

Developing Reflective Practice through Structured Learning Portfolios in Project-Based Engineering Education: A Longitudinal Case Study

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ABSTRACT

Reflection is an essential professional competence in engineering, yet opportunities for explicit training, feedback, and assessment remain limited in engineering educational programs. This study investigated how structured learning portfolios support the development of reflective practice in a master's-level project-based engineering course and explored students' perceptions of their value for learning and formative assessment. A longitudinal case study was conducted in a 20-week biotechnology engineering course involving 16 master's students. Students completed five individual Project Journal entries guided by prompts. Reflection quality was analysed using the Hatton and Smith framework, with changes over time examined using linear mixed-effects modelling. Students' perceptions were explored through an anonymous end-of-course survey. Reflection quality increased significantly across the five journal entries, indicating progression from predominantly descriptive towards more dialogic and critical reflection. Students reported that the journals enhanced their understanding of project work, engagement with scientific literature, and awareness of their learning and teamwork. The journals also provided teachers with valuable insights into students' reasoning, conceptual understanding, and professional development. These findings suggest that structured learning portfolios, supported by repeated reflective practice prompts and formative feedback, can scaffold reflective practice while strengthening opportunities for formative assessment in project-based engineering education.

KEYWORDS

Reflective practice,
learning portfolios,
formative assessment,
project-based learning,
educational
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Introduction

Engineering graduates are expected not only to possess strong technical knowledge but also to exercise professional judgement, adapt to rapidly changing technologies, collaborate across disciplinary boundaries, and make informed decisions in situations characterised by uncertainty. These capabilities require engineers to critically examine their assumptions, evaluate evidence, learn from experience, and continuously adapt their practice. Reflection is therefore increasingly recognised as a core

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component of engineering competence and lifelong professional learning rather than an activity confined to educational settings (Riemer, 2004; Turns, Sattler, Yasuhara, Borgford-Parnell, & Atman, 2014). Within higher education, reflective practice has been associated with deeper learning, improved critical thinking, stronger professional identity, and greater capacity to integrate theoretical knowledge with practical experience (Biggs, 1999; Branch & Paranjape, 2002; King, 2002; Rogers, 2001; Rook et al., 2025; Russell, 2022).

Despite this recognition, learning activities explicitly designed to develop reflective practice remain relatively limited within engineering education. Engineering curricula have traditionally emphasised technical knowledge, analytical problem solving and correct solutions, while reflective activities often receive less attention than in disciplines such as teacher education and the social sciences (Kim et al., 2021; Riemer, 2004; Turns et al., 2014). Although project-based and problem-based learning environments provide rich opportunities for reflection, students do not necessarily develop reflective competence simply through participation in such activities (Csavina, Nethken, & Carberry, 2016; Scully, O'Leary, & Brown, 2018). Instead, studies suggest that engineering students frequently approach reflective tasks descriptively, focusing on summarizing events rather than critically analysing their own learning, questioning assumptions, or considering broader implications (Csavina et al., 2016; Lewis, 2016; Turns et al., 2014). Reflection therefore appears to require deliberate training rather than emerging spontaneously through experience alone.

Learning portfolios have been proposed as one approach for supporting reflective practice in higher education. By encouraging students to document experiences, relate them to previous knowledge and critically examine their learning over time, portfolios can promote metacognitive awareness while simultaneously providing evidence of students' developing understanding (Alt, Raichel, & Naamati-Schneider, 2022; Moon, 2002; Struyven, Blicke, & De Roeck, 2014; Veine et al., 2020). When integrated with formative feedback, portfolios may further scaffold students' progression from descriptive towards increasingly sophisticated forms of reflection (Ash, 2009; Scully et al., 2018). Within engineering education, however, the use of reflective portfolios remains comparatively limited, and empirical evidence regarding how students' reflective practice develops longitudinally within authentic project-based environments is still scarce. Learning portfolios may also provide teachers with insight into individual learning in group-based projects, where assessment often focuses primarily on group outcomes.

The potential value of learning portfolios may also be understood through the perspective of educational scaffolding. Scaffolding refers to instructional support that enables learners to engage with tasks that may initially be difficult to perform independently, through structures such as prompts, modelling and formative feedback (Puntambekar & Hübscher, 2005; Wood, Bruner, & Ross, 1976). In reflective learning, such support may include structured prompts, repeated opportunity for practice, and individual formative feedback that encourage students to move from description towards analysis, interpretation, and critical evaluation. From this perspective, learning portfolios can function not merely as repositories of student work but as structured learning environments for developing reflective competence while simultaneously making students' reasoning visible to both learners and teachers.

This perspective is particularly relevant in master's level engineering project courses, which are inherently designed to develop not only disciplinary knowledge but also professional capabilities including teamwork, scientific reasoning, project management and independent judgement. Because assessment of such courses is frequently based on group-based outputs, individual students' conceptual understanding, professional development and achievement of learning outcomes may remain difficult to evaluate. Structured learning portfolios may therefore function as scaffolds that both support students' development of reflective practice and provide opportunities for formative assessment of individual student learning within a group-based learning context.

The present study investigates a structured learning portfolio design, implemented through *Project Journals* in a master's level biotechnology engineering project course at a Swedish university. Students completed five individual journal entries throughout the semester, supported by prompts intended to scaffold progression in reflective practice. Reflection quality was analysed longitudinally using the Hatton and Smith framework, ranging from descriptive writing to critical reflection (Hatton & Smith, 1995), and students' perceptions of the journals were explored through an end-of-course survey.

The study addresses the following research questions: 1) How does the quality of engineering students' written reflection develop during repeated participation in a structured learning portfolio activity embedded within a master's project course? 2) How do students perceive the contribution of structured learning portfolios to their learning, reflective practice and participation in project-based engineering education?

By examining both longitudinal changes in reflective writing and students' experiences of the learning activity, this study contributes empirical evidence on the use of structured learning portfolios to support the development of reflective practice while strengthening formative assessment in project-based engineering education.

Methods

Research design

This study was based on a longitudinal case study designed to investigate how a structured learning portfolio supported the development of reflective practice in a master's level engineering project course. The study combined quantitative and qualitative data to examine changes in students' reflective writing over time and to explore students' perceptions of the learning design.

The pedagogical design drew on principles of educational scaffolding through structured reflection prompts, repeated opportunities for practice and individual formative feedback. The core prompts remained largely consistent across entries 1-4, while the feedback was responsive to each student's writing and revisited in subsequent submissions. Reflection quality was analysed longitudinally using the Hatton and Smith framework (Hatton & Smith, 1995), while student perceptions were explored through an anonymous end-of-course survey.

Educational context

The study was conducted during one semester in a 20-week master's level project course in Biotechnology Engineering at a Swedish research-intensive university. The course, corresponding to 15 ECTS credits, is based on authentic biotechnology research projects in which students work collaboratively supervised by academic researchers.

Sixteen students participated in the course. Eleven students were enrolled in an international Master's programme in Pharmaceutical Technology and five were fourth-year students in a five-year Biotechnology Engineering programme. The course language was English, and the student cohort represented diverse linguistic and educational backgrounds. Students worked in groups of four or six, intentionally composed after short interviews to balance diversity in prior experience, educational background and gender. Each project involved approximately 160 hours of laboratory work in academic research laboratories.

The 16 students worked in four project groups, each undertaking a separate project addressing research aims in different phases of biopharmaceutical development, typically involving optimization of assays

and experimental workflows. Although the projects differed in scientific aims, they all involved iterative experimental work, trouble-shooting, interpretation of results, engagement with scientific literature and methodological decision-making. Each group was supervised by one or two researchers and/or PhD students at the host department, and the project design was jointly proposed by the supervisors and the course coordinator. The course coordinator was not involved in practical supervision of the project groups. The supervisors supported the scientific and practical work of their respective groups but were not involved in the Project Journal activity, which was administered and reviewed by the course coordinator. Consequently, students worked within different research and supervisory contexts, although the Project Journal instructions and formative feedback process were common across the cohort.

The course is assessed on a Pass/Fail basis and aims to develop both disciplinary knowledge and professional competencies, including scientific reasoning, project management, teamwork and reflective understanding of research practice. Before the implementation of Project Journals, course assessment focused primarily on group-based, summative outputs, consisting of a written project report and an oral presentation at the end of the semester. Although these assessments evaluated project outcomes, they provided limited opportunities to monitor individual students' achievement of several of the intended learning outcomes. Completion of the five Project Journals was mandatory but the quality of reflection did not contribute to the course grade. This was a deliberate design choice to allow students to engage in formative reflection without tailoring writing to a grading rubric.

Learning portfolio design

A structured learning portfolio referred to as the Project Journal, was incorporated as part of an updated course design intended to strengthen formative assessment and scaffold the development of reflective practice. The Project Journal was complemented by several other learning activities in the course, including project planning seminars, literature discussions, student-led lab demo tours, and iterative report writing with formative feedback.

Each student completed five individual Project Journal entries distributed across the semester. The prompts followed the Retell-Relate-Reflect framework (Rolheiser & Schwarz, 2001; Ryan, 2013), in which students move from describing an experience, to connecting it with previous knowledge or experience, and finally to interpreting its meaning and implications. The Project Journal was guided by these three recurring prompts focused on the project work: 1) *Retell*: Describe significant project activities, observations and experiences; 2) *Relate*: Connect experiences and observations to previous courses, scientific literature or earlier knowledge; 3) *Reflect*: Apply judgement, give opinion and communicate insights through interpreting the significance of experiences, evaluate decisions, identify challenges, consider alternatives and discuss implications for future learning and the project.

Additionally, students were for the second part of each entry asked to reflect on their role within the project team, identify challenges encountered since the previous submission, and formulate personal goals for the coming project period. Guidelines for the first four entries stated that the text should comprise approximately 1000 words. For the fifth and final entry for which no word limit was set, students were asked to provide a reflection on the scientific outcome of the project, their own learning and development in relation to the course learning outcomes, and their role and experience within the project team.

Students maintained a single Project Journal document throughout the semester, containing all previous entries and the course coordinator's comments. For each new submission, students were instructed to revisit earlier feedback and mark any additions or revisions made in response to the comments. They were also encouraged to build on previous entries rather than repeat earlier

descriptions, with the aim of making progression in the project, their understanding, laboratory confidence and participation in the project team visible over time. The instructions emphasised that students were not evaluated according to achievement of specific project milestones but were expected to demonstrate their individual progression towards the intended course learning outcomes.

The Project Journal activity was coordinated centrally by the course coordinator and used the same instructions and submission schedule for all project groups; project supervisors were not involved in scoring or providing journal feedback. Each journal entry was read by the course coordinator shortly after submission, and individual written feedback was returned to students within one week, well ahead of the following journal entry. Feedback was embedded as comments in the journal document and was individualised and responsive to the student's writing rather than based on a standardised feedback rubric. Comments typically encouraged students to elaborate their reasoning, connect observations to previous knowledge or scientific literature, consider alternative interpretations, and discuss the implications of experimental outcomes for the wider project and their own learning. Students were instructed to address relevant comments in subsequent submissions by revising or extending earlier entries and marking new/edited text in the document, thereby creating an iterative written dialogue between student and teacher across the semester. At approximately the midpoint of the course, the Project Journal activity was discussed with each student group separately, providing an opportunity to clarify expectations and discuss their experiences of the reflective writing process.

Data collection

All 16 students completed all five Project Journal submissions, resulting in 80 journal entries. This dataset formed the basis for the longitudinal analysis of reflective practice. A second dataset comprised an anonymous end-of-course survey completed after all summative assessment activities had been concluded. Fifteen of the sixteen students responded (94% response rate). The survey combined Likert-scale items concerning students' experiences of the Project Journal with open-ended questions inviting comments on perceived learning, reflective practice and the usefulness of the learning design.

Analysis of reflective practice

Students' reflective writing was analysed using the four-level framework developed by Hatton and Smith (Hatton & Smith, 1995), which distinguishes descriptive writing, descriptive reflection, dialogic reflection and critical reflection.

One overall reflection score was assigned to each complete journal entry. Scoring focused primarily on the Reflect part of the Retell-Relate-Reflect structure, although reflective reasoning appearing in the Relate section was also considered. Descriptive content included under Retell was not scored as low level reflection, since students were explicitly expected to apply descriptive writing in that part. Scores were assigned through an overall judgment of the predominant level of reflection demonstrated in the entry rather than according to the highest-level statement present. Particular emphasis was placed on whether reflective claims were supported by concrete examples from the student's own project experience, reasoning or observations. This helped distinguish well underpinned reflective reasoning from isolated or generic statements not clearly grounded in the project context.

Scoring was based directly on the Hatton and Smith category definitions as interpreted by the analyst:

1. Descriptive writing: factual description without explanation or interpretation.
2. Descriptive reflection: inclusion of explanations, reasoning or justification.

3. Dialogic reflection: exploration of alternative interpretations, questioning and internal dialogue.
4. Critical reflection: interpretation within broader professional or contextual perspectives, including questioning assumptions and considering wider implications.

Hatton and Smith scores were assigned retrospectively after completion of the course. The scores were used exclusively for research purposes, were not communicated to students and did not contribute to course grades. Because the scorer had also served as course coordinator and provided formative feedback during the course, scoring could not be blinded to student identity. To reduce the influence of knowledge of an individual student's previous scores, entries were organised by submission round so that earlier scores for the same student were not visible during scoring.

Longitudinal changes in reflection quality were analysed using a linear mixed-effects model, treating journal entry number (1-5) as a continuous fixed effect and student identity as a random intercept to account for repeated measurements within students. The fixed effect estimate therefore represents the average change in reflection score associated with each successive journal submission. Results were verified using repeated-measures analysis of variance (ANOVA), and Mauchly's test was used to assess the assumption of sphericity. Statistical analyses were performed in R using the lme4, lmerTest and ez packages.

Analysis of student perceptions

Survey responses were analysed using a convergent mixed-methods approach. Likert-scale responses were summarised descriptively, while open-ended responses were analysed thematically to identify recurring perceptions regarding reflective practice, learning, engagement and formative assessment. Representative quotations are presented in the Results to illustrate themes identified across participants rather than as isolated evidence.

Ethical considerations

Participation in the research study was voluntary and did not influence course assessment. Following completion of the course, all students received written and verbal information about the study and provided informed consent for the use of their Project Journals for research purposes. Consent was collected electronically through the university's learning management system. Journal scoring was conducted only after course completion and was not shared with students or used in grading.

Results

Development of reflective practice

The first research question examined how students' reflective practice developed throughout repeated participation in the structured learning portfolio. Across the five Project Journal submissions, the quality of students' reflective writing increased overall (Figure 1). Reflection scores, assessed using the Hatton and Smith framework, increased from a mean of 2.0 in the first journal entry to 2.9 in the final submission, corresponding to an overall shift from predominantly descriptive reflection towards more dialogic and, in some entries, critical reflection. Across all 80 journal entries, the mean reflection score was 2.5. The linear mixed-effects model demonstrated a significant improvement in reflection

quality over time ($p = 8.6 \times 10^{-7}$), with an average increase of 0.21 in reflection levels between consecutive submissions. Repeated-measures ANOVA confirmed this trend ($p = 3.6 \times 10^{-5}$), and Mauchly's test indicated that the assumption of sphericity was satisfied ($p = 0.78$).

Baseline reflection quality varied considerably between students, although longitudinal development was evident for most participants. Eight students increased one reflection level between the first and final journal entry, while three students improved by two levels. One student consistently demonstrated the highest reflection level throughout the course, indicating little opportunity for further progression within the scoring framework. Although the overall trajectory was positive, some participants showed stable scores across several entries or temporary decreases between submissions, indicating individual variation in reflective performance over time. Although students worked in four different project groups, no clear clustering of reflection scores by project group could be observed.

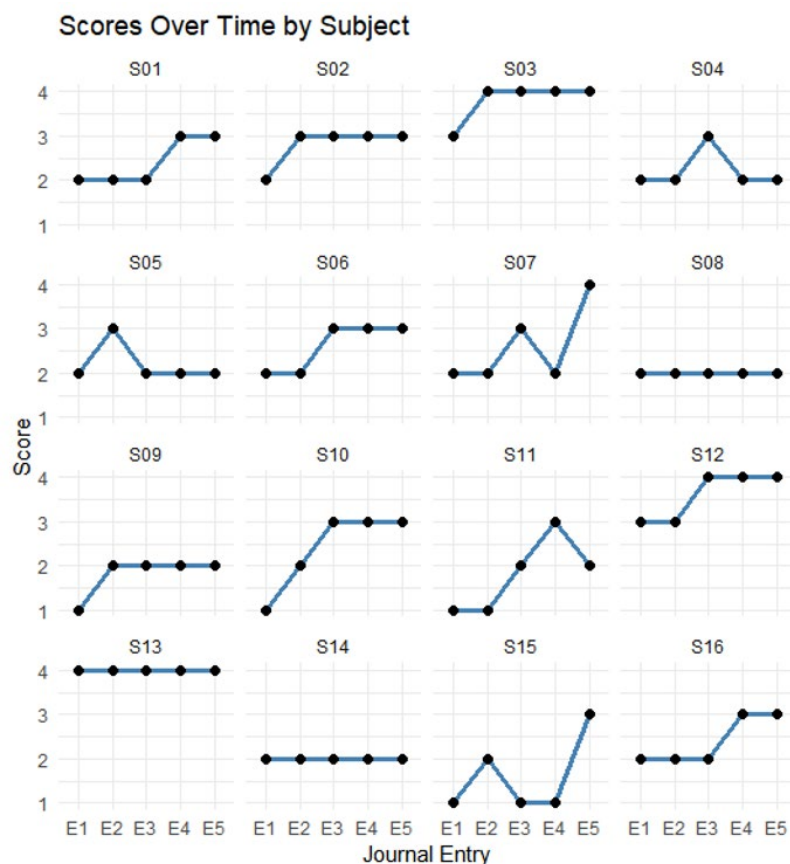


Figure 1. Quality in reflection per individual across the five Project Journal entries, as scored based on the Hatton & Smith four-level scale.

No statistically significant differences in average reflection scores were observed between students enrolled in the Biotechnology Engineering programme and those in the international master's programme in Pharmaceutical Technology, nor between female and male students. Although the cohort size limits interpretation of subgroup analyses, these findings suggest that the learning portfolio design supported reflective practice across students with diverse educational and linguistic backgrounds.

The nature of students' reflections also changed qualitatively during the semester. Early journal entries frequently focused on describing laboratory activities or reporting experimental progress. As the semester progressed, students increasingly connected project experiences with previous knowledge, scientific literature and broader engineering reasoning. Later entries more often questioned experimental decisions, considered alternative explanations, acknowledged uncertainty and reflected upon limitations of their work.

Representative examples illustrating the four Hatton and Smith reflection levels are presented in Table 1, to illustrate differences between descriptive reporting and analytical and contextually grounded reflection.

Table 1. Example of text extracts from Project Journal entries assigned different reflection scores. Excerpts were selected retrospectively from entries that already had been scored and were presented to illustrate the interpretation of the four Hatton & Smith levels.

Score	Interpretation	Example 1	Example 2	Example 3
1. Descriptive writing	Account of events and observations, no analysis	<i>"I have gained insights that it might not be so easy to obtain a high amount of DNA, which also is an important insight to our project."</i>	<i>"... our purpose was exploring the influence on colony counting of different parameters, and so far, we have done the experiments for [listing parameters tested]"</i>	<i>"By carefully altering the original protocol to optimize key parameters (i.e., plating time, plating methods etc), our group was able to increase the reliability of our total CFU counts."</i>
2. Descriptive reflection	Reasons and justifications	<i>"I think one reason for our success with Part B is thanks to our trouble shooting in part A were we got a lot of practice and got used to ex utilizing []. This was shown last week when my colleagues made the judgement to do a step twice since they could intuitively see that the sample was too cloudy. This is important and shows critical</i>	<i>"By analyzing the results alongside provided literature on M13 phage and lab protocols, I have gained a deeper understanding of the purpose of CFU titration in phage screening . First, the pHAT vector carried by ... [providing an example]"</i>	<i>"The initial guess is that this is caused by the enzyme not completely cutting the DNA, or it may be caused by the excessively high DNA concentration"</i>

		<i>thinking to adjusting protocol, something that we would have been unable to do the first day.</i>		
3. Dialogic reflection	Questioning, considering alternatives	<i>“After reading [reference] I concluded that using phosphate buffer as we do in our experiments was the best way to reach higher absorbances, opposed to adding chlorine to the buffer which results in lower [signals]. As a point for future experiments it might be interesting to modify the pH to get better readings”</i>	<i>“In contrast, this project involves working with living cells, requiring us to adapt our methods based on bacterial behavior and unpredictable results. Unlike structured courses where protocols are predefined, we can choose to modify our procedures as needed. For example, we initially planned ...”</i>	<i>“Is the enzyme still acting on the substrate? Is it still bound to the substrate and displayed together with the substrate band? I wonder what will happen if we extend the reaction time on the PCR machine? In addition, what is the concentration range of the sample to make the band clear and sharp?”</i>
4. Critical reflection	Placing events in broader context, questioning assumptions, thinking about consequences, taking on a critical view on the potential influence of various factors.	<i>“This setup allowed us to test and optimize the concentration of catcher antibodies, aiming to maximize specific binding while minimizing background signal [...] Future studies could explore concentrations between 0.1–0.5 µg/mL to determine whether even lower amounts can be used without compromising assay performance.</i>	<i>“What stood out most is that the techniques we use, DNA gel electrophoresis, Western blot, CFU, and PFU, all complement each other. They don’t follow in a strict order, but each gives different insight into the same thing: the quality and performance of the phage libraries [...] Working this way has changed how I view lab work, from something you “do correctly” to</i>	<i>“These optimized steps helped reduce variability and will be useful as a standardized protocol in the lab. However, since we didn’t include biological replicates or statistical analysis, we can’t say whether the observed differences are statistically significant. The trends are promising, but future work should validate them with larger datasets and</i>

			<i>something you constantly refine, combining results and knowledge across methods.”</i>	<i>independent repeats”</i>
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Students' perceptions of the learning portfolio design

The second research question explored students' perceptions of the structured learning portfolio. Overall, survey responses indicated positive perceptions of the Project Journal. Eleven of the fifteen survey respondents (73%) reported that the journals contributed to the development of their reflective practice, while thirteen students (87%) considered the formative feedback valuable for improving subsequent reflections (Figure 2).

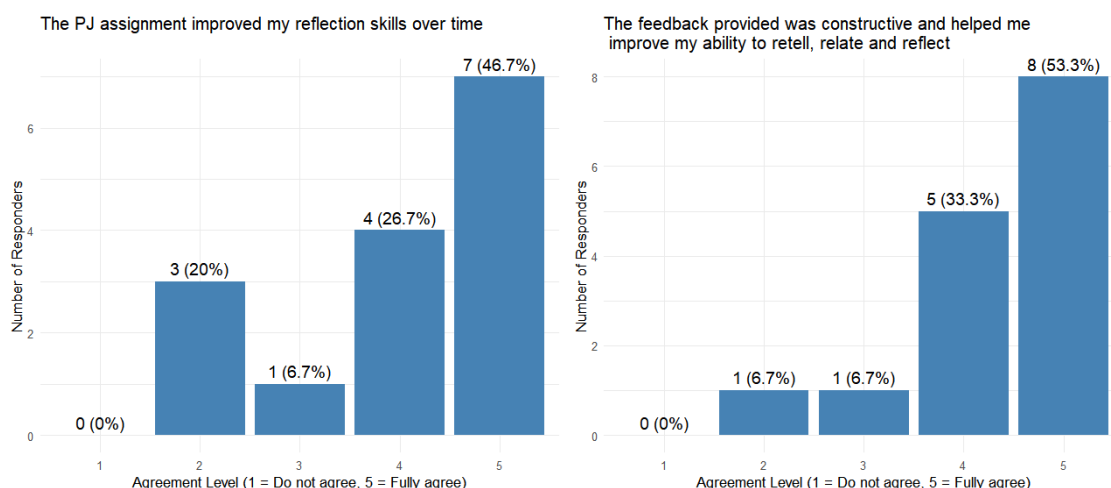


Figure 2. Student's perception of the Project Journal (PJ) assignment assessed by an anonymous survey. Shown are responses to two of the eleven survey items, selected to illustrate perceived development of reflective practice and the value of formative feedback.

Students' written comments suggested that the journals supported several interconnected aspects of learning. First, students described becoming more deliberate in interpreting experimental outcomes rather than simply documenting laboratory activities. Reflection was frequently described as helping them understand the purpose of experiments, evaluate project progress and integrate theoretical knowledge with practical experiences.

One student explained:

"I thought it was a good assignment to have; it made me reflect over the purpose of experiments and why we got the results we have."

Rather than merely recording project activities, students described reflection as an opportunity to analyse decisions, interpret unexpected findings and consider how individual experiments contributed to the overall project.

Second, many students perceived that the journals promoted continuous engagement throughout the semester. Twelve respondents (80%) reported that the journals improved their understanding of the project as a whole, while ten students (67%) considered that the activity increased their engagement with the project, encouraged additional reading of scientific literature and strengthened their analytical thinking.

Several students also highlighted that the iterative nature of the journals encouraged continuous rather than retrospective learning. Instead of postponing reflection until report writing, students reviewed project experiences throughout the semester and connected emerging observations with previous entries and formative feedback.

Despite these positive experiences, some participants described uncertainty regarding expectations during the first submission, particularly concerning the intended depth of reflection and the integration of scientific literature. These comments indicate that reflective writing were unfamiliar to several students at the beginning of the course.

Learning portfolios as a mechanism for formative assessment

Beyond supporting students' reflective practice, the Project Journals generated evidence of individual learning that would otherwise have remained largely invisible within the collaborative project environment. Importantly, the journals enabled the course coordinator to follow individual students' development throughout the semester rather than relying solely on final group reports. Entries frequently revealed students' scientific reasoning, interpretation of experimental outcomes, awareness of methodological limitations and understanding of project objectives. There were several cases of students who contributed relatively little during group discussions due to either quieter personality or language barriers, but who demonstrated substantial conceptual understanding through their written reflections. The journals therefore provided an additional perspective on individual student progression that complemented observations from project supervision and oral assessment.

The journals also provided insight into development of professional competencies. Reflections on teamwork evolved from descriptions of completed tasks towards increasingly thoughtful consideration of collaboration, communication and personal responsibility within multidisciplinary teams. Many students recognised changes in their own participation, confidence and ability to contribute to collective decision-making, indicating development beyond disciplinary knowledge alone.

Finally, the journals created opportunities for formative dialogue between teacher and student. Individual feedback enabled misconceptions and challenges to be identified during the course, while subsequent journal entries allowed students to respond to earlier comments. Although the present study did not explicitly investigate the independent contribution of feedback, students reported that the iterative feedback was supporting both their understanding of the project as well as their reflective competence. However, not all students demonstrated measurable improvement in reflection quality despite receiving targeted feedback.

Taken together, these findings suggest that structured learning portfolios functioned not only as a scaffold for developing reflective practice but also as an approach for making individual learning visible within project-based engineering education.

Discussion

The purpose of this study was to investigate how a structured learning portfolio design supported the development of reflective practice within a master's-level engineering project course and how students

perceived its contribution to learning. Reflection quality increased over the five Project Journal entries, although individual trajectories varied, and students generally perceived the journals and formative feedback as supporting their learning and reflective practice. The Project Journals also provided evidence of individual reasoning and development that was not always visible within the group-based project environment. Together, these findings suggest that structured reflective writing can support both the development of reflective competence and formative assessment within project-based engineering education.

Developing reflective competence through scaffolded learning

The longitudinal improvement observed in students' reflective writing provides support for the view that reflective competence can be deliberately trained rather than assumed to emerge naturally through project participation. Reflection scores increased significantly across the five journal entries, while students described becoming increasingly aware of how experimental decisions, scientific literature and teamwork contributed to their learning. Taken together, these findings suggest that students did not simply write more about their experiences but developed more sophisticated ways of reflecting on their project work.

The structured and iterative support provided through the Project Journal offers one possible explanation for this development. Rather than asking students to reflect in an open-ended manner, the learning portfolio design was based on structured prompts that guided reflection, repeated opportunities for reflective practice throughout the semester, and individual formative feedback. The core prompts remained largely consistent across the entries, while the feedback was responsive to each student's writing and students were asked to revisit earlier comments and build on previous entries. The scaffolding therefore did not involve a systematic decrease of support in terms of written prompts in line with the original scaffolding concept (Puntambekar & Hübscher, 2005; Wood et al., 1976). Instead, a structured and iterative form of scaffolding was applied to rather help students engage in increasingly complex reflective reasoning over time.

These findings extend previous work on learning portfolios (Moon, 2002; Scully et al., 2018; Veine et al., 2020) by illustrating how reflective practice may develop when it is integrated in authentic engineering projects and supported through repeated formative interaction between student and teacher. At the same time, the observed improvement could not be attributed solely to the portfolio design. As the project progressed, students also encountered increasingly complex activities involving interpretation of results, troubleshooting, decision-making and evaluation of project outcomes, which inherently may have provided progression towards higher-level reflection.

Importantly, not all students demonstrated the same trajectory of development. Several students entered the course already demonstrating highly developed reflective skills, while others progressed more gradually or showed variation between entries. The projects were broadly similar in structure but progressed at somewhat different rates, with periods of troubleshooting and experimental setbacks occurring at different time points. No clear clustering of reflection trajectories by project group was apparent. Nevertheless, differences in project activities and timing may have influenced the opportunities students had to demonstrate higher-order reflection. Variation may also depend partly on the nature of the project activities being reflected upon and how individual students responds to formative feedback. These observations highlight the importance of designing reflective learning activities that can accommodate variation in prior experience and confidence in reflective writing, and adapting formative support to individual students.

Learning portfolios as formative assessment in collaborative project courses

An important insight from this study was that the Project Journals also functioned as a means of formative assessment by making individual students' reasoning visible throughout the group-based project course. Assessment in project-based engineering education frequently relies on collective outputs such as reports and presentations, making it difficult to evaluate individual development during the learning process. In the present study, the journals provided opportunities to identify misconceptions, monitor progression towards learning outcomes and provide individualised feedback before final assessment. In the specific course batch, misconceptions or limited reflective reasoning were primarily handled through written feedback in the journal itself, while recurrent challenges were conveyed to the respective supervisor and discussed at the group level during the midterm meeting. Equally important, the Project Journals revealed aspects of learning that might otherwise have remained hidden, including students' scientific reasoning, professional judgement and developing understanding of research practice. The study also demonstrated that Project Journals can provide alternative evidence of learning for students whose understanding is not readily visible through oral participation in group-based project environments. While written reflection should not replace other forms of assessment, it may complement them by revealing reasoning, conceptual understanding and professional development that are difficult to observe through group interactions alone.

This finding shows that reflective writing may serve a dual educational purpose. Rather than representing an additional assessment activity, learning portfolios can simultaneously support students' development of reflective competence while providing educators with evidence of individual learning within group-based settings.

Designing reflective learning environments

The findings also offer insights into how reflective learning activities may be designed within engineering education. Students' survey responses consistently suggested that reflection became meaningful when embedded in authentic projects rather than being experienced as an isolated writing exercise. Students frequently described reflection as meaningful for interpreting unexpected experimental outcomes, connecting theory with practice and understanding the broader purpose of their projects. This supports previous observations suggesting that meaningful reflection requires explicit guidance, authentic contexts and repeated opportunities for training (Csavina et al., 2016; Scully et al., 2018).

Several students nevertheless expressed uncertainty about what was expected from reflective writing, particularly early in the course. In the studied cohort, students were introduced to the purpose of learning portfolios and the structure of the Project Journal, but examples distinguishing different levels or reflective writing were not explicitly discussed. Furthermore, some students remained primarily descriptive despite repeated individual feedback. This is in line with studies showing that feedback may raise expectations but do not automatically support the students with all the tools needed for critical reflection, such as critical analysis of assumptions, integration of theory, or considering implications of outcomes (Ash, 2009). In the subsequent course cohort, the introduction to the assignment was therefore expanded to include discussion of reflective practice as an important professional engineering skill and explicit examples illustrating descriptive, dialogical and critical reflection. Although the result of that adaption has not yet been evaluated, this should provide stronger support for students who are unfamiliar with reflective writing.

The study also raises questions regarding the role of generative AI in reflective assessment. Some students reported using AI primarily to improve language or explore possible explanations for experimental outcomes. High-scoring reflections, however, depended upon students' ability of relating

experiences to their own highly specific project context. Such highly contextualised setting may therefore reduce opportunities for superficial AI-generated learning portfolio entries, while AI may still provide opportunities for language support. As AI becomes increasingly integrated into higher education, future reflective learning designs should consider how assessment can continue to promote authentic reflective thinking.

Limitations

Several limitations should be considered when interpreting the findings. First, the study represents a single longitudinal case study conducted within one master's level engineering course with a relatively small cohort. Although the findings provide valuable insight into reflective learning within this context, they should not be interpreted as generalisable across engineering programmes. Second, improvement in reflective writing cannot be attributed solely to the Project Journal. Students simultaneously participated in an intensive research project involving laboratory work, literature studies and supervision, all of which may also have contributed to the development of reflective competence. The study therefore demonstrates the potential of the integrated educational design rather than establishing causal effects of the Project Journal as an individual learning activity. Furthermore, although all students completed all five entries, reflection quality did not contribute to the course grade and the level of engagement may therefore have varied between students. Third, reflection quality was assessed by a single researcher using the Hatton and Smith framework. Although scoring followed predefined criteria and was conducted after completion of the course and in order of submission round rather than student, the interpretation inevitably involved subjective judgement. Future studies should therefore include multiple independent raters and assessment of inter-rater agreement. Finally, the study did not examine whether development in reflective writing was associated with performance in the final project report, oral presentation, or other course outcomes. Whether development of reflective competence translates into improved project performance or professional competence therefore remains an important question for future studies.

Implications for engineering education

The findings have several implications for engineering teachers seeking to strengthen reflective practice within project-based courses. Reflective competence should be viewed as a skill requiring deliberate training rather than an outcome expected to emerge automatically from project experiences. Structured learning portfolios appear particularly well suited for project-based courses because they simultaneously support student learning and provide opportunities for formative assessment of individual progress within group-based settings. Finally, integrating reflective writing throughout a course, rather than limiting reflection to end-of-course evaluations, may strengthen both students' learning processes and teachers' ability to provide formative feedback.

Future research

Future studies should investigate the transferability of these findings across different engineering disciplines and student populations. Studies examining alternative forms of scaffolding and different feedback would further strengthen understanding of how reflective competence develops. Further exploring how reflective writing can continue to support learning while adapting to the use of AI in education is also an important focus. Finally, longitudinal research following students beyond individual courses could investigate whether scaffolded practice of reflective skills contributes to the development of professional engineering identity and lifelong learning.

Conclusion

This longitudinal case study demonstrates how a structured learning portfolio can function as more than a reflective writing assignment within project-based engineering education. By integrating structured prompts, iterative reflection and formative feedback, the learning design supported development of reflective competence while simultaneously making individual learning visible in a group-based project course setting. The study provides empirical evidence that reflective competence can be scaffolded through repeated opportunities for structured reflection embedded within authentic engineering course projects. It also demonstrates how learning portfolios can strengthen formative assessment by revealing individual students' conceptual understanding, scientific reasoning and professional development throughout a project course rather than only through final group-based project outputs. Finally, it illustrates how reflection, assessment and project-based learning can be intentionally integrated within a single pedagogical design rather than implemented as separate learning activities.

Although conducted within a single master's level engineering course, the findings contribute with insight in educational design for promoting reflective practice in engineering education. Reflection appears most meaningful when closely connected to authentic engineering challenges, supported through iterative scaffolding and accompanied by formative feedback. As engineering programmes continue to emphasize student's professional competencies alongside technical expertise, structured learning portfolios offer a practical way to combine reflective practice, formative assessment and project-based learning within a single learning design.

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Declaration of Interest

The author has no financial or competing interest to declare.

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