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Preliminary Quality Assurance Framework for Asynchronous PBL in Mechanical Engineering: Advanced Experimental Methods

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Preliminary Quality Assurance Framework for Asynchronous PBL in Mechanical Engineering: Advanced Experimental Methods

This paper presents a pilot study building toward a quality-assurance (QA) framework to evaluate the transition from a face-to-face synchronous course to a mostly asynchronous Project-Based Learning (PBL) format in an advanced Mechanical Engineering course. We present preliminary data triangulating two sources of information: a student survey (n=46) and instructor reflections. These sources of data are used to examine whether the redesigned assessment system supported active meaningful learning, and specifically, whether the PBL format supported students in: (1) studying continuously throughout the semester; (2) following the recommended course plan/syllabus; (3) preparing for projects (written submission and oral defense); (4) understand the rationale behind the new design; and (5) achieve meaningful learning, defined here, as the ability to select and justify design components of experimental systems.

Our data revealed three concrete issues a QA process should address early. (1) Transparency and alignment of outputs and course products: students were unsure what exactly to submit and why, This led the lecturer to clarify these issues in the PBL assignments. Some reported losing points for elements that were never requested, this resulted mostly due to the lack of experience of the TAs. This required the instructor to email clarifications later, and oral-defense questions were not always aligned with pre-defined goals, due to some misunderstandings between the lecturers and specific TAs. (2) Workload and pacing: support sessions clustered near deadlines (and were occasionally skipped), which made steady, syllabus-aligned progress difficult and pushed work into the last days. (3) Assessment validity: In several cases, the oral defense probed material outside the scope or depth of a team's project; under time limits, this can reward quick recall rather than reasoned explanation.

In response, the instructor (second author) defined specific QA controls for the next run: publish a single authoritative project brief and rubric (with exemplars) and allow enough room to show quantitative reasoning. Further, lessons learned included releasing a short "what may be asked" outline for the oral defense and emphasizing for students the option to ask for clarification or to confer briefly as a team. In addition, it is recommended to make the course's spiral structure explicit so students can connect each task to the general method. Finally, we propose to set expectations for defense preparation (about 3–4 hours when prior study is assumed) and check them mid-course, and train/calibrate TAs using shared samples, joint scoring, and short debriefs to keep grading consistent.

Building on these data, we propose a lightweight QA framework around four key processes of 1) Planning and Design, 2) Implementation, 3) Review, and 4) Revise and Re-plan. These processes were based on three domains with concrete indicators and instruments. The domains are:

(1) Transparency & Alignment
(2) Workload & Pacing
(3) Assessment Validity & Reliability

This blueprint directly addresses the study's goals: promoting continuous learning, syllabus-aligned work, project preparedness, design-rationale clarity, and discipline-specific meaningful learning, and is intended for adaptation by other advanced PBL engineering courses transitioning work into lower-contact, asynchronous formats.

1. Introduction

In recent years, engineering programs have increasingly shifted project-based learning (PBL) into online or low-contact formats. The modality shifts that were first originated by necessity [1] are now motivated by scalability, flexibility, and the ability to sustain hands-on experiences through remote infrastructure while still developing students' technical and professional competencies [2], [3]. Evidence from engineering PBL implementations suggests meaningful affordances for these transitions. These affordances include flexible participation and the potential to maintain performance levels when online practices intentionally combine timely formative feedback, tailored technical support, and opportunities for social connection [4]. Notably, to maintain a positive, impactful learning experience, a transition to low-contact PBL requires deliberate design as well as procedures to evaluate it [5], [6].

An evaluation of instructional design for a low-contact PBL learning modality requires an explicit Quality Assurance (QA) framework. Such a framework should aim at both high-quality operational deployment as well as auditable procedures in day-to-day course implementations. In higher education, quality is inherently multi-dimensional depending on its purpose [7], [8]. Thus, the standards set for QA evaluations should specify and check alignment between intended outcomes, learning activities, supports, and assessment practices. Standards-based QA approaches used in online course design offer pragmatic mechanisms to operationalize these checks [9]. However, open questions remain about which QA indicators best capture PBL-specific issues, especially teamwork processes and authentic assessment integrity, in predominantly asynchronous delivery.

In the current work, we address these open questions by reporting a pilot implementation of a predominantly asynchronous PBL course in mechanical engineering. We do so by analyzing two complementary evidence sources - a student survey and instructor reflection notes. We use these data to pinpoint where quality risks surfaced during delivery, particularly around alignment of expectations, workload, and pacing in asynchronous teamwork, and the validity and reliability of authentic assessment, including oral defenses. Based on the findings, we translate the general term "quality" into a set of practical, auditable QA domains, indicators, and course-level controls that instructors can implement within a single term for a low-contact PBL course design. In the next sections, we review the literature on online and low-contact PBL learning contexts and on QA for course design and delivery. We then present our methodology and results. Finally, we discuss our findings, their limitations, and propose directions for future research.

2. Background and Related Work

Low-contact PBL in engineering education.

Recent work on PBL for engineering education emphasizes its value for developing real-world skills, while also noting that robust, well-documented implementations are uneven across contexts, making design decisions and evidence of effectiveness especially important when PBL is moved online [10]. In asynchronous or low-contact engineering PBL, the central design tension is that flexibility (time/place independence) often comes at the cost of coordination, shared sensemaking, and timely instructor guidance. These are the mechanisms that team-based PBL typically relies on to keep groups moving and learning [5]. Further, studies of remote and online design projects show that moving collaboration online can exacerbate issues relating to these mechanisms, such as uneven participation, communication breakdowns, and scheduling issues [11].

Evidence from online engineering design PBL further suggests that instructional practices such as structured milestones, prompt formative feedback, as well as technical support and scaffolds can help sustain skill development and performance [4]. Related work on remote labs echoes a similar tension between the greater flexibility offered by remote labs and the increased demand for self-regulation, which supports learning most effectively when paired with deliberate structure. At the same time, research tracking students' experiences in online engineering PBL indicates that students' perceptions are shaped by interacting design features such as the way collaborations are supported, instructor facilitation, as well as clarity and communication of expectations [12]. Therefore, one way to address this tension is through a high structure instruction design that emphasizes preparation phases, teamwork supports, progress meetings, feedback loops, and reflective reporting [13]. Notably, making sure a given low-contact PBL implementation includes the required components to support student regulation, skill development, and productive team collaboration requires an organizing framework for both instructional design and quality assurance. In the next section, we review the literature on QA in higher education.

Quality assurance in higher education.

Quality assurance (QA) in higher education is best understood as a system of decisions and procedures that operationalizes what "quality" means, generates evidence about whether it is being achieved, and supports improvement. A core challenge is that quality is not a single construct, but rather a multi-dimensional construct that should be explicitly defined by the relevant stakeholders. For example, "Quality" in higher education can be defined as "fitness for purpose," as achieving excellence on a specific criterion, or as the consistency between outputs [7]. Given this multidimensionality, QA in higher education should clarify which conception of quality is being evaluated.

Reviews of online-learning QA commonly converge on domains such as clear learning objectives, coherent organization and navigation, appropriate assessment and feedback, meaningful interaction, learner support, accessibility, and fit-for-purpose technology [9], [14]. The online-learning QA indicator literature provides a menu of actionable domains (e.g., assessment design, feedback timeliness, learner support, interaction), while standards-based systems offer a practical mechanism for documenting expectations and running structured review cycles. These together form a foundation for QA procedures that can be implemented within a term [9], [14]. Further, much work points to the importance of institutional scaffolds for the integration of QA into online course design [15]–[17]. However, as PBL places unusual weight on coordination, distributed work, and authentic assessment, an open applied question remains - which QA indicators and controls are most diagnostic for detecting breakdowns specific to asynchronous team projects (e.g., collaboration dynamics and assessment defensibility) early enough to intervene during course delivery?

The current work.

To address this gap, the current work is set to probe and document common issues in a low-contact BPL course design at an engineering faculty and use them as a basis for a preliminary framework for the evaluation of quality in such an educational context. We do so by addressing the following research questions:

- RQ1) What are student perceptions of learning gains related to low-contact PBL course resources?
- RQ2) What student factors drive quality evaluation in low-contact PBL courses?
- RQ3) What insights can be gained by triangulating instructor observation with student feedback?

To address these questions, we surveyed engineering students who took a low-contact PBL course delivered at an engineering faculty in a research-intensive university in the Spring 2023 term.

Method

Course and academic context

The course in which we piloted the quality assurance evaluation was a Spring 2023 offering of an advanced Introduction to Experimental Methods and Measurements course delivered in the Faculty of Mechanical Engineering. The course is a 2.5 credit advanced course that is usually delivered in a F2F modality (weekly 2h lecture and a 1h tutorial). Due to several technical issues, the course was delivered in a low-contact modality for the first time as a pilot in the Spring of 2023.

92 students werer enrolled to the course. The course included recordings with embedded quizzes, as well as three PBLs, which the students had to work on in pairs. For each PBL, students had to submit a report. To check that the students have done their work independently and that they understand all aspects of their report, the pairs of students passed an oral exam (10-15 minutes) after the submission of each report. To ensure independent work, student guidance/mentoring was given to each pair individually. To cope with the high load of mentoring, written assessment, and oral assessment, there was a TA responsible for each PBL. The lecturer wrote the PBL assignments and a bank of questions for the oral exams. During this semester of transition, the lecturer guided the TAs on how to provide mentorship, to evaluate the written PBL reports, and to conduct the oral exams.

Tools and procedure

To answer the research questions and build toward an established QA framework for remote PBL courses in engineering education, we distributed a survey to the Spring 2023 course cohort (n = 46). Students were Mechanical Engineering students in advanced semesters registered for the course. The study was IRB approved. Data were collected at the end of the semester through an anonymous survey distributed to students. Following the analysis of survey results, the instructor drafted his reflections on the course as well as the students' feedback. These notes were used to triangulate and contextualize students' input.

Student survey

The survey included two Likert-scale matrix questions. One addressed students' use of course resources (recordings, office hours, and alignment between the work on the project and the theoretical part of the course). The second one was meant specifically to evaluate students' experience during the project defense.

In addition, the survey asked students to report how they used course resources and their study habits (e.g., defense preparation, initiation of work).

Alongside the Likert-scale questions, students answered one open-ended item inviting additional feedback on their experiences with the project workflow and the oral defense ("We would be happy to hear any additional comments or insights regarding the way you worked on the project and the defense".

Instructor reflections.

Instructor reflections were based on the results of the survey and used in triangulation with survey responses (open-ended and closed questions) to generate meaningful themes for a preliminary QA framework.

Data Analysis

For the student survey, we computed descriptive statistics for the Likert-scale items to characterize overall perceptions of key course components - recorded lectures, consultation meetings, and the oral group defense. In parallel, we analyzed open-ended responses to identify recurring patterns in students' experiences. We then triangulated these findings with the instructor's reflections, comparing their convergences and divergences in terms of themes that were reinforced across sources and points where perceptions differed between students and the instructor. This triangulation process is used to inform a preliminary QA framework for low-contact PBL course design.

Results

RQ1: What are student perceptions of learning gains related to low-contact PBL course resources?

In this section, we provide a mixed analysis of key themes that emerged from students' responses to both the open-ended questions as well as the Likert-scale items. These are the base for the QA framework we propose.

Theme 1 - Transparency of evaluation criteria and alignment with the course

This theme refers to the alignment between required course outputs and the evaluation criteria. Such an alignment is reflected by an evaluation criterion that is clear, transparent, and explicitly connected to what was communicated to students throughout the semester.

Several open-ended responses echo the importance of this dimension in designing a low-contact PBL course:

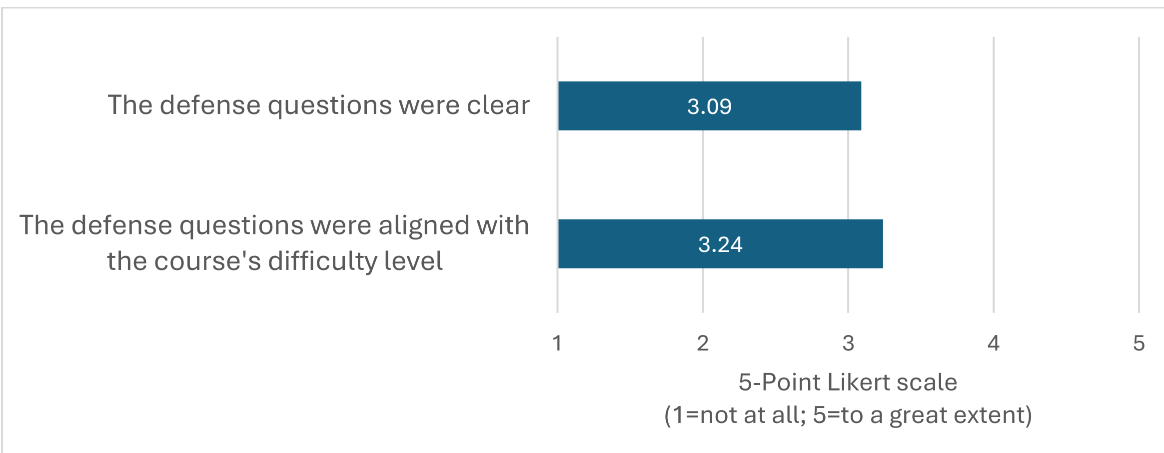
> *It felt that the course did not serve as preparation for the project. Each project was accompanied by lengthy searches on Google and ChatGPT because the project definitions were very general and unclear. In addition, the limitations set on the project outputs (one page/word count per question) meant we had to cut a lot of material we would have wanted to include, which created a situation where we were essentially guessing what topic would be more relevant (again, because the expectations for the project were not clearly defined…).* [Student 1]

The mini-projects themselves were not very clear, and the questions felt insufficiently detailed. Every time we came to an office hour focused on the project, we were given new things to do that weren't included in the project questions themselves, and in the end it really hurt us because some questions simply weren't detailed enough - and points were taken off for things we didn't even know existed or that we were supposed to do (they are not listed as requirements in the mini-project). [Student 2]

The projects were written in a very unclear way, and the course staff had to send clarification messages about parts of the projects. A main problem with these clarifications was that the content of the clarification email contradicted what was written in the project (i.e., the project asked A, and the email said they meant Z, where the meanings are opposite). Later, during the defense, it happened that the TA or lecturer contradicted the clarification again, the project itself, or the answers they themselves had given during consultation. [Student 4]

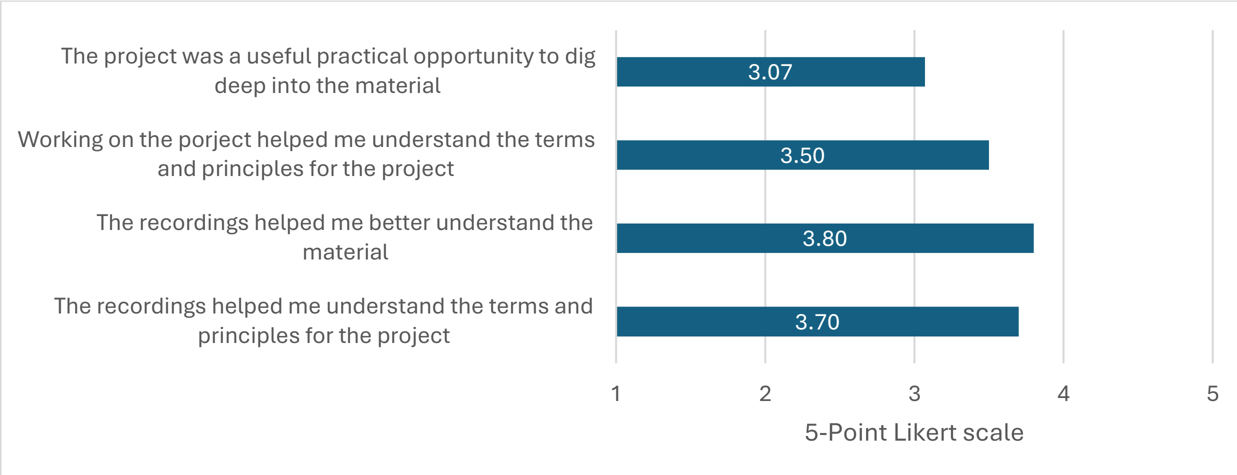
Transparency and alignment also surfaced as important aspects relating to the degree to which the defense was perceived as clear and aligned with the course. As seen in Figure 1, students reported relatively low means on these two dimensions of transparency and evaluation criteria.

Figure 1. Project oral defense: clarity and alignment (n = 44-46)



Students' perceptions of the recordings further resonate the importance of transparency and alignment. Figure 2 shows the distribution of student responses for the contribution of the recordings and the mini-projects to their learning on a 5-point Likert scale (1=not at all; 5=contributed a lot).

Figure 2. Contribution to learning of course components (n=45-46)



As seen in Figure 2, the recordings were perceived as contributing to students' learning, while the project was perceived as contributing to a lesser extent. The following student quote from an open-ended question provides more elaboration for students' perceptions:

> *In my opinion, the course was run very well. The learning methods were diverse, and the short quizzes after each recording made us pay attention and stay focused during the lecture. The recorded lectures were of a very high quality!! In my view, the projects required a reasonable and proportionate level of effort relative to the number of course points, and they made us try to understand the learned material well. The questions in the projects mostly related to the material taught in the lectures, though sometimes they also went a bit beyond that* [Student 1]

Based on these results, several QA recommendations are suggested. First, students consistently rated the recorded lectures as highly effective, pointing at several important design elements that could be used as a reference standard for other resources. Mainly the design elements that contributed to the positive impression were the clear expectations, stable structure, and paced engagement that helped students make the most of them. Transferring these elements into the mini-project workflow suggests that such assignments should be released early with explicit success criteria including both a rubric and exemplars. Further, project timeline should be paced to mirror the recommended weekly schedule (e.g., staged milestones aligned to specific weeks or topics) so students can build iteratively rather than retrofit understanding close to the deadline. Finally, project-related supports such as office hours, clarifications, and examples should be front-loaded and standardized with a single source of truth and early consult window to preserve the same predictability and clarity that made the recordings effective.

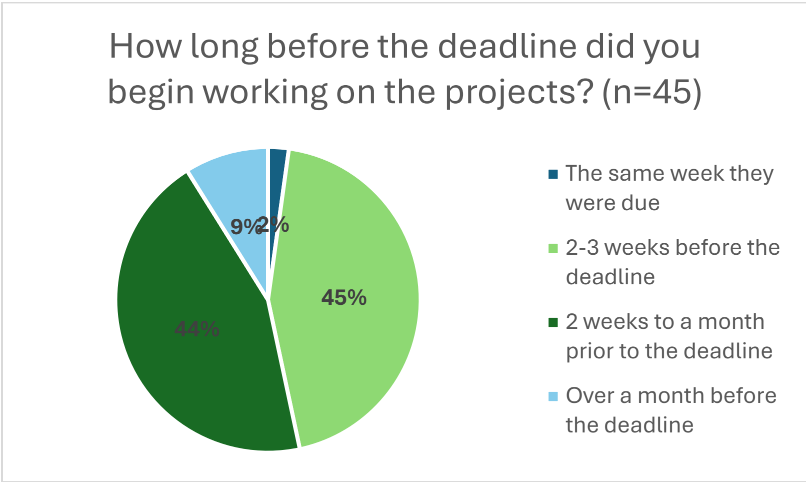
Theme 2 - pacing and workload in asynchronous PBL

In an asynchronous, project-based format, pacing is the designed rhythm of the course. Such rhythm is the specification of when students are expected to engage with learning materials (e.g., recordings), how project work is distributed over time (milestones vs last-minute crunch), and when supports and feedback are delivered.

In terms of following the course's schedule, 87% of all students reported watching all the recordings according to the recommended schedule, suggesting that, despite the low-contact, students made sure to stay on track with available asynchronous resources.

In terms of project-work, the majority of students (89%) reported allowing two to three weeks of work before the deadline for the projects. In a 13-week semester, this suggests that most students worked continuously throughout the semester. See Figure 3 for the distribution of time spent working on the project before submission (self-report).

Figure 3. Time spent working on the project



A few student quotes are also in support of the importance of pacing and time planning for PBL in a low-contact course context:

> *The guidance meeting that was held for the first two projects took place too close to the submission deadline. As a result, following the meeting, we had to substantially rewrite the projects under time pressure, within just a few days.* [Student 1]
>
> *For the third project, no meeting was held at all, and in my opinion, this could be reflected in the grading of the third project, in terms of a mismatch between your expectations and what was actually done. Even if [students did not send] enough concrete questions in advance about the third project, a guidance meeting is still important and meaningful, to go over the project, coordinate expectations, and clarify points.* [Student 2]

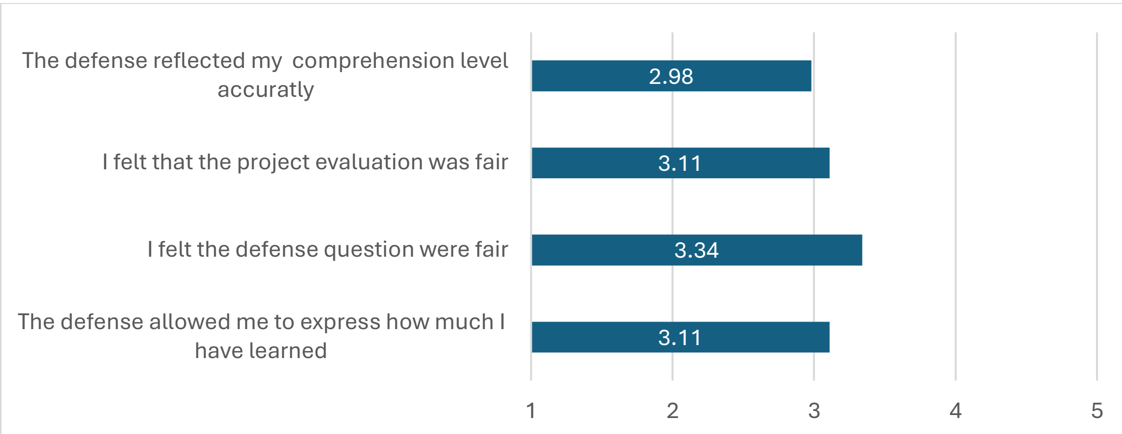
Likert-scale questions regarding onsultations with the teaching staff about the project suggest that they were perceived as only moderately helpful (M= 2.93, SD = 1.32, n = 45), although students reported coming prepared for these meetings (M=3.40, SD = 1.16, n = 45). It is possible that issues such as pacing and workload, as mentioned in the quotes above contribute to these findings. Our data thus suggest that while most students worked continuously, in terms of synchrony with instructional support (e.g., office hours), sometimes if deadlines cluster and consultations and clarifications sessions occur close to submission, work towards the project may shift to a deadline-oriented process.

In terms of pacing and workload, several key QA recommendations surface from students' responses. Mainly, it is key to ensure that different course components are spread and spaced throughout the academic semester with relevant instructional scaffolds that are available to them. This can ensure that deadlines, milestones, and support sessions are met through incremental progress rather than through deadline-oriented last-minute work.

Theme 3 – Assessment validity

Students' survey responses (see Figure 4) show a relatively low mean for the perceptions of fairness and validity of the oral defense.

Figure 4. Defense fairness and validity.



In the open-ended responses, students described the defense questions as sometimes extending beyond the project scope or depth and as difficult to interpret under time pressure, which they perceived as creating a gap between what was learned and what the assessment rewarded. This pattern aligns with the Likert results showing more moderate ratings for fairness/alignment than for preparedness or time adequacy, suggesting that the key tension centered on what the defense measured and how consistently it aligned with the written project work.

> *In my view, the grading of the projects was very excessive and overly strict, especially given that there is a gap of tens of percentage points between the defense grade - where we demonstrate knowledge on random questions related to the course material and the project - and the project grades. We put a lot of thought into these projects, and it seems there was no consideration of that at all.* [Student 6]

> *The projects were defined in very general terms, with no specific requirements (especially since the report was required to be under one page), yet points were deducted for things that were not explicitly requested to appear in the report. For sections where our lack of understanding was evident, many points were deducted (this may be connected, since the feedback contained very few comments). The projects themselves were not clear enough and required additional clarification to understand what the author intended.* [Student 7]

> *The way the written project was graded was unfair. The comments given about missing parts were not included in the project-writing brief. In addition, the oral questions were often not related to the material relevant to the mini-project and, in general, to the course. A gap was created between the material that was learned and its application in the projects and in the defense.*[Student 8]

QA recommendations specific for assessment validity, include applying a construct alignment check on relevant assessment items to ensure each assessment (including oral defenses) has explicit scope boundaries, questions/tasks mapped to intended outcomes, and basic reliability supports (e.g., scoring anchors and brief assessor calibration) to minimize format-driven variance.

RQ3) Triangulation and contextualization: Instructor reflections

Here, for the purpose of generating a QA framework for PBL in low-contact engineering courses, we treated the instructors' reflection memo as a second, independent data source that both corroborated and contextualized the patterns emerging from the student survey.

For transparency and alignment, the instructor suggested revising project wording, explicitly stating evaluation criteria, emphasizing when quantitative justification is expected, and increasing flexibility in length constraints. For pacing and workload, he suggested issuing "coordination of expectations" statements that connect projects to the recorded lectures and encourage students to revisit relevant recordings while working. Finally, for assessment validity under oral-defense constraints, he suggested publishing explicit norms for the defense. These should include the limited coverage due to time, right to request clarification, brief team consultation, and a deliberate mix of project-specific and course-concept questions.

The reflections also introduced a unifying pedagogical framing of spiral learning from general-to-specific and back, and thus highlighted a requirement for TA calibration and training as a mechanism for improving consistency in assessment practices. As triangulation, the reflection memo provided convergent evidence that the primary challenges were less about student effort and more about making expectations, timing, and assessment constructs explicit and consistent.

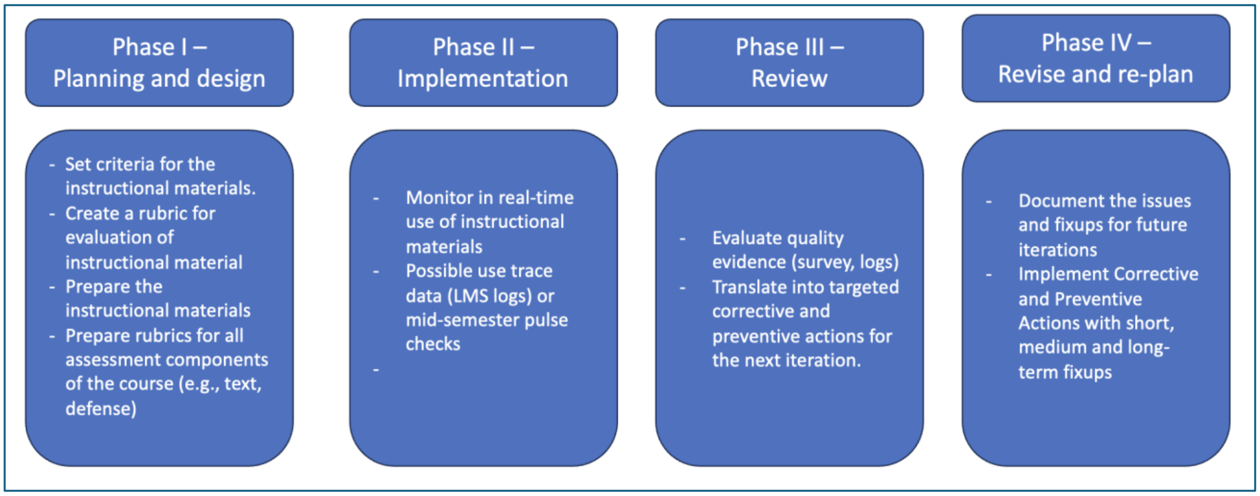
Discussion

Our findings show two clear patterns that are important in the context of a low-contact PBL course design, differentiating synchronous from asynchronous resources and interactions. First, asynchronous learning resources, such as recordings, are a one-time design effort that can be set so that they are available by a specific schedule for specific requirements. As such, these resources were perceived as valuable, and students took full advantage of them. Synchronous assignments, however, show a different pattern, as they require ongoing coordination with peers as well as with the teaching staff and thus may present an additional burden that asynchronous resources do not, making their affordances less apparent for the learners.

Further, our findings reveal the great importance of transparency of requirements and assessment criteria as well as the alignment between the resources and the expected outputs of the course, including expectations regarding the oral defense. Students reported several occurrences of high-stakes misalignment, and the instructor resonated these with suggestions for improvement for future iterations.

These future iteration guidelines, along with the highlights of student feedback, led to the development of the following QA framework. Specifically, we propose a four-phase QA framework for low-contact asynchronous PBL courses that operationalizes continuous improvement across project cycles, as presented in Figure 5.

Figure 5. A proposed QA framework for low-contact PBL courses



In Phase I (Planning & design), instructors specify quality criteria and produce audit-ready artifacts (rubrics, exemplars, defense blueprint/question bank, and a single "source of truth" FAQ with a change log), explicitly aligning project tasks and assessment expectations with recorded resources. In Phase II (Implementation), delivery quality is monitored through uptake indicators and standardized consultation/clarification routines, with pacing scaffolds (milestones and early feedback windows) to reduce last-minute rework. In Phase III (Review), quality evidence (survey metrics, open-ended themes, and instructor reflections) is triangulated to diagnose breakdowns in transparency and alignment, workload pacing, and assessment validity. In Phase IV (Revise), findings are translated into corrective and preventive actions that are documented and standardized for the next iteration, creating a repeatable QA loop that prioritizes clarity, consistency, and construct-aligned assessment.

This framework is explicitly informed by the empirical patterns surfaced in the study and is designed to feed forward into subsequent course iterations. The findings showed that students consistently valued the asynchronous recordings (high perceived learning contribution and high reported uptake), while quality risks clustered around the low-contact PBL components, particularly (a) transparency and alignment of project requirements and evaluation criteria, (b) pacing and workload when clarifications and consultations occur close to deadlines, and (c) assessment validity under time-bounded oral-defense constraints. The framework translates these observed risks into concrete QA controls (e.g., rubric traceability, a single source of truth for clarifications, milestone-based pacing, and outcome-tagged defense prompts with assessor calibration), thereby converting the lessons learned from this pilot into standardized design practices. In turn, it informs future design by specifying what artifacts must exist before delivery, what minimal indicators should be monitored during implementation, and how evidence from student feedback and instructor reflection should be triangulated into corrective and preventive actions, supporting iterative refinement of the course while preserving the strengths of the asynchronous learning resources.

Limitations

This study has several limitations. First, the survey sample was modest (N=~46 students), which limits statistical power and the generalizability of descriptive patterns beyond this cohort. However, the goal of the study was not population-level inference, but the identification of actionable quality risks. Therefore, the convergence between Likert trends, recurring open-response themes, and the instructor's structured reflection strengthens interpretive credibility through triangulation. Second, the course context is relatively advanced and discipline-specific, and the intervention occurred in a single course instance at one institution, which may constrain transferability. At the same time, the QA framework is intentionally framed at the level of process controls such as a single source of truth for clarifications, rubric traceability, pacing scaffolds, defense blueprint, and calibration. These are broadly applicable to low-contact PBL formats across engineering domains. Third, this was an early iteration of the low-contact design, so some issues may reflect typical first implementation effects. Yet this is precisely where lightweight QA is most valuable: the framework formalizes how early-cycle evidence is converted into corrective and preventive actions that can be tested and refined in subsequent offerings.

Conclusions and future work

This work examined a low-contact, asynchronous PBL course design and identified distinct strengths and quality risks across course components. Survey evidence indicated that students perceived the recorded lectures as a strong contributor to learning and reported high uptake, while challenges clustered around the project and oral-defense procedure. Triangulating student survey findings with the instructor's reflections enabled the development of a lightweight, four-phase QA framework that translates these risks into concrete, repeatable controls and minimal evidence checks. The proposed framework offers a practical pathway for engineering instructors to preserve the flexibility benefits of low-contact delivery while improving coherence, fairness, and construct-aligned assessment through iterative QA-driven course redesign.

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