Learning portfolios as a tool for promoting reflection in engineering education

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***Abstract*— Reflection is a key component of deep learning and professional development, yet it remains underutilized in engineering education. This study evaluates the implementation of Project Journals (PJs), a form of learning portfolio, as a structured tool to promote reflection among second cycle engineering students in a project course. Sixteen students submitted five PJ entries throughout the semester, guided by prompts to retell, relate, and reflect on their project work and team role. Reflection quality was assessed using the Hatton & Smith four-level scale. Results showed significant improvement in reflection quality over time, with students reporting enhanced reflective skills and positive perceptions of the assignment. The PJ format also supported formative assessment, early engagement, and individual accountability. Despite challenges such as language barriers and varied interpretation of the task, the intervention proved effective in promoting critical thinking and contextual learning. The study highlights the value of structured reflection in engineering education and offers insights for optimizing portfolio-based learning activities.**

***Index Terms*— Learning portfolios, reflection, project-based learning**

I. Introduction

Reflection is the process of consciously questioning and assessing knowledge, ideas, and learning experiences. It involves critical analysis of what was effective, what could be done differently, and how experiences inform future decisions and personal growth [1-3]. Reflection is not only essential for deep learning [4, 5] but is also a key attribute of successful professionals, including engineers who must adapt to complex, real-world challenges [6]. Reflection is however rarely practiced explicitly in engineering education. Curricula often prioritize technical knowledge transfer through lectures, with limited opportunities for structured reflection [6-8]. While discussion-based learning and problem-based approaches are increasingly adopted, soft skills such as reflection and critical thinking are seldom assessed or supported with formative feedback.

Practical elements like experimental work and course projects can foster reflection if designed appropriately. However, studies show that engineering students do not automatically develop these skills [9, 10]. Previous reports have found that when asked to reflect, engineering students often summarize knowledge rather than contextualize it or reflect on its relevance [9, 11, 12].

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Learning portfolios offer a structured method for practicing reflection [3, 13, 14]. In these, students describe experiences, their meaning, and what they have learned. When well-designed, learning portfolios encourage critically reflective learning and provide evidence of progress toward learning objectives [10].

This study evaluates the introduction of Project Journals (PJs), a form of learning portfolio, in a second cycle project course in engineering education. The aim was to assess whether PJs improved students' reflection skills over time and how students perceived the assignment in relation to their learning.

II. Material and Methods

A. Course Context

The study was based on the LTH course *Projects in Biopharmaceuticals* (KIMN15), a 15-credit course spanning over a full semester. Sixteen students participated in 2025: eleven from an international master's program in Pharmaceutical Technology and five from a 5-year Engineering Biotechnology program. The course was redesigned in 2025 to include formative and individual assessment activities. In addition to team-based lab work (~160 hours), students participate in project planning, journal clubs, lab demonstrations, and the PJ assignment. The grading scale is Pass/Fail, with learning outcomes requiring interpretation of experimental results, creative problem-solving, and reflection on team roles.

B. Project Journal Assignment

The goal and structure of the PJ assignment were introduced at a seminar in the first course week. Each student submitted five PJ entries during the course, guided by prompts focusing on project activities (Part 1):

- **Retell**: Summarize the main points, describe the significant concepts or details.
- **Relate**: How does the project (e.g. technologies used and experimental outcomes) relate to your previous experiences/courses and/or literature? Give examples, make comparisons and connections.
- **Reflect**: What does the work so far mean for the project as a whole and for your learning. Apply judgement, give opinion and communicate insights.

In Part 2, students were prompted to reflect on their role in the team.

Feedback was provided individually by the course coordinator, and students marked revisions in red in subsequent entries. The final entry included a reflection on scientific outcomes and personal learning.

C. Reflection Scoring and Analysis

Reflection quality was scored using the Hatton & Smith four-level model [15]:

1. **Descriptive writing**: A factual account of activities or observations without explanation or analysis.
2. **Descriptive reflection**: Inclusion of reasons, justifications and explanations.
3. **Dialogic reflection:** Questioning activities and observation and considering alternatives.
4. **Critical reflection:** Placing an activity or observation in a wider context, for example relating it to experiences from other fields, questioning assumptions, considering alternatives, and taking on a critical view on the potential influence of factors.

Entries were scored independently at each timepoint. Changes over time were evaluated using ANOVA and Linear Mixed Models (LMM) to account for individual variability. All students provided written informed consent for use of their texts. Scoring was performed after the course had been graded.

D. Student Perception Surveys

Two anonymous surveys were conducted at the end of the course: prior to the introduction of PJs (2024, 65% response rate), and after the implementation (2025, 94% response rate), to evaluate student perception of the PJ assignment. The surveys included both Likert-scale ratings and open-ended comments.

III. Results

A. Motivation for Implementation

In the previous version of the course, assessment was solely group-based and summative (written report and oral presentation), which risked individual contributions to go unassessed. The PJ assignment was introduced to promote early engagement, support reflection, and enable individual formative assessment. In a pre-implementation survey, 73% of respondents supported the idea of learning portfolios, and 64% believed that they would improve understanding of the project. Comments were also in support of introducing PJs.

"Regarding periodic summary - I think it's a great idea. Although we reflected on our project during the lab phase, I think it will be good to have to put it in writing as well. […] It could also be valuable to get additional comments on the work and the reasoning regarding the theory and interpretation of the results as you go along. So that less questions are brought up during the report writing phase, which I think would help both teachers and students."

B. Student Perception of the PJ Assignment

Post-course survey results after implementation showed that 73% of students felt that the PJ assignment improved their reflection skills and 87% perceived the written feedback as helpful. Comments were generally positive, though some students found the task time-consuming or unclear initially:

"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."

"PJ assignment is a good setting for me to review and reflect on the experimental progress and results during this period, as well as the problems and gains in group cooperation and other aspects."

"The PJs for me were always complicated, at the beginning I did not know what to write, and I had no idea we were supposed to read literature and reflect and relate it to our project."

C. Effect on Reflection Quality

Reflection quality scores improved over time (LMM p = 8.6e-07; ANOVA p = 3.6e-05). The average score increased from 2.0 (Entry 1) to 2.9 (Entry 5). Eight students improved by one level, and three improved by two levels (Figure 2). Five scored the same in the final entry as in the first, although one of these consistently scored 4. No significant difference was found between the two student programs. Examples below illustrate the scoring levels:

- Score 1 (Descriptive writing)

"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."

- Score 2 (Descriptive reflection)

"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"

- Score 3 (Dialogic reflection)

"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?"

- Score 4 (Critical reflection)

"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 […], 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 independent repeats"

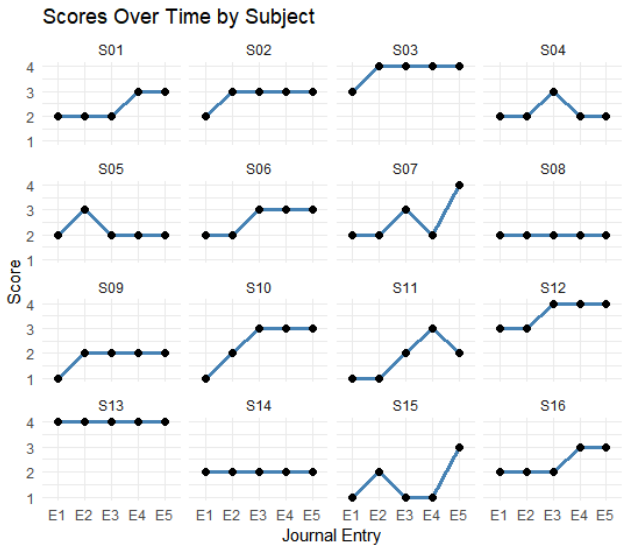

Figure 2. Quality in reflection per individual across the five PJ entries, as scored based on the Hatton & Smith four-level scale.

D. Impact of Language and Skills

Notably, the PJs provided a platform for quieter or less fluent students to demonstrate understanding. Despite varied English proficiency, no significant discrepancy in scores was observed. In the anonymous survey, four students reported that they had "sometimes" used generative AI tools during the assignment, even though they had been instructed to refrain from it when writing the PJs:

"Sometimes, I used ChatGPT to help analyze the possible reasons when we encountered failures during the experiment. It also helped me find relevant research and correct my writing grammar."

Suspicion of AI use was noted in some entries, but high scores were underpinned by concrete reasoning, which were lacking in some generic reflective text:

"The hands-on experience [...] directly complements the theoretical knowledge gained in class. This connection between coursework and practical research reinforces my understanding of assay development and analytical validation"

In contrast, a student with modest English skills frequently demonstrated dialogic reflection:

"When I got home that day I realized that we should not test the ssDNA concentration but DNA50 because the vector originally existed in the form of a plasmid and it is a double-stranded circular DNA not a single-stranded one"

E. Reflections on Teamwork

Although not formally scored, reflections on teamwork also tended to improve over time. One student wrote in Entry 1:

"I wrote the lab outline, organized experimental steps, listed and sequences, listing test conditions, and calculated reagent volumes. In the second week, I participated in team meetings, and carried out my assigned tasks."

In Entry 5, the same student reflected:

"That said, I found myself a bit passive when it came to overall task planning. I hope that in the future, I can not only execute tasks well but also take more initiative in planning and organizing group work. [...] However, I did face some challenges due to language barriers, which sometimes made it difficult for me to fully express my ideas or questions."

Others reflected well on their role in the team throughout the course, exemplified by text from one student, from Entry 2, 3 and 5, respectively:

"...my role in the team has continued to involve practical participation, but I have also found myself helping to clarify experimental details during discussions. For example, ..."

"... my focus has shifted more toward interpreting results and reading relevant literature to support improvements. For example, [...]. I also brought up using a stronger washing buffer to reduce background in the Western blot, which was something supported by what I had read. These contributions felt natural because we were constantly reflecting on the data and trying to understand what the results were telling us, and then deciding what we needed to adjust next."

"I also realized that we all work differently — some are fast, others more detail-focused — but as long as we agree on the "what," we can always find a "how." This mindset helped reduce group tension and increased our overall collaboration."

F. Reflections on Learning

The final PJ entries revealed meta-cognitive insights into learning processes. Students described growth in experimental design, literature analysis, and group work:

"This project has been one of the most hands-on and realistic research experiences I've had during my education. Instead of following a predefined lab manual like in earlier courses, we had to make our own decisions, sometimes on the spot, and that was a bit intimidating at first. But it really helped me grow."

"Due to some experimental limitations, many parameter differences were not obvious, making interpretation difficult. However, by reading related papers and comparing similar experimental principles and conditions—such as […], I was able to analyze others' findings and apply them to our situation. This helped me build a broader understanding of theoretical knowledge and provided more ideas for solving problems."

"At first, I didn't fully understand why we made these changes—I just followed instructions. But over time, I gradually learned to consider the feasibility of each operation, and how each factor contributes to the outcome when designing experiments."

"Looking back, I'm proud of how much I've grown. At the start, I felt unsure even about basic lab techniques like pipetting. But over time, I found myself not only contributing across all phases, from experiments to editing, but also sharing practical lab technique tips with teammates in other courses, and helping our group stay focused and aligned.[...] I've gone from hesitating at the bench to confidently explaining and presenting the full scientific story — from pipette to PowerPoint."

"In previous courses I have been used to working with other students that have a very similar knowledge as myself, so this new setting really helped to develop my ability to work in a group of people with different previous experiences, and still making sure that everyone is able to contribute and learn from the project."

IV. Discussion

This study demonstrates that structured, formative reflection tasks like Project Journals can effectively train critical reflection skills in engineering education, where such practices are typically of low priority. Students showed significant improvement in reflection quality, supported by both quantitative scoring and qualitative feedback. Although previous studies have reported that engineering students often use descriptive summarization rather than critical thinking when asked to reflect [9], only 25% of the first entries were scored as purely descriptive in this study. As expected, baseline reflection skills varied among students, but for most students with an initial low score, quality of reflections improved through iterative feedback. Examples of critical reflection demonstrated students placing project activities within a broader scientific context, questioning established protocols, challenging assumptions, and considering the limitations and consequences of their experimental designs.

Although Learning Portfolios as a tool to promote deep learning have strong support in literature, some studies have reported that students commonly perceive reflection as a waste of time [9, 11]. In contrast, this study found that clear guidance, rubrics, and feedback helped frame the activity as meaningful. While proficiency in academic or expressive writing may indeed influence portfolio quality [11], the use

of a scoring system helped emphasize reasoning over language fluency.

In addition to fostering reflection, the PJ assignment yielded several other benefits critical for project-based learning. They provided an approach for individual, formative assessment of student progress toward learning outcomes, a necessity in a group-based course where individual achievement of learning objectives can remain hidden until the final assessment, or risk not being assessed at all. The PJ assignment also encouraged early and active engagement in the project, including literature search. The course coordinator could use the PJs to monitor individual progression, identify misconceptions, and proactively provide support. Student comments on teamwork and learning highlighted metacognitive aspects, by demonstrated self-awareness as well as adaptation to a diverse group dynamic, which are crucial components for professional growth.

Several limitations that challenge data interpretation can be highlighted. The causal effect of the PJ assignment is confounded by the inherent improvement in cognitive skills from working on an advanced level project for a full semester. Although scoring was guided by a classification model, the interpretation was still largely subjective and would have benefited from a second opinion. The scoring was, however, performed for research purposes only and did not contribute to the formal assessment of students.

Future aspects include optimization of assignment design through improved rubrics for both text entries and feedback, to further promote critical reflection skills, and an essential, reflective engineering mindset.

V. Conclusion

The introduction of Learning Portfolios in the form of Project Journals was in this course a successful intervention which resulted in improved reflection quality and a positive perception of PJs as a valuable learning tool. Although the assignment is time consuming both from a teacher and student perspective, the benefits in terms of reflection skills, earlier profound engagement by individual students, and evidence of achieved learning outcomes makes it a relevant approach for advanced level project courses with a limited number of students.

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