Undergraduate engineering report writing - education support by peer review

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ABSTRACT: This study introduces a novel and scalable on-line peer learning intervention in a final-year mechatronics module to enhance students' technical report writing competencies. Based on a four-quadrant model, the intervention involved over a thousand students in structured peer assessment and feedback on technical reports over four years. Quantitative analysis revealed a significant 35% decrease in failure rates, with overall passing rates reaching approximately 95% after a second attempt, while qualitative observations indicated logical organisation and coherence improvements. However, the study also identified challenges, including peer evaluation leniency, difficulty distinguishing technical content from polished writing and feedback inconsistencies. The implications of these findings for iterative refinement to bridge technical communication gaps are discussed, aligning with accreditation priorities. The potential for optimising this discipline-embedded approach to foster critical competencies for engineering graduates' professional success is also highlighted.

INTRODUCTION

Communication skills have been a concern worldwide for decades. Organisations and employers increasingly value communication skills highly for engineering graduates, often rating them as important as or even more valued than some technical competencies [1-5]. Studies indicate that engineering students face challenges in developing professional writing skills, with differences persisting between student and practitioner writing even as students progress through their education [5-8].

The International Engineering Alliance [4] and the Engineering Council of South Africa's [9] Graduate Exit Level Outcomes underscore the importance of effective communication. Achieving the required mastery remains a challenge for undergraduate students, particularly in under-resourced global south (South African) contexts where there is a lack of time and facilitators to work closely with smaller groups of students. The need to more efficiently and effectively assist students in their engineering writing served as an initial impetus for this study.

While several complex factors perpetuate these student writing gaps, there is room for improvement. The engineering curriculum traditionally centres on mathematical and scientific foundations, with communication viewed as supplemental [6-8]. Programmes rarely require writing-intensive courses; typical offerings provide basic introductions but little tailored instruction in discipline-specific communication [6]. These challenges include logical organisation, concise expression and effective integration of technical content, which often persist even as students progress through their education. These difficulties frequently continue despite students completing prior writing courses, suggesting a gap between academic writing instruction and the complex rhetorical demands of engineering communication in both educational and workplace contexts [3][7]][8]. However, the right interventions can increase opportunities to expand expertise through feedback iteratively. Large enrolments may currently constrain individualised guidance on specialised technical writing [10], but this can change with the right strategies.

This article is focused on an intervention at a traditional research-intensive institution in South Africa. A final year mechatronics engineering module, which requires an open-ended experimental design report as a summative assessment - saw nearly 50% of students fail in 2020. Despite excelling in previous mathematics and science modules, the students demonstrated a concerning inability to integrate diverse engineering disciplines with technical communication - a barrier to graduation. This chasm reveals unresolved gaps in consolidating conceptual, practical and communication abilities. The lack of opportunities to iteratively cultivate expertise and scaling constraints pose barriers to addressing such deficiencies as standalone issues [7][10]. Comprehensive interventions grounded in learning sciences are imperative. This article details the peer learning intervention, drawing on the relevant literature, and makes several recommendations. The study aims to provide insights for engineering educators in diverse large-class and resource-constrained contexts.

PEER LEARNING IN COMMUNICATION COMPETENCE DEVELOPMENT

Well-designed peer learning interventions that engage students in collaborative domain-specific problem analysis and knowledge application can enrich learning sciences pedagogy, especially for critical competencies like written communication [11][12]. Peer engagement complements other high-impact practices and responds to shifting educational priorities for measurable ethical, skill-oriented and equity-advancing outcomes [13]. Systematically implemented peer review and assessment build metacognitive awareness and content mastery through the social construction of standards, co-creation of meaning, exposure to diverse strategies, and expectations of intellectual generosity in giving and receiving critiques [14-16].

Peer impacts permeate engineering education but target technical, mathematical, computational and hands-on abilities. Less focus has been applied to evidence-based peer methods to meaningfully improve communication and emotional intelligence at scale and sustainably [17-19], even though accreditation bodies increasingly value it [4]. It is imperative to review existing learning scaffolds and cultural assumptions, exposing this imbalance [20].

Technical writing presents incremental challenges as complexity shifts from summarisation to integration, analysis and knowledge generation [21]. The pedagogical transition from template production to intellectually generative communication requires calibrated iterative practice with multidimensional content [22]. However, many engineering programmes lack curricula supporting iterative technical writing expertise through continuous feedback [6][10]. Large enrolment constrains individual cultivation of operational, compositional and rhetorical competencies except in elite contexts [8][23]. This lies in direct tension with professional demands.

Studies show that structured peer response and assessment build metacognitive awareness of rhetorical decision-making and empower students to negotiate disciplinary expectations, genres and conventions [23][24]. Peer audiences motivate developing logical flow and clarity to convey substantiated interpretations [25]. Additionally, transitioning from anonymous to non-anonymous peer assessment can enhance feedback quality and students' comfort with the process while maintaining the benefits of initial anonymity in reducing interpersonal burdens [26]. On-line collaborative platforms further enable scalable peer-writing interventions [10]. Rubric-guided review protocols address conceptual gaps and technical writing criteria from vocabulary usage to visual presentation [27]. Studies find peer rating mechanisms and calibrated self-assessment opportunities incentivise higher-order concerns before final high-stakes submissions, improving genre mastery and self-efficacy [18].

These benefits underpin the present study, which addresses the research need for integrated communication-focused peer pedagogies within authentic large-scale engineering curriculum contexts. It leverages scalable on-line tools for sustainable skills advancement measurable through multi-indicator assessment. The following sections detail this research-supported peer learning innovation for enhancing metacognition and technical writing expertise.

METHODOLOGY

Research Aim and Questions

This study aimed to assess the efficacy of an on-line peer learning system integrated into a final-year engineering module to enhance technical report writing competence and improve learning outcomes at scale. The central research question was:

- Does participation in iterative rubric-based peer assessment and feedback on technical reports within a discipline-specific course lead to measurable gains in students' written communication expertise and related learning outcomes compared to performance before peer intervention?

In this article, the authors detail the design and implementation of the peer learning intervention and present an initial analysis of the measurable gains in students' technical writing proficiency and related learning outcomes.

Participants and Dataset

The study context was a required mechatronics module at Stellenbosch University, South Afrika, taken by approximately 220 final-year students annually. Five years of historical cohorts (2020-2024) encompassing approximately 1,000 students were tracked using an integrated dataset compiling grade changes between report attempts, peer participation indicators, reviewed rubric codes, and self-perceived communication improvements. Comprehensive inclusion responded to graduation prerequisites while ensuring ethical data usage.

INTERVENTION DESIGN

Approach

A novel four-quadrant model was developed to understand better students' challenges in integrating technical and communication skills. This framework emerged from an in-depth evaluation of student performance on an experimental design assignment, which revealed distinct gaps in the technical and communication domains, each with corresponding *process* and *product* dimensions [28].

	Product	Process
Technical	- Conceiving a meaningful investigative goal and methodology - Synthesising knowledge to identify a research question and experimental approach	- Demonstrating rigour and viability of experimental design - Understanding *how* the experiment works and *what* data is needed
Communication	- Ensuring coherence, clarity and logical flow of the written argument - Distilling the technical process into a compelling narrative	- Using discipline-specific language, graphics, data, references and formatting effectively - Translating the *product* into a polished document

Figure 1: Four-quadrant model for integrating technical and communication skills in engineering education.

As illustrated in Figure 1, the four-quadrant model divides the technical and communication components into *product* and *process* dimensions. For the technical component, the *product* dimension involves conceiving a scientifically meaningful investigative goal and methodology, while the *process* dimension encompasses the conceptual rigour and viability of the experimental design. Similarly, for the communication component, the *product* dimension focuses on the coherence, structure and logical flow of the written argument, while the *process* dimension involves precisely using discipline-specific language, graphics and formatting to convey the technical work effectively.

Analysing student performance using this four-quadrant model revealed specific challenges in each quadrant. Technical product deficiencies arose when students struggled to align their investigative goals with course learning outcomes, while technical process weaknesses stemmed from a lack of hands-on investigation experience. Communication product issues emerged when technically sound work was documented poorly, and communication process flaws manifested in inaccurate or substandard language use, data presentation and formatting.

Peer Feedback Process and Integration into the Module

The peer learning system was embedded into the required final-year mechatronics module, linked to an open-ended experimental design assignment with high historical failure rates despite prerequisite coursework. Due to resource constraints, opportunities for supplemental writing interventions were limited. The standalone course structure and lack of iterative feedback mechanisms permitted progression without holistic skill mastery. The on-line Moodle workshop tool integrated the peer learning system into the module. The workshop functionality in Moodle enabled customised peer review sequence organisation, a randomised peer group selection, plagiarism checking, consolidated feedback and participation tracking. Randomly auto-assigned groups (n = 5) enabled sufficient diversity in critiques based on team dynamics scholarship.

Figure 2 illustrates the workflow for the assignment. Students had four weeks following the assignment's release to develop a draft report for peer evaluation. This timeline allowed for foundational technical work before peer critiques focused on communication.

A question-and-answer session was also held to clarify the assignment. In one iteration, an on-line quiz assessed students' abilities to identify criteria in the example report excerpts, but students gamed this rather than engaging deeply. More effective was providing complete exemplar reports for self-assessment - a marginal failure example and an excellent example. Students read and graded these reports against the rubric, then reviewed instructor annotations explaining grades to reveal the expected norms and standards.

Students had one week to complete four peer reviews within their workshop group. Reviews were not anonymous, aligning with industry practice of face-to-face peer feedback. Reviewer incentives included a buddy rating system where students evaluated the quality of feedback provided by their peers. This granted bonus marks for careful critiques but could also deduct marks for low-effort reviews (comprising ~5% of the overall grade). However, students still needed to pass regardless of peer and buddy rating marks.

The peer feedback was returned to the authors for report revision. Students had another week to incorporate improvements into their reports before final submission. The iterative cycle of drafts and peer critiques aimed to cultivate self-regulated learning, as students had to critically assess their own and others' writing against the rubric standards. The process aimed to advance both technical and written communication competencies in parallel. However, no direct group collaboration occurred beyond the peer reviews.

Students who do not achieve a passing grade on their first attempt at the summative assessment have the opportunity to revise and resubmit their work based on the feedback received from the lecturer. This second attempt is an integral part of the learning intervention, as it allows students to apply the insights gained from peer review and self-reflection to improve their technical writing skills. The availability of a second attempt also aligns with the iterative nature of the learning process and supports the development of resilience and perseverance in the face of challenges.

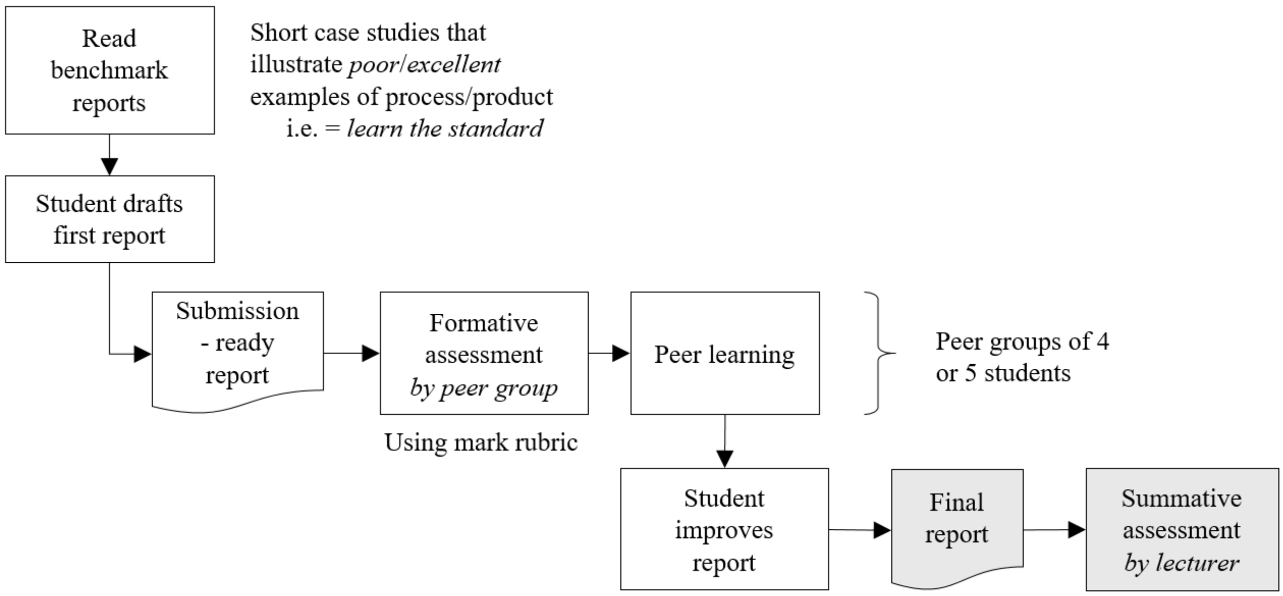

Figure 2: Peer feedback process implemented in the study.

Rubric Design

A custom rubric was designed to mirror summative grading metrics to facilitate standards calibration. Criteria evaluated both the quality of technical decisions and writing execution using the four-quadrant model framing to identify competency gaps. By first reviewing provided exemplars and then evaluating peers' drafts against rubric standards, students developed an awareness of norms for accurate, precise technical writing aligned to course outcomes [14].

The rubric used for peer assessment incorporated weighted criteria spanning conceptual knowledge, procedural skills, writing technique, data literacy, conclusions support and knowledge integration across report sections:

1. Introduction clarity - scored based on contextual framing, aim definition and motivational quality.
2. Literature grounding - scored based on literature review depth and contextualisation quality.
3. Methods explanation - scored based on comprehensiveness in describing equipment, variables, protocols, controls and data recording.
4. Analysis discussion - scored based on the data processing explanations, interpretive quality and conclusion relevance.
5. Editorial standard - scored based on spelling, grammar, coherence, captions, references and adherence to specified formatting guidelines.

The trait descriptors emphasised supportive, growth-oriented language aiming to motivate refinement efforts. Rubric validation and piloting confirmed usability.

INITIAL FINDINGS

Quantitative Outcomes

Analysis of achievement records before and after peer learning implementation showed a significant decrease in failure rates, the primary quantitative indicator. Historically, nearly 50% of students failed the summative technical report assessment. In contrast, three years of peer learning data has indicated a marked reduction to approximately 35% of students failing (a relative decrease of 30%).

The learning intervention consistently resulted in an approximately 35% improvement across all four years it has been trialled, with a slight upward trend in first-time pass rate, but for the 2023 cohort. It is important to note that students who do not pass the summative assessment on their first attempt are given a second opportunity to revise and resubmit their work.

As shown in Figure 3, when considering the results of both attempts, the overall passing rates average 95% across the four years of the study. *While some students may struggle initially, most meet the required standards with additional support and iteration.*

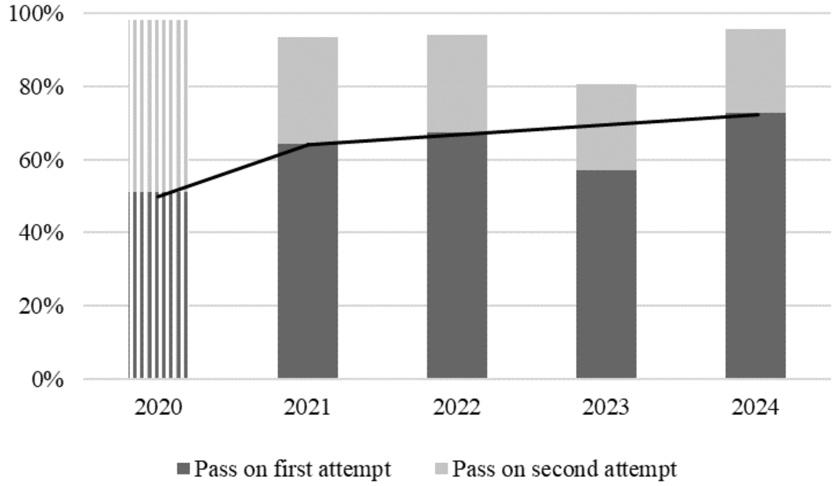

Figure 3: Pass rates of cohorts. The 2020 cohort (stripped bars) baseline only included a summative assessment with no peer review. The 2021 to 2024 cohorts (solid bars) included a formative peer review. The dark grey bars show the percentage of students who passed the summative assessment on their first attempt. Since the students must pass the graduate attribute, the light grey bars show those who do not at first achieve a passing grade and pass on their second attempt.

The analysis further revealed clusters of students exhibiting trajectory outcomes, as depicted visually in Figure 4. It is very clear from the large scatter in Figure 4 that there is practically no correlation between formative and summative grades. Despite exposure to the rubric and poor and excellent exemplars, many students fail to imbed the standard. The most significant performance gains emerged among students who displayed substantive progress from the initial formative to the final summative report, benefiting from peer input to upgrade competencies.

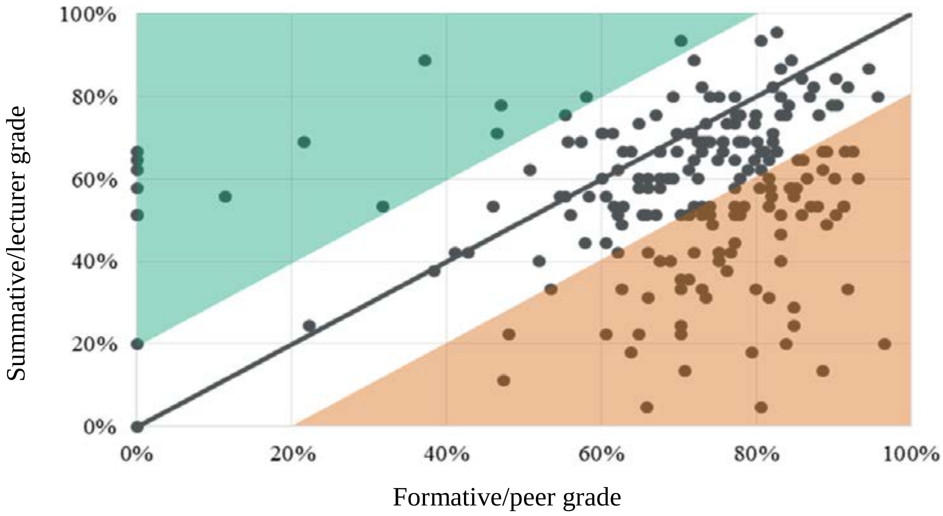

Figure 4. Scatterplot graph showing the impact of peer learning on student grade changes for the 2024 cohort. The *x*-axis is the average grade the peer group gave during the formative assessment; the *y*-axis is the grade the lecturer gave during the summative assessment. Each data point is the formative and summative grade of each student in the class. The diagonal line shows grade parity between formative and summative assessments.

In Figure 4, these data points occur far to the left and above the diagonal parity line (the green area). Conversely, another distinct segment either disregarded peer critique, inadequately implemented peer feedback, or failed to imbed the standard adequately and remained below expectations. These data points fall in the orange triangle, far to the right and below the parity line. In between are the data points for students, where the integration of peer feedback allows the students' grades to remain roughly unchanged, from the formative assessment with their very lenient peers to the stricter summative evaluation of the lecturer. This is the largest fraction of the class. Whilst the students may not have fully imbed the standard, the peer review process does improve their performance, as shown in Figure 3, with the first-time pass rate increasing from 50% to 73%.

Qualitative Outcomes

Significant progress was observed in the logical organisation and coherence of the reports, suggesting that exposure to peer work and critiques facilitated the integration of technical processes with effective communication strategies.

The majority of students found the peer reviews they received to be helpful, constructive and insightful. Many reviewers provided detailed feedback on each section of the report, pointing out areas for improvement and offering suggestions. Students appreciated when reviewers took a mentoring approach, giving positive and negative feedback. However, some students felt that the feedback they received was too brief, vague, inconsistent with the marks given or failed to provide suggestions for improvement. A few reviewers did not give any written feedback at all.

Qualitative written feedback from the students on their peers ran the entire spectrum from excellent through mediocre to absent. Some example quotes (verbatim) from students' statements on their peers are captured below:

- *The best review I have ever seen done by a fellow student. Read through the whole report, highlighted grammar errors and gave great advice to all the sections specified. Cannot exaggerate enough how thorough this peer review was done.*
- *Feedback was excellent and really in-depth discussed what is wrong and what needs to be changed. The feedback was straight to the point and although once again brutal, really went out of their way to properly criticise the report. This really helped.*
- *Although very brief, feedback was given. However, it was only positive. No negative or constructive feedback was given. Therefore, the quality of the review is insufficient.*
- *Terrible feedback. Hardly any feedback given for most marking criteria. Their marking is grossly inconsistent with others markings. Honestly, this marking is disrespectful towards their peers in terms of the lack of effort.*
- *No feedback was given for any of the sections and marks were not consistent with other markers.*

As each student is supposed to provide qualitative feedback for their four or five peers, the data set size is significant. Each statement was assessed in terms of the seven qualitative outcomes (A - G), with the percentage of responses that fall within each outcome bucket for each cohort year, given in Table 1 below. Note that multiple qualitative outcomes potentially apply to each statement so that the sum of the figures in a column will exceed 100 percentage points. Outcomes A - D reflect positive feedback, whilst E - G reflect negative feedback. It is clear from the percentages in Table 1 that the positive feedback outcomes increased from 2021 through 2024, whilst adverse outcomes decreased over the same period.

A quality of feedback (*QoF*) metric was defined with the following formula:

$$QoF = \frac{10A + 9B + 8C + 7D + 5(1-E) - 6(1-F) - 10(1-G)}{55}$$

where *A* to *G* are the fractions of each outcome class, the coefficients are the weightings given in Table 1, and where an inverse scale (-10 is poor, 0 is excellent) is used for adverse outcomes of E, F and G. (The inverse scale is marked in Table 1 by the negative weightings). The *QoF* metric also shows a clear year-on-year improvement.

Table 1. Qualitative assessment of student or their peers' effort during the formative peer review. Example student quotations for each qualitative outcome are shown in the footnotes to the table.

	Qualitative outcomes	wt	2021	2022	2023	2024
A	Reviewer provided specific, actionable suggestions for improvement	10	48%	55%	61%	65%
B	Feedback demonstrated understanding and critical analysis of the report	9	52%	58%	63%	67%
C	Reviewer provided detailed comments on each section of the report	8	55%	63%	68%	72%
D	Reviewer highlighted both strengths and weaknesses	7	41%	38%	43%	45%
E	Reviewer gave feedback that was too brief or vague	-5	36%	32%	28%	25%
F	Feedback was inconsistent with the marks given	-6	22%	18%	16%	14%
G	Reviewer provided no written feedback	-10	10%	8%	7%	5%
	Quality of feedback (QoF)	55	68	70	74	76

Notes:

A: Incredibly detailed and thorough review, extensive justification for all ratings given. Makes great use of marking rubric, referencing it constantly. Honestly the best feedback I have ever received, 2024

B: The peer review provided insightful and detailed critiques, combining constructive and positive feedback effectively, with clear justifications for the marks awarded, 2024

C: Reviewer gave in depth feedback on entire report. Provided specifics of each section with clear explanation and expectations. Line by line comments were given clearly showing great effort in feedback, 2024

D: The reviewer distinguished themselves by adopting a mentoring stance, offering comprehensive and constructive feedback that highlighted areas for improvement while affirmatively recognising the strengths of the work, 2024

E: Two lines of feedback, nothing specific to any headings or marking criteria. Other markers gave 33 and 34 where this reviewer gave 16 (less than half the others). This feedback really has not helped me *did not go in-depth enough in almost all areas* is the only thing I will be able to take from this, 2021

F: Marks very inconsistent with feedback. Feedback also does not specify where report can be improved and does not cover all of the marking criteria stated in the rubric, 2021

G: No feedback was given for any of the sections and marks were not consistent with other markers, 2022

DISCUSSION

Despite the positive results, the lecturer's assessment of the summative reports revealed ongoing problems that must be addressed. Some groups of students were too lenient in their peer evaluations and did not meet the expected standards. Additionally, several students still struggled to distinguish between good technical work and writing that merely looked polished on the surface. This suggests a persistent mismatch between understanding the process and creating a high-quality final product (as supported by Figure 4). Although incentives and measures were implemented to encourage students to take responsibility for their learning, inconsistencies in the quality and level of detail in peer feedback remained a limitation. Some students provided excellent feedback, while others gave minimal, vague or no feedback at all. This study did not account for other potentially influential factors, such as student workload and self-confidence, which may have contributed to the observed inconsistencies in peer feedback quality. Indeed, a variety of contextual factors must be considered when implementing peer learning interventions, and the following discussion addresses some of these key considerations.

Addressing the inconsistency in peer feedback quality is crucial for the effectiveness of the peer learning intervention. However, assessment options are constrained, as students cannot be prevented from passing the graduate attribute based solely on the quality of their peer feedback. This limitation reflects the challenge of ensuring consistent student engagement in learning activities despite the provision of resources and support. Future iterations of the intervention could explore additional strategies to motivate students and ensure more consistent and high-quality feedback, such as providing explicit training on giving constructive feedback.

The lack of correlation between peer formative grades and instructor summative grades, as illustrated in Figure 4, suggests that students may not yet be able to accurately judge the quality of their peers' work, even when provided with a rubric and exemplar reports. This can be attributed to several factors. Firstly, despite exposure to marginal and excellent exemplar reports and the use of a rubric, students may still struggle to fully grasp the nuances of the engineering report genre and its expected practices. The rubric, while providing a summary of the genre standards, may not serve as a detailed guide to report writing. Secondly, students will likely be inexperienced in developing a fully integrated engineering report that pays equal attention to technical and communication aspects and the process and product dimensions. This lack of experience can be partly attributed to the limited opportunities for students to practice report writing integrated with engineering practice throughout the department's four-year curriculum, despite recommendations against this in the literature.

As mentioned in the introduction, engineering programmes often view communication as supplemental to the core technical curriculum, with writing-intensive courses rarely required and limited discipline-specific communication instruction provided [6]. This lack of experience may hinder their ability to accurately and consistently evaluate their peers' work. As students progress through the iterative peer learning process and receive feedback from their peers and the instructor, they are expected to develop a more comprehensive understanding of the genre standards and improve their ability to provide valid and reliable assessments. It is recommended that the required practices for integrating communication skills with engineering content be implemented from the start of the first-year engineering programme and consistently reinforced throughout the curriculum.

CONCLUDING REMARKS

In this article, the authors detail the design, implementation and early observations of a peer learning system embedded within a final-year mechatronics module to enhance students' technical report writing competencies. The intervention yielded promising results, significantly decreasing failure rates and improving students' ability to integrate technical processes with effective communication strategies. Despite the decrease in failure rates, an initial failure rate of 35 % still presents challenges. However, with the opportunity for a second attempt and the support provided by the peer learning system, the overall passing rates consistently reached approximately 95 % across the four years of the study.

Qualitative feedback highlighted areas requiring further development, such as addressing leniency in peer evaluations, enhancing students' ability to distinguish between technical content and polished writing, and improving the consistency and quality of peer feedback. Future versions of the programme should prioritise providing extra training and resources to help students improve their reviewing skills and to expose them further to performance examples of various qualities.

Notably, the peer learning intervention described in this study specifically targeted technical report writing skills. The transferability of these skills to other engineering communication genres was not within the scope of this research. Future studies could explore interventions targeting additional genres to enhance students' communication competencies.

While integrating writing support into technical modules is beneficial, it does not replace the need for dedicated engineering communication courses. However, the findings from this study can inform the design of such courses, suggesting the potential value of incorporating structured peer review activities and opportunities for iterative practice and feedback, particularly in large class, resource-constrained contexts.

By continuously refining the peer learning system based on the insights gained from this study, the intervention can be optimised to foster the development of critical technical communication competencies essential for success in the engineering profession. The findings from this research will inform ongoing efforts to bridge the gap between students' technical and communication skills, ultimately contributing to the development of well-rounded, competent engineering graduates.

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