 to 3.70 ($\Delta = +0.35$; $dz = 0.35$). Presentation confidence showed a smaller but positive change (3.45 to 3.70, $\Delta = +0.25$; $dz = 0.25$).

Teamwork and Feedback Constructs: These remained high at both time points (pre $M = 4.00$, post $M = 4.20$), with 90% favorable responses at post-test. The continued high ratings indicate sustained effectiveness.

Motivation to Pursue Engineering: Motivation declined slightly from 4.30 (pre) to 4.00 (post), a change of −0.30. However, post-test ratings remained well above the midpoint (4.0/5.0), indicating continued strong engagement. This recalibration is consistent with prior first-year engineering research, where initial enthusiasm often resets as students gain realistic exposure to engineering practice and performance standards.

4.3 Post-Only Digital Portfolio Outcomes

Post-survey items specific to the digital portfolio indicate that the portfolio effectively supported integration and reflection. A majority of students agreed that the portfolio helped them:

- Identify strengths and areas for growth as learners (75% favorable, $M = 3.58$)
- Connect classroom learning to professional engineering contexts (75% favorable, $M = 3.75$)
- Express an emerging engineering identity (67% favorable, $M = 3.67$)
- Increase confidence using digital tools and software (67% favorable, $M = 3.83$)

Portfolio Completion and Engagement: Completion rates were high for core components (project pages, homepage, reflections, and contact page). Documentation of field experiences was less consistent, indicating a targeted opportunity for improved instructional scaffolding, such as required reflection prompts or explicit rubric weighting tied to experiential learning outcomes.

4.4 Qualitative Insights from Student Reflections

Qualitative responses from the post-survey provided explanatory context for the quantitative results and clarified how students experienced the portfolio-enhanced project sequence. Across 12 respondents, student feedback clustered around six non-mutually exclusive themes: (1) career readiness and professional showcasing, (2) reflection and growth, (3) design-process development, (4) teamwork and communication, (5) digital portfolio skill development, and (6) limited or mixed perceived impact. Table 2 summarizes the qualitative themes, representative evidence, and occurrence rates.

Table 2 summarizes the qualitative themes, representative evidence, and occurrence rates.

Theme	Evidence from student responses	Representative quote	Occurrence
Career readiness and professional showcasing	Students described the portfolio as a tool for resumes, internships, interviews, employers, and future job applications.	"When potential internships want to see projects/resume, I can simply send them the link to my up-to-date website." (P7)	11/12 (92%)
Reflection, growth, and emerging engineering identity	Students connected the portfolio to self-assessment, motivation, personal journey, and visible growth over time.	"Writing about my own experiences and the experience I want to gain made me more motivated to pursue the path I want to." (P7)	8/12 (67%)
Design-process development and iteration	Students referenced planning, testing, revising, documenting failures, and improving designs after evaluation.	"I learned how important it is to look closely at what didn't work and make changes instead of just moving on." (P12)	8/12 (67%)
Teamwork, communication, and feedback	Students identified growth in communicating with teammates, resolving conflicting ideas, presentations, and group accountability.	"I overcame the conflicting ideas with other people and was able to articulate my points to them and listen to their ideas." (P4) "I had to find a way to communicate with my group members in a different way." (P11)	10/12 (83%)
Digital portfolio and visual communication skills	Students noted improvement in website design, organization, visuals, Adobe/Wix use, and online presentation of work.	"I was able to design a website and also able to figure out how to design things on Adobe." (P11)	4/12 (33%)
Limited or mixed perceived impact	Some students viewed the portfolio mainly as a repository or reported that it did not substantially change their view of engineering.	"I think of it simply as a repository." (P5) "I get how that's less appealing to whoever I'm showing it to, but it didn't change anything." (P8)	4/12 (33%)

Note. Percentages are based on 12 post-survey respondents. Codes were not mutually exclusive; a single response could be coded under multiple themes.

The most prominent themes, career readiness/professional showcasing (92%) and teamwork/communication (83%), indicate that students primarily perceived the portfolio as both a professional artifact and a medium for articulating collaborative engineering work. Many students described using the portfolio for internships, job applications, and interviews, highlighting its value beyond the classroom. Others emphasized how the portfolio supported reflection on failures, planning, and iterative design improvement, reinforcing its role in making the design process visible and transferable.

Themes related to reflection, growth, and engineering identity (67%) further suggest that the portfolio contributed to students' understanding of their development as engineers. Students reported increased motivation, awareness of learning progress, and ability to connect experiences across projects. Similarly, design-process development (67%) responses indicate that students began to recognize the importance of iteration, evaluation, and continuous improvement.

While less frequently reported, improvements in digital communication and portfolio development skills (33%) demonstrate that students gained experience in organizing and presenting technical work in an online format. However, the presence of a "limited or mixed impact" theme (33%) provides an important boundary condition. Some students viewed the portfolio primarily as a repository or reported minimal changes in their perception of engineering, suggesting variability in how students engaged with reflective components.

Overall, these qualitative findings align with the quantitative gains reported in Sections 4.2 and 4.3, particularly in areas of real-world connection, communication, and professional identity development. At the same time, the variation in student responses highlights the importance of instructional scaffolding to support deeper reflection, particularly in documenting field experiences and engaging meaningfully with the portfolio as a professional learning tool.

5. Discussion

The results provide evidence-based support for the instructional model. The most pronounced gains occurred in students' perceived connection between coursework and real-world engineering practice, a central goal of the multidisciplinary project sequence and reflective digital portfolio. The moderate effect size ($dz = 0.55$) indicates practical educational significance: on average, students' agreement with "course activities connect to authentic engineering" increased by half a scale point.

This finding aligns with experiential learning theory and prior first-year engineering research, suggesting that when design projects are combined with structured opportunities for students to curate, reflect on, and articulate their work in a professional portfolio, students develop a more coherent understanding of how classroom activities map to engineering practice.

Improvements in technical communication and presentation confidence support the portfolio's role as a formative assessment mechanism that reinforces ABET-aligned outcomes. Rather than treating communication as a discrete skill, the portfolio required students to repeatedly articulate design intent, results, and reflections across multiple project contexts, creating numerous opportunities for skill building and feedback integration.

The slight decline in general motivation (−0.30) is interpreted as a developmental recalibration effect, consistent with prior research on first-year engineering. As students encountered authentic design constraints, interdependent teamwork, and realistic performance standards, selfassessments became more nuanced and grounded while remaining positive ove engagement with engineering work.

An important interpretive consideration is that the observed gains in perceived connections to real-world engineering reflect the combined influence of the technical curriculum and the portfolio, rather than the portfolio in isolation. The multidisciplinary project sequence provides the authentic experiences that could plausibly shift students' perceptions, while the portfolio is deliberately structured to make those connections explicit by asking students to explain what they did, why it matters, and how it relates to engineering practice. Because the study did not include a comparison section without portfolios, we do not claim that the portfolio alone caused the observed changes; instead, we interpret the portfolio as a mechanism that helps students consolidate and articulate the impact of their project experiences. Designing future comparison studies or staggered implementations would enable a clearer separation of curriculum and portfolio effects.

The post-survey portfolio findings indicate that digital portfolios functioned as both identity-building and integrative tools. Notably, 75% of students agreed the portfolio helped them connect classroom learning to professional contexts and identify areas for growth, outcomes that support both professional identity formation and metacognitive development.

Beyond the confines of the first-year course, students are encouraged to use their portfolios as living professional artifacts that evolve throughout their undergraduate careers. As they move into sophomore, junior, and capstone courses, students add project pages, internship and undergraduate research summaries, and co-curricular experiences, and are explicitly coached to draw on these curated artifacts when applying for internships, jobs, and graduate programs. This ongoing use reinforces the portfolio's role as a professional development practice, supporting students in constructing coherent narratives about their engineering trajectory rather than treating the portfolio as a one-semester exercise.

The lower engagement with field-experience documentation suggests a specific instructional refinement: additional scaffolding through required reflection prompts, exemplars, or explicit rubric weighting could strengthen the connection between experiential learning and documented reflection, further amplifying portfolio impact and exemplifying Criterion 4–style "closing the loop" practices described in ABET-focused continuous improvement case studies [31], [33], [34].

6. Conclusions

This study demonstrates that integrating project-based learning with structured digital engineering portfolios in the first year yields measurable gains in students' ability to connect academic work to engineering practice, communicate technical ideas, and reflect on professional growth. The observed effect sizes, particularly for real-world connection ($dz = 0.55$) and technical communication ($dz = 0.50$), support this approach as a high-impact instructional practice for first-year engineering education.

Key contributions include:

1. Empirical evidence linking first-year digital portfolios to improved professional articulation and practice awareness, addressing a gap in the literature on portfolio effectiveness in first-year settings.
2. Demonstration of moderate educational effects using a scalable, low-cost instructional model, suggesting that portfolio-enhanced project-based learning is accessible to institutions with varied resources.
3. Identification of actionable refinements (e.g., enhanced scaffolding for field-experience documentation) that support continuous improvement aligned with ABET Criterion 4.
4. Evidence supporting ASEE priorities in experiential learning, professional formation, and assessment-informed curriculum development.

Collectively, these findings suggest that reflective digital portfolios, when intentionally aligned with multidisciplinary projects, represent a high-impact practice for advancing ABET-aligned student outcomes, engagement, and early engineering identity formation in first-year programs. The instructional model is transferable across institutions and provides a practical framework for educators seeking evidence-based approaches to first-year curriculum enhancement.

7. Limitations and Future Work

7.1 Limitations

Several limitations should be considered when interpreting findings. First, the matched sample size (n = 10) was relatively small, limiting statistical power and generalizability. While effect size estimates (Cohen's *dz*) were included to emphasize practical significance, these estimates should be interpreted conservatively and viewed as indicative rather than definitive. Future implementations with larger cohorts will enable more robust inferential analysis and subgroup comparisons.

Second, the study relied primarily on self-reported survey data, which may be subject to response bias and social desirability effects. Although survey findings were triangulated with portfolio artifacts and instructor observations, future work would benefit from incorporating objective measures, such as rubric-based longitudinal portfolio scoring, external evaluator ratings, or performance data from subsequent design courses.

Third, some constructs exhibited ceiling effects at the pre-survey stage, particularly teamwork and motivation items (pre-means of 4.0–4.3). While this indicates strong baseline attitudes, it may have masked additional growth. Refinement of survey instruments to include higher-resolution or scenario-based items could better capture nuanced developmental changes.

Finally, documentation of field experiences within digital portfolios was less consistent than other components, indicating a need for stronger instructional scaffolding such as required reflection prompts, exemplars, or explicit rubric weighting tied to experiential learning outcomes.

Although the portfolio is threaded through multiple required courses in this program, the evaluation reported here focuses only on the first-year implementation. As a result, the findings primarily capture the short-term impact of a semester-long portfolio experience integrated with a project-based curriculum, rather than the full longitudinal effect of a multi-year portfolio practice. In programs where the portfolio is used only within a single course, some of the longer-term benefits we describe, such as sustained professional identity development and cumulative, multi-project narratives, may be attenuated. Future research will examine how continued portfolio use in sophomore, junior, and capstone design courses shapes students' long-term professional formation and post-graduation outcomes.

7.2 Future Work

Future work will focus on:

- Expanding the dataset across multiple cohorts and institutional contexts to strengthen generalizability and enable more robust inferential analysis.
- Implementing improved portfolio scaffolds, such as field-experience reflection templates and exemplar portfolios, to address lower engagement with experiential documentation.
- Conducting longitudinal tracking to examine whether early gains in reflection, communication, and engineering identity persist into sophomore- and capstone-level courses and impact retention rates.
- Exploring differential impacts on underrepresented populations and transfer students, further aligning first-year innovation with inclusive excellence and equity-minded assessment practices.
- Disseminating replicable resources (rubrics, project templates, reflection prompts, digital platform recommendations) through ASEE publications and open-access repositories to facilitate adoption at other institutions.

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Appendix I

Pre-Survey: First-Year Engineering & Digital Portfolio

This pre-survey gathers baseline information on your design thinking, digital literacy, communication, and professional identity before the start of the course.

Section A: Background Information

Intended Engineering Discipline or Major: ________________________

Prior experience with online portfolios or website platforms (e.g., Wix, WordPress):
☐ None ☐ Limited ☐ Moderate ☐ Extensive

Prior engineering or design experience: ☐ None ☐ Minimal ☐ Moderate ☐ Extensive

Comfort level with digital tools and software (1 = Not comfortable → 5 = Very comfortable): 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Describe briefly what you think an engineering portfolio is:

____

____

Sections B: Likert Scale Items (1 = Strongly Disagree → 5 = Strongly Agree)

#	Statement	1	2	3	4
1	I regularly reflect on how I learn in engineering courses.	☐	☐	☐	☐
2	I can identify my strengths and weaknesses as a learner.	☐	☐	☐	☐
3	I see connections between classroom topics and real-world engineering practice.	☐	☐	☐	☐
4	I know how to articulate how my design process works.	☐	☐	☐	☐
5	I use reflection to improve my technical performance.	☐	☐	☐	☐
6	I document my learning process effectively through portfolios or notebooks.	☐	☐	☐	☐
7	I am confident writing about technical topics for a general audience.	☐	☐	☐	☐
8	I can visually present engineering work in a clear and professional way.	☐	☐	☐	☐
9	I feel prepared to discuss my technical work with peers or faculty.	☐	☐	☐	☐
10	My current writing and presentation skills meet professional standards.	☐	☐	☐	☐
11	Peer feedback helps me improve how I communicate my work.	☐	☐	☐	☐
12	I can explain how engineering improves society and everyday life.	☐	☐	☐	☐
13	I see myself as an emerging engineer.	☐	☐	☐	☐
14	I understand how different engineering disciplines connect (civil, mechanical, electrical, environmental).	☐	☐	☐	☐
15	I am motivated to pursue a future in engineering.	☐	☐	☐	☐
16	I can apply the steps of the engineering design process to new problems.	☐	☐	☐	☐
17	I feel confident creating and testing design prototypes.	☐	☐	☐	☐

18	I can identify the constraints and criteria for successful design solutions.	☐	☐	☐	☐
19	I am comfortable making design decisions in a team setting.	☐	☐	☐	☐
20	I can provide and receive constructive feedback from peers.	☐	☐	☐	☐
21	I feel respected and valued in my project team.	☐	☐	☐	☐
22	I am improving my technical communication skills (written, visual, oral).	☐	☐	☐	☐
23	I understand how engineering connects to ethical and societal issues.	☐	☐	☐	☐
24	I am more confident using digital tools and engineering software.	☐	☐	☐	☐
25	I can manage and present my engineering work in an online portfolio format.	☐	☐	☐	☐
26	I reflect on how my projects demonstrate growth in curiosity, creativity, and connection (3 Cs).	☐	☐	☐	☐

Section C: Open-Ended Reflection

What do you hope to gain from developing your digital or engineering portfolio this semester?

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____

____

Describe any concerns you have about public or digital presentation of your work.

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____

____

What personal or professional skills do you hope to strengthen in this course?

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In what ways do you think hands-on or project-based learning will influence your development as an engineer?

____

____

____

Appendix II

Post-Survey: First-Year Engineering & Digital Portfolio

This post-survey evaluates your experience and learning outcomes from the first-year engineering course, with emphasis on digital portfolio development, teamwork, reflection, and professional identity formation.

Section A: Portfolio Experience

Average hours per week spent developing your portfolio: ☐ <1 ☐ 1–3 ☐ 3–5 ☐ 5+

Which components did you complete in your portfolio? ☐ Home Page ☐ Project Pages ☐ Reflection Blog ☐ Field Experience ☐ Contact Page_

Prior experience with online portfolios or website platforms (e.g., Wix, WordPress):
☐ None ☐ Limited ☐ Moderate ☐ Extensive

Number of peer feedback sessions participated in: ☐ None ☐ 1–2 ☐ 3–4 ☐ 5 or more:

Comfort level with digital tools and software (1 = Not comfortable → 5 = Very comfortable): 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Describe briefly what you think an engineering portfolio is:

Sections B: Likert Scale Items (1 = Strongly Disagree → 5 = Strongly Agree)

#	Statement	1	2	3	4	5
1	I regularly reflect on how I learn in engineering courses.	☐	☐	☐	☐	☐
2	I can identify my strengths and weaknesses as a learner.	☐	☐	☐	☐	☐
3	I see connections between classroom topics and real-world engineering practice.	☐	☐	☐	☐	☐
4	I know how to articulate how my design process works.	☐	☐	☐	☐	☐
5	I use reflection to improve my technical performance.	☐	☐	☐	☐	☐
6	I document my learning process effectively through portfolios or notebooks.	☐	☐	☐	☐	☐
7	I am confident writing about technical topics for a general audience.	☐	☐	☐	☐	☐
8	I can visually present engineering work in a clear and professional way.	☐	☐	☐	☐	☐
9	I feel prepared to discuss my technical work with peers or faculty.	☐	☐	☐	☐	☐
10	My current writing and presentation skills meet professional standards.	☐	☐	☐	☐	☐
11	Peer feedback helps me improve how I communicate my work.	☐	☐	☐	☐	☐
12	I can explain how engineering improves society and everyday life.	☐	☐	☐	☐	☐
13	I see myself as an emerging engineer.	☐	☐	☐	☐	☐
14	I understand how different engineering disciplines connect (civil, mechanical, electrical, environmental).	☐	☐	☐	☐	☐

15	I am motivated to pursue a future in engineering.	☐	☐	☐	☐	☐
16	I can apply the steps of the engineering design process to new problems.	☐	☐	☐	☐	☐
17	I feel confident creating and testing design prototypes.	☐	☐	☐	☐	☐
18	I can identify the constraints and criteria for successful design solutions.	☐	☐	☐	☐	☐
19	I am comfortable making design decisions in a team setting.	☐	☐	☐	☐	☐
20	I can provide and receive constructive feedback from peers.	☐	☐	☐	☐	☐
21	I feel respected and valued in my project team.	☐	☐	☐	☐	☐
22	I am improving my technical communication skills (written, visual, oral).	☐	☐	☐	☐	☐
23	I understand how engineering connects to ethical and societal issues.	☐	☐	☐	☐	☐
24	I am more confident using digital tools and engineering software.	☐	☐	☐	☐	☐
25	I can manage and present my engineering work in an online portfolio format.	☐	☐	☐	☐	☐
26	I reflect on how my projects demonstrate growth in curiosity, creativity, and connection (3 Cs).	☐	☐	☐	☐	☐
27	The portfolio process helped me identify my strengths and growth as a learner	☐	☐	☐	☐	☐
28	Writing reflections improved my understanding of the design process.	☐	☐	☐	☐	☐
29	I am more aware of how classroom learning connects to professional content	☐	☐	☐	☐	☐
30	I regularly used feedback from peers/instructors to revise my portfolio.	☐	☐	☐	☐	☐
31	Developing the portfolio improved my teamwork and feedback literacy.	☐	☐	☐	☐	☐
32	The portfolio helped me express who I am as an engineer.	☐	☐	☐	☐	☐
33	I feel more connected to the engineering community.	☐	☐	☐	☐	☐
34	The portfolio made me more confident in pursuing my career path.	☐	☐	☐	☐	☐

Section C: Open-Ended Reflection

How did the digital portfolio project change the way you think about engineering?

____

____

____

Which part of your portfolio most effectively represents your growth as an engineer?

____

____

____

What would you improve if you were to continue building your portfolio?

____

____

How do you plan to use your portfolio for internships, courses, or professional networking?

Reflecting on the semester, what part of your learning or design process improved the most?

Describe one challenge you overcame while working on your portfolio or team projects.