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The Impact of E-Portfolios on Student Success in a Structural Analysis Course

Dr. Ricardo Zaurin, University of Central Florida

Dr. Zaurin is a Senior Lecturer for the Department of Civil, Environmental, and Construction Engineering at the University of Central Florida. His research is dedicated to High Impact Teaching and Learning Practices, Active Learning, Project-Based Homework, Experiential Learning, and Adaptive Learning.

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Abstract

Engineering programs are always looking for innovative strategies to enhance student learning, promote reflective practice, and meet accreditation expectations such as those established by the Accreditation Board of Engineering and Technology (ABET). This study investigates the impact of integrating an E-portfolio into a Structural Analysis (SA) course on students' learning outcomes, reflection, and overall success.

E-portfolios come in different forms, but they are essentially a digital collection of student work accompanied by reflective comments. They help students to connect theory and practice, strengthen metacognitive skills, and provide evidence of learning. While E-portfolios are well documented in first year and capstone design courses, limited research explores their use in foundational technical courses such as SA, a core component of the Civil Engineering curriculum. This study aims to address that gap through sharing the author's experiences and results after implementing e-portfolio for SA in a large public university.

The goals of this research were: (1) to evaluate the influence of E-portfolios on students' reflective learning and conceptual understanding of structural analysis principles; (2) to examine the relationship between E-portfolio use and student performance; and (3) to capture student perceptions of integrating reflection into a traditionally problem-solving–oriented course. The E-portfolio included KWL (Know, want to learn, learned) reflections for each learning unit, practice problems, assessments, reports, case-studies, and connections to prior and future coursework and professional practice. After each examination, students were provided with an opportunity to conduct a revision of their work, identifying mistakes, explaining misconceptions, and proposing strategies for improving their performance in future assessments.

Quantitative data, including mid-term exams and final grade comparisons with previous semesters taught by the same instructor (used as a baseline), were used to assess performance outcomes. Qualitative data, from student reflections and surveys are converted into qualitative data and used to measure attitudes toward learning and self-assessment. Preliminary findings indicate that students' success increased, and they demonstrated improved conceptual reasoning, problem-solving accuracy, and deeper engagement with course material. Additionally, students reported favorable feedback for reflection, error analysis, and validation which are skills that align directly with ABET Student Outcomes related to problem-solving, communication, and lifelong learning.

1. Introduction, Background, and Related Work

Structural Analysis is a fundamental course in the civil engineering curriculum, serving as foundation for subsequent coursework in structural steel design, reinforced concrete, bridge engineering, and senior capstone design. The course requires students to integrate previous knowledge from statics and mechanics of materials while acquiring new knowledge related to structural systems such as compatibility, deflections, indeterminacy, load paths, influence lines, and system responses. These concepts are essential not only for future classes but also for professional practice, where engineers must interpret analytical results, evaluate modeling assumptions, and apply engineering judgment.

Students usually perceive SA as abstract and heavily based on mathematical procedures. Prior research has shown that students often see this course as a set of several solution techniques and not as a tool to understand the structural behavior [1], [2]. This is more evident in large-sized courses, where instructors' emphasis is on just showing the application of procedures for problem solving. Very few opportunities are left for reflection, conceptual integration, and learning from mistakes [3], [4].
Traditional structural analysis courses mainly use summative assessments such as midterms and final examinations to evaluate the students' learning progress. It is true that practice and repetition are useful techniques for problem solving and memorization however, they do not necessarily stimulate conceptual understanding or transferring of knowledge to other contexts [5], [6]. As a result, students may solve exam questions and, at the same time, lack the metacognitive skills required to assess other possible solutions, identify misconceptions, or adapt these purely numerical procedures and strategies to other cases. These limitations are especially pronounced in analytical courses, contributing to elevated failure rates (DFW grades) and reduced retention and persistence [7], [8].

To address these issues, engineering education research has suggested the use of metacognition, self-regulated learning, and reflection to improve the student learning outcomes. Metacognition and self-regulated learning are critical for engineering students' success in analytical courses [9], [10]. Metacognition involves students' awareness of their thinking, planning strategies, monitoring comprehension, and evaluating performance, while self-regulated learning emphasizes goal setting, strategic action, and reflection. In large technical courses, students often struggle to self-assess their understanding or transfer knowledge to new problems. Empirical studies on exam wrappers, structured error analysis, and post-assessment revisions indicate that such interventions support deeper conceptual understanding, encourage learning from mistakes, and promote more effective learning strategies [11], [12].

E-portfolios have been used very often as a pedagogical tool since they provide a mechanism that contains the students' work and progress during the course however, at the same time promotes students' reflections and metacognitive practice within engineering coursework. E-portfolios are commonly defined as a digital representation of students' work and their reflective commentaries about the different experiences, and learning [13]. They have been shown to support learning, provide documentation of achievements, help with developing students' professional identity, and integrate learning experiences inside and outside of the classroom [14]- [16]. Engineering education research has shown that e-portfolios have been widely implemented in first-year programs, project-based courses, and capstone design experiences, where they have been used to assess engagement, learning outcomes, support accreditation, and promote synthesis across disciplinary boundaries [17] – [20]. More recent studies have reported that E-portfolios can also be effective tools for promoting self-regulated learning through the inclusion of goal setting, reflection, and iterative improvement throughout a semester [21], [22].

The products included in the E-portfolios are aligned with several ABET Student Outcomes (1–7). Examples of solved problems and reflective explanations provide evidence of students' ability to identify, formulate, and solve complex engineering problems (Outcome 1). Written reflections and summarization activities support effective communication with both technical and non-technical audiences (Outcome 3). Connections to real-world applications and case studies encourage consideration of professional responsibilities and societal context (Outcome 4). Revisions and reflections promote habits of lifelong learning and professional development (Outcome 7), while reflections linking prior and future coursework reinforce engineering judgment and appropriate use of analytical tools (Outcome 6).

Despite the documented benefits of E-portfolios in engineering education, their application in mainly analytical courses remains limited. Most implementations focus on introductory level courses and capstone projects however; little attention has been given to courses such as SA.

This study addresses this gap by examining the implementation of an E-portfolio in a junior-level SA course at a large public university. The E-portfolio was designed to support reflective learning, metacognitive awareness, and integration of knowledge through KWL reflections, structured post-exam revisions, connections between analytical solutions and real-world structures, and identification of links with prior coursework, future design courses, and professional practice. This research investigates the impact of this intervention on student performance, success rates, and perceptions, with particular attention to metacognition and self-regulated learning. The findings contribute to the ASEE literature on evidence-based instructional strategies in civil engineering analysis courses and offer insights relevant to both student success initiatives and ABET accreditation.

3. Research Questions

This study was guided by the following research questions:

1. How does the integration of an E-portfolio influence students' reflective learning and conceptual understanding in Structural Analysis?

2. What impact does the E-portfolio have on student performance and course success rates?
3. How do students perceive the use of reflection and revision in a traditional problem-solving-oriented course?
4. How does engagement with the E-portfolio support metacognitive awareness and self-regulated learning**?**

4. Methods

4.1 Course Description

The study was conducted in a required junior-level Structural Analysis course at a large public university. The course follows Statics and Mechanics of Materials and precedes Design Courses such as Reinforced Concrete and Steel Design. Enrollment consisted of 139 students in two consecutive semesters (73 students enrolled in first and 66 students in the second) for the control group (without an E-portfolio) and 137 students in also two consecutive semesters (enrollment of 68, and 69 students respectively) both offered with the E-portfolio. All courses were taught by the same instructor as a mixed-mode blended class with approximately 50% of face-to-face lectures and the rest via prerecorded posted videos. All the content, strategies, and class material remained identical.

For the control group (no E-portfolio) the evaluation assessment was determined by 4 mid-term exams (50%), a final exam 20%, homework (5%), and the laboratory (25%). To include the E-portfolio in the course, the assessments had to be slightly changed: 4 mid-term exams (50%), laboratory (22.5%), final exam (15%), and complete E-portfolio (12.5%).

4.2 E-Portfolio Structure

The E-portfolio was implemented as a semester-long, cumulative work. The main components included:

4.2.1) Cover Page: With information about the university, department, course, and student identifiers.

4.2.2) Students Introductions: they presented a profile of them indicating their goals, any anecdote (if they want), hobbies, interests (academically and extracurricular), and any other fact they consider relevant and want to share.

4.2.3) Baseline Assessment: The first week of class, students were asked to take an announced proctored quiz with the basic concepts from Statics that they need for being successful in Structural Analysis: particle equilibrium, rigid body equilibrium, trusses, and internal forces including shear and moment diagrams. After completing the assessment, the students were allowed to review their work and they were required to complete a revision of it. They filled a template where at the left side as the original work, and on the right the revised work. Students needed to also circle/highlight and explain their mistakes and prepare a reflection on what they should have done better and what actions they will take to prevent this type of situation from happening again.

4.2.4) KWL Reflections: **Course** KWL: at the beginning of the semester, after reading the syllabus, students documented what they think they know about the course, and what they would like to learn in the class. At the end of the semester, they completed it with what they learned. Each module/topic KWL chart: same process but referred to each chapter. At beginning of each chapter, they completed what they think they know (prior knowledge), what they wanted to learn (learning goals), and at the end of the chapter, what they learned (post chapter understanding of the concepts).

4.2.5) Practice problems before each assessment: Students documented and included in the E-portfolio all the problems they worked on before each assessment with their solutions.

4.2.6) A summary of the laboratory reports and its relationship with the course, previous and future courses, real life, and professional practice.

4.2.7) Each mid-term assessment: documented in the same way as the baseline assessment. Original work (highlighting and explaining the errors), revised work, and reflection on what they missed, why, and what will they do in the future to avoid these mistakes (Figure 1).

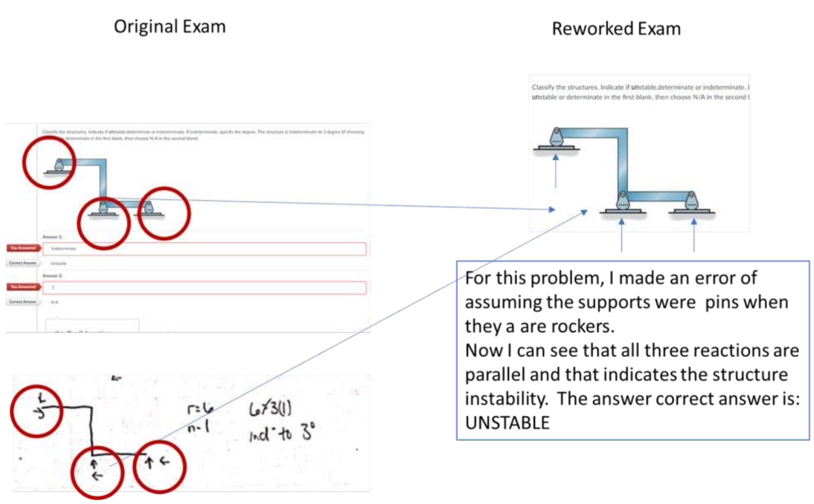


Figure 1. Example of question reworked by the students.

4.2.8) For every chapter/topic, each student must include real-life pictures of structures resembling those studied in the classroom and explain them.

4.2.9) Additionally, at the end of every chapter/module, students must include and discuss a case-study related to the learned topics.

4.2.10) KWL last column (what they learned).

4.2.11) The final reflection: this was performed first by answering a list of questions.

Were my expectations for the course achieved? Why or why not? What could I have done better? What prior knowledge did I bring to the course? What were my expectations for this course? Were they fulfilled? What was my greatest accomplishment for this course, and how will I apply it in my personal life or place of work? What was my greatest challenge for this course, and what steps did I take, or will I take to overcome it? What is the #1 priority that I need to accomplish before the next course, and how will I achieve it? What were some important concepts, factors, and ideas that I discovered/learned this course? In what specific area do I still need help, and what can I do to help myself? Did I reach my goals for this course? If so, what did I specifically do to help myself? If not, what can I do to improve, and what will I do differently next course? What did I do specifically to contribute to my peers' learning this week? What did I learn from them? What do I want to learn more about and why? How did I grow, improve, and develop myself during this course? Be specific. Explain how you will apply this to your personal or work life. After answering the questions, the students prepared a condensed version as a 5-paragraph essay.

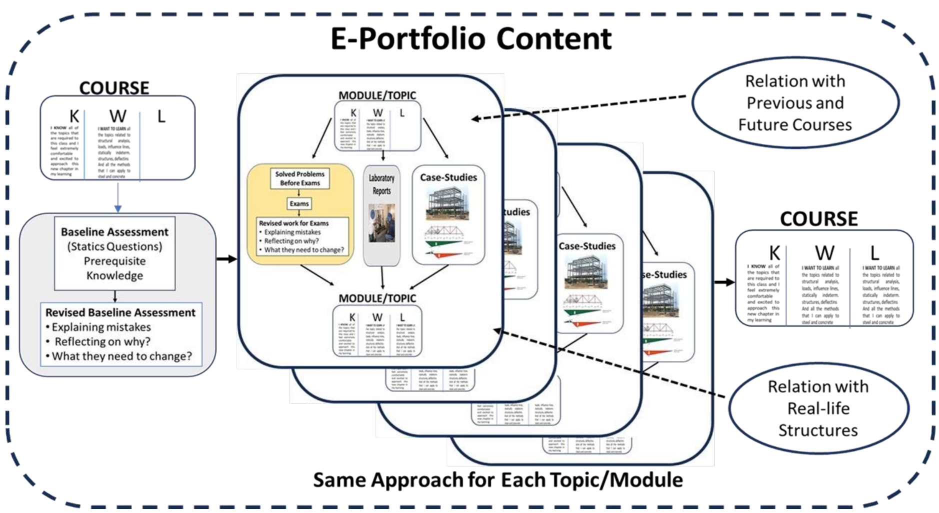


Figure 2. E-Portfolio Content

Figure 2 illustrates the structure of the e-portfolio and its integration into the course workflow. The E-portfolio was graded based on reflection quality, conceptual clarity, completeness, and evidence of learning growth. All their coursework were provided, including annotated problem solutions and reflective commentary linking structural analysis concepts to professional practice. An assessment rubric was provided to the students.

4.3) Data Collection

Quantitative data included all the students' grades in 5 examinations (Exams 1-4 plus the final exam) from both the baseline (control group without E-portfolio) and intervention semesters (with E-portfolio). A students' perception survey was administered at the end of the intervention semesters with 11-item Likert-scale questions. The survey captured attitudes toward reflection, metacognition, learning from errors, and linking course content to professional applications. A total of 108 students completed the survey. Then, the responses were converted to percentages, and a quantitative analysis of the converted descriptive data was performed and presented as bar charts and tables.

4.4) Data Analysis

Quantitative grade data was analyzed using descriptive statistics, including mean, and standard deviation. In addition, because the exam scores were clustered within students, a 2-level growth hierarchical linear model (HLM) was used to study the effect of the E-portfolio on performance and learning growth. Results are also presented as side-by-side tables and bar charts.

Qualitative survey responses were analyzed to identify patterns related to metacognition, self-regulation, and conceptual understanding. These Likert-scale responses were converted into percentage distributions and plotted as well.

5) Results

5.1) Descriptive statistics

A total of 276 students were included in the analysis, with 139 students in the control group (no E-portfolio) and 137 students in sections with E-portfolio. Each student completed five examinations during the semester. Table 1 presents descriptive statistics.

Table 1. Descriptive Statistics for Exam Performance.

Condition	**Students (N)**	**Observations**	**Mean Score**	**SD**
Control	139	695	58.42	28.71
E-Portfolio	137	685	71.36	22.94

Students in the sections with E-portfolio demonstrated higher mean exam scores overall compared to students in the control group.

5.2 Hierarchical linear model (2-level)

A two-level hierarchical linear model was used to examine changes in student performance over time. At Level 1, exams grades were modeled as a function of time, capturing individual growth trajectories. At Level 2, student-level predictors (E-portfolio vs. control), were used to explain variability in both initial status and growth rates. The cross-level interaction between time and condition ($\gamma 11$) measured whether the rate of performance change differed by the incorporation of the E-portfolio. Equations (1), (2), (3), and (4) were used as described below.

Level 1 Model (within student: Exam grades' performance)

$$GRADE_{ti}=\pi_{0i}+\pi_{1i}(EXAM_{ti})+e_{ti} \tag{1}$$

$GRADE_{ti}$: Score of student *i* on exam *t*

π_{0i}: Student *i*'s initial performance (Exam 1 baseline)

π_{1i}: Student *i*'s rate of improvement across exams

$EXAM_{ti}$:Time coded as 0,1,2,3,4 (Exams 1, 2, 3, 4, Final)

e_{ti}: student variability

Level 2 Model (Effect of E-Portfolio on students)

Initial Performance (Intercept): $\pi_{0i}=\gamma_{00}+\gamma_{01}(EPORT_i)+r_{0i}$ (2)

Improvement over exams (Slope): $\pi_{1i}=\gamma_{10}+\gamma_{11}(EPORT_i)+r_{1i}$ (3)

Combined Model:

$$GRADEt_i=\gamma_{00}+\gamma_{01}(EPORT_i)+\gamma_{10}(EXAM_{ti})+\gamma_{11}(EXAM_{ti}\times EPORT_i)+r_{0i}+r_{1i}(EXAM_{ti})+e_{ti} \tag{4}$$

Level 1 corresponds to the 5 exam scores (N=1,380), level 2 are the students (N=276), the predictor is the E-portfolio (Control=0, E-portfolio=1). An unconditional model revealed significant between-student variability, with an intraclass correlation coefficient (ICC) of 0.47, indicating that 47% of the variance in exam performance was attributable to differences between students, justifying the use of multilevel modeling. Results from the full model indicated that participation in the e-portfolio condition significantly predicted higher exam performance. Students in sections with E-portfolio scored, on average, 12.91 points higher per exam than students in the control group. $\gamma_{01} = 12.91$, $SE = 2.41$, $t = 5.36$, $p < .001$. This represents an improvement equivalent to approximately one full letter grade.

Student performance improved across the semester at a relatively weak rate in the control group $\gamma_{10} = 2.87$ and a relatively strong rate in the experimental group $\gamma = 5.81$.

A significant effect of time was observed as well, indicating that student performance improved across the semester, $\gamma_{10} = 2.87$, $SE = 0.41$, $t = 7.00$, $p < .001$.

Also, and maybe more importantly, the presence or absence of E-portfolio and time was statistically significant, $\gamma_{11} = 2.14$, $SE = 0.58$, $t = 3.69$, $p < .001$.

This may suggest that students in the E-portfolio semesters improved at a greater rate compared to students in the control group. Over the five-exam semester, this corresponded to an additional learning gain of approximately 10.7 points. Variance component analysis show significant variability at both the student and exam levels. Results from the model show approximately 18.7% of the between-student variance and 22.4% of the within-student variance (considered to be large effects for educational research).

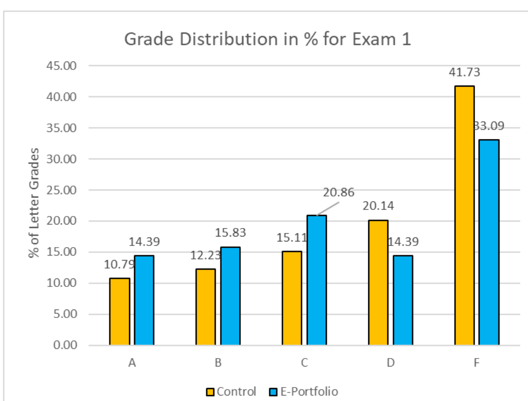
The HLM analysis shows two major findings: 1) Students using E-portfolios achieved significantly higher overall academic performance and 2) Students using E-portfolios demonstrated greater learning growth across the semester. These results suggest statistical evidence supporting the effectiveness of E-portfolio as a tool in the structural analysis course.

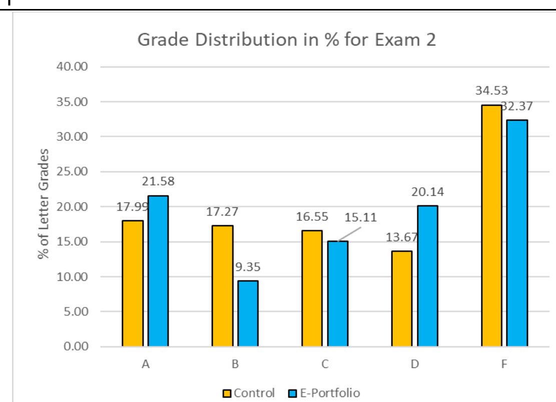
5.3 Letter grades distribution per exam.

To compare the letter grades distribution in the exams, the withdrawals were not included in the results for this part because some students withdrew at different times during the semester, making the total number different for every exam. However, all the grades were included for the course success statistics presented later.

Table 4. Percentage of students' letter grades per exam.

Control Group (No Portfolio)						Group with E-Portfolio					
%	Exam 1	Exam 2	Exam 3	Exam 4	Final Exam	%	Exam 1	Exam 2	Exam 3	Exam 4	Final Exam
A	10.79	17.99	0.72	5.04	2.88	A	14.39	21.58	11.51	25.9	10.07
B	12.23	17.27	7.19	17.99	5.04	B	15.83	9.35	15.11	15.11	16.55
C	15.11	16.55	14.39	15.83	13.67	C	20.86	15.11	17.27	15.83	12.95
D	20.14	13.67	14.39	17.99	5.04	D	14.39	20.14	24.46	10.79	30.22
F	41.73	34.53	63.31	43.17	73.38	F	33.09	32.37	30.22	30.94	28.78





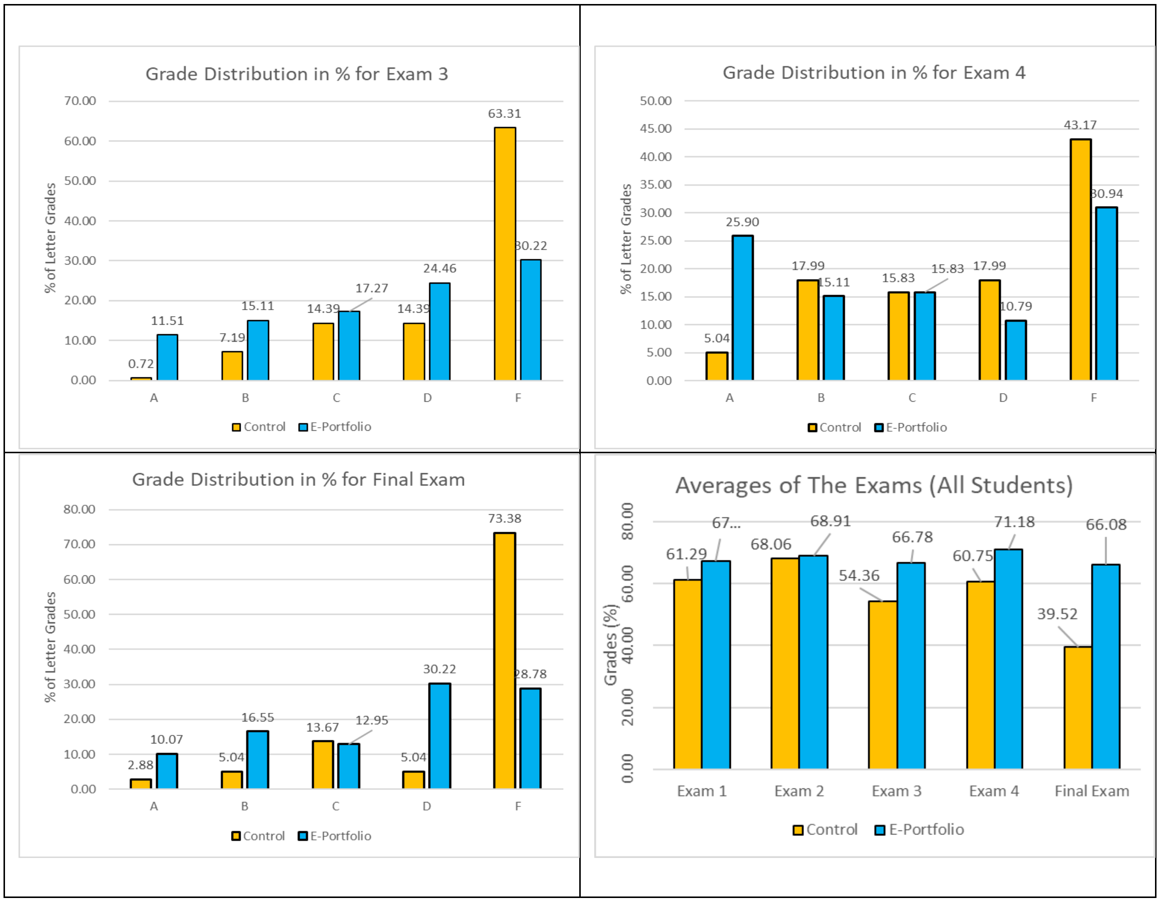


Figure 3. Percentages of Grades Distribution per Exam.

Table 5. Comparison of Final Grade Distributions With E-portfolio (n=137) and Without E-Portfolio(n=139)

Final Course Grade Distribution (%)

Grade	Control (no Portfolio)	Courses with E- Portfolio
A	8.67	13.19
B	30.67	38.89
C	27.33	32.64
D	16.67	6.94
F	9.33	3.47
W	7.33	4.86
Total	100	100

	Control (no Portfolio)	Courses with E- Portfolio
ABC (Success Rate)	66.67	84.72
DFW (Failure rate)	33.33	15.28

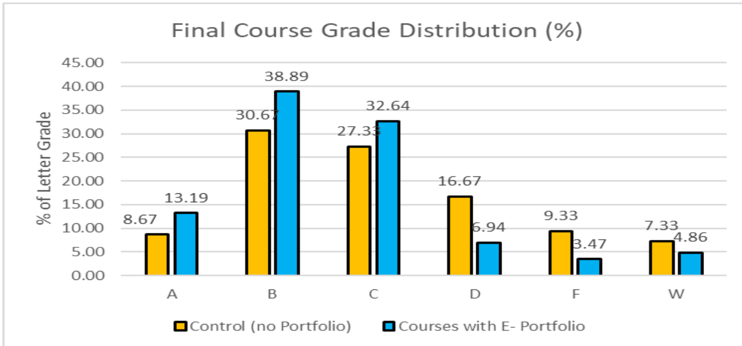


Figure 4. Final course grade distribution (A-W) expressed as a percentage.

The increase in A, B, and C grades and a reduction of DF grades suggests a migration of the grade distribution toward success indicating that the e-portfolio intervention was effective for the students' performance while reduction in the W's may indicate improved persistence among students (Table 5 and Figure 4).

As can be observed in Figure 5, the implementation of the e-portfolio was associated with a substantial improvement in student success. The ABC success rate increased from 66.7% in the non-portfolio course to 84.7% in the e-portfolio-based course. Correspondingly, the DFW rate decreased from 33.3% to 15.3%.

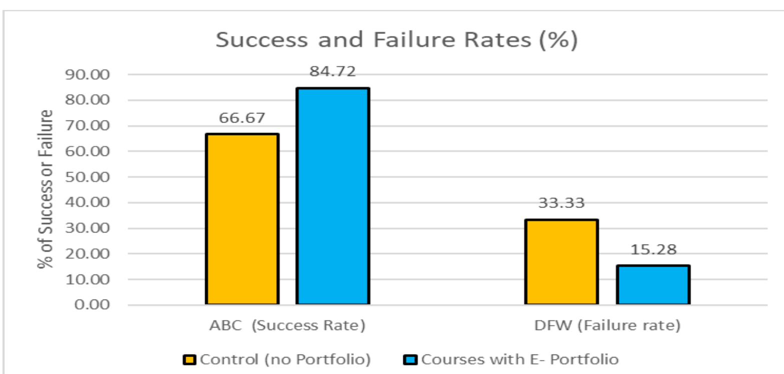


Figure 5. Success (ABC) and Failure (DFW) rates as percentages.

5.4 Student Survey Results: Metacognition and Self-Regulated Learning

The 11-item Likert survey explored students' metacognitive awareness, reflective learning, and perceived benefits of the e-portfolio. Out of the 137 students that participated in the courses with e-portfolio, 108 answer the survey and their responses are summarized in table 6.

Table 6. Student Perception Survey Results (N=108)

#	Survey question	1	2	3	4	5	M	SD
1	With the E-portfolio I learned significant aspects of Structural Analysis regardless of my grade in this course	0	1	3	40	64	4.6	0.6
2	I liked the knowledge I acquired by creating the E-portfolio	11	9	23	32	33	3.6	1.28
3	Creating the E-portfolio helped me to better understand the concepts	11	12	18	31	36	3.6	1.32
4	Reworking the exams forced me to learn from my mistakes	6	3	16	39	44	4	1.08
5	E-portfolio forced me to link class concepts with real life situations	4	10	20	36	38	3.9	1.11
6	Relating the topics with case-studies situations I understand better real life problems	3	6	20	40	39	4	1.01
7	Reflecting after each module improved my understanding of the class	2	14	32	32	28	3.7	1.06
8	KWL charts highlighted my strengths/weaknesses	10	17	25	31	25	3.4	1.26
9	E-portfolio improved my perspective of structural analysis	8	15	21	30	34	3.6	1.27
10	E-portfolio helped connecting structural analysis with past/future courses	4	12	15	47	30	3.8	1.08
11	E-portfolio was good for summarizing my progress in the class	9	15	25	29	30	3.5	1.26

Survey data suggest strong evidence of metacognitive engagement as shown in the charts below. Descriptive statistics show that, in general, students had positive feedback about the E-portfolio. The mean for all the questions is above the neutral (M=3), ranging from the highest: “With the E-portfolio I learned significant aspects of Structural Analysis regardless of my grade in this course” (M = 4.55, SD = 0.60) to the lowest: “KWL charts highlighted my strengths/weaknesses” (M=3.41, SD = 1.26). Another of the questions: “Reworking the exams forced me to learn from my mistakes” (M = 4.04, SD = 1.08) may suggest that the students’ reflections combined with exam corrections worked well as metacognitive mechanisms. Items related to application and knowledge transfer such as linking class concepts with real-life situations (M = 3.87) and understanding real-life problems through case studies (M = 3.98 also received a high score indicating the positive value of the E-portfolio. However, the questions related to reflection (like KWL charts and summarizing progress) showed positive means (M = 3.41, and M=3.52) but the standard deviation is high, indicating a marked difference in how the students perceived this type of tools. It is the author’s opinion that acquiescence, if any, is not of great impact since an important range of values can be observed in the mean from 3.51 (KWL charts) to 4.55 (learning regardless of the grade), representing more than one Likert point. Also, the values for the standard deviation (SD) range from 0.6 to 1.32 showing great variability.

6. Discussion, Conclusion, Limitations, and Future Work

One of the most important findings of this study is the effect of the E-portfolio and time. As per the HLM, students using the E-portfolio improved at a faster rate through the semester. These results suggest that the E-portfolio positively influenced learning, understanding, and knowledge retention. Results also suggest that the E-portfolio implementation is associated with improved course outcomes. While some of the effect size is modest, the changes in the percentage of grades are very important for engineering education, where retention and progression are critical concerns. A, B, and C grades increased by approximately 18% points which corresponds to 27% improvement. Consequently, the D, F, and W were reduced from 33.33% to 15.28% reflecting a reduction on the failure rate of around 54%. This suggests that E-portfolios are more than an additional assessment but a tool for supporting engagement, reflection, and continued learning. Looking at the analyses together, these findings support the use and incorporation of E-portfolios as a high-impact instructional practice that enhances student engagement, reflection, and academic success, aligning with ABET Student Outcomes.

However, some limitations of this study exist since the e-portfolios were implemented by only one instructor and in one institution. Additionally, the surveys rely on self-reported students' data. Future work could include a more comprehensive longitudinal tracking of metacognition and performance in the same course taught by other instructors and multiple institutions.

Based on the results, despite the limitations discussed, this study suggests that the implementation of e-portfolios provide an effective mechanism to enhance student success, reflective learning, and metacognitive development in the Structural Analysis course. Quantitative data demonstrate higher success rates (ABC) and reduced DFW outcomes, while survey results confirm gains in self-regulated learning and conceptual understanding. Incorporating reflection, error analysis, and professional integration in engineering coursework are very important learning components that strongly align with ABET outcomes and supports preparation for professional practice as well.

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