Research in Engineering Education Symposium (REES)
Regional Conference in Engineering Education (RCEE)
& Research in Higher Education (RHEd)
September 29 – October 3, 2025
Johor, Malaysia

Generative AI is the Enabling Technology for Abundant Feedback

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ABSTRACT

BACKGROUND & CONTEXT

Traditional feedback practices often face limitations in scalability, timeliness, and learner engagement, resulting in an instructor-led, scarcity-driven approach that prioritises efficiency over depth and effectiveness. In this paper, we introduce the concept of abundant feedback, a transformative student-centred feedback model which may be enabled by generative AI and emerging technologies, and which reimagines feedback as continuous, personalised, and integral to the learning process.

PURPOSE OR GOAL

The aim of this paper is to define the concept of *abundant feedback* by outlining the key dimensions of abundance and their meaning. This definition is especially important at this point in time, as the use of GenAI tools are rapidly evolving and are being adopted in education, although sporadically and without a shared conceptual foundation. Defining abundant feedback provides a conceptual reference point for guiding more coherent and purposeful integration in education.

APPROACH OR METHODOLOGY

This paper uses a conceptual approach, drawing from educational theory, feedback research, and emerging applications of generative AI to frame and define abundant feedback.

OUTCOMES

We propose a minimal set of key dimensions of abundance as volume, availability, relevance and character. Abundant feedback supports iterative formative assessment and enhances students' evaluative judgment, feedback literacy, and agency.

CONCLUSIONS

The paper explores how abundant feedback can foster a more inclusive, responsive, and learner-centred feedback culture, with far-reaching implications for learner engagement and teaching practices

KEYWORDS

Abundant Feedback, Artificial Intelligence, Building Capacity, Feedback Literacy.

https://doi.org/10.52202/086293-0051

Introduction

Feedback is the act of providing learners with instructions, guidance or support about their performance on assessments, coursework, or learning activities, with the primary aim of supporting their academic development and improving future performance (Hattie & Timperley, 2007; Nicol & Macfarlane-Dick, 2006). In engineering education, feedback can take various forms, including written comments, verbal discussions, electronic annotations, or peer evaluations (Black & William, 2009). Timely, high quality feedback is an essential and critical part of the learning process, but it is expensive to provide at scale (Shute, 2008; Gikandi et al, 2011). Currently, both leaner engagement with learning and the scalability of learner-centered pedagogical approaches present ongoing challenges in engineering education (Felder & Brent, 2005).

Amidst increasing enrolments and evolving industry demands for skilled professionals, instructors are now pushed even further past their nominal workloads (Stuart & Leong, 2020; Eger & Henderson, 2021; Crosthwaite, 2021). The entire engineering education curriculum is also currently adapting to disruptions to the pedagogical approaches. The rise of the generative artificial intelligence (GenAI), a subset of AI designed to produce novel content, including text, images, music, code, and videos, by leveraging advanced machine learning techniques such as Generative Adversarial Networks (GANs) and transformer-based models (GPTs). These models are trained on extensive datasets to identify patterns and structures, enabling them to generate outputs that closely mimic human creativity and productivity. The combination of GenAI and industry requirements to shift towards a more human centred and less technically focused engineer is also shifting the training requirement to be more self-sufficient and socially aware (Van den Beemt et al, 2020; Quince et al, 2024).

Technology can support instructors to provide more feedback, or the same feedback sooner, and feedback on some lower-order tasks can now be automated. Until now, however, these advances have only served to scale linearly, allowing the same humans to provide more feedback (Henderson et al, 2019). With the advent of GenAI, the provision of feedback can now be scaled more effectively than ever before. GenAI systems are capable of producing automatically generated, customised outputs in response to even simple or general input prompts (Lee & Moore, 2024; Quince & Nikolic, 2025). The ability to provide personalised, customisable, timely and large volume of information, with minimal need for human correction, opens the door to truly abundant feedback. It is this abundant model of feedback that is explored in this paper.

The paper is positioned as a conceptual paper, which sets out to define abundant feedback by outlining the key dimensions of abundance and their meaning. This definition is especially important at this point in time, as the use of GenAI tools is rapidly evolving and are being adopted in education, although sporadically and without a shared conceptual foundation. Therefore, defining abundant feedback within this paper provides a conceptual reference point for guiding more coherent and purposeful integration in education. This paper commences with a literature review of key feedback concepts and the challenges facing the provision of high-quality feedback. It explores the key concepts of abundant feedback and their meaning and examines the consequences of abundant feedback for the curriculum, showing how GenAI can be the enabling technology for new models of feedback for student learning.

Feedback in Contemporary Education

Feedback has been posited as one of the most influential and powerful tools that learners in higher education have to determine the success of their studies (Hattie & Timperley, 2007). Hattie and Timperley define feedback as information that is given by an agent, where the agent can be an instructor, peer, self, written test or experience.

There are many dualities to feedback, depending on *what* kind of purpose it serves. Directive feedback is instructional in nature (Straub, 1996), it provides the receiver with an explicit instruction to improve or fix their work (Shute, 2007). Facilitative feedback is commonly guiding

(Shute, 2007) and can be a part of a feedback process which encourages self-agency (Nieminen et al, 2022) or the ability to be self-directed (Choi & Anderson, 2016).

Another pair of feedback types are descriptive and evaluative. Similar to directive and facilitative, they operate in a sequence. Evaluative feedback is typically provided through summary comments or grades that judge the quality of student work against set criteria, it is usually characterised by the lack of emphasis on the direct outcomes (Chan & Lam, 2010). Descriptive is a feedback type where the goal is to action it (Rodgers, 2006). It aligns with summative, where the goal is to create an understanding for the receiver of why it is effective or not.

Feedback can be categorised as formative or summative, depending upon when it is delivered in the learning process. Formative feedback is provided throughout a project or unit of study, with the intention of supporting the learning process (Cobbold & Wright, 2021). Summative feedback is provided at the completion of learning task, providing an explanation for assessment outcomes and suggestions for future improvements. Summative feedback has been shown to be less engaging for learners (Cobbold & Wright, 2021), serving more as a justification of marks, rather than supporting self-directed and meta-cognitive learning.

Learners are required to make judgements on the quality of the feedback, if they will use the feedback to enhance their work and if this feedback should inform their thinking moving forward (Tai et al, 2018). Feedback has been positioned as requiring more than one cycle to ensure that learners are able to reach the purposeful end of the feedback process. This aligns with Nicol and Macfarlane-Dick (2006) who describes feedback as a requirement of the self-proficiency for learning, which moves past the previous definitions where feedback was viewed as a didactic process.

More recently we see the emergence of the concept of feedback literacy, defined as the ability to understand, interpret and use feedback effectively. Carless & Boud (2018) expand feedback literacy by appreciating feedback, making informed judgements, managing affective responses and taking action. Building on this foundation, some researchers have proposed that feedback literacy should also encompass proactive dimensions such as feedback seeking, highlighting the learner's active role in generating and engaging with feedback. This concept is core to many professions and we content may be one of the most influential to the defining characteristics of a good engineer.

Challenges in Feedback Practices within Engineering Education

Expanding on the statements from Section 2, the following table was generated by investigating the literature for current issues or challenges with feedback practices within engineering education. Table 1 shows the analysis and synthesis of key articles (Winston et al, 2017; Evans, 2013; Male & Boulter, 2022; Williams et al, 2019; Smith & Smith, 2021; Linder et al, 2021; Jessop et al, 2014; Melles et al, 2020; Boud, 2015; Dochy et al, 2019). These articles were selected based on a targeted search using Google Scholar using combinations of terms such as "feedback practices" "engineering education" and/or "higher education". Papers were selected if they were peer-reviewed, relevant to feedback practices, and offered widely cited foundational perspectives or recent contributions to the field.

Table 1: Challenges in feedback practices

Theme	Challenges
Scalability	Large cohorts in engineering create significant instructor workload. Individualised feedback becomes difficult at scale
Timeliness	Feedback delays can reduce learners' motivation to engage and improve

https://doi.org/10.52202/086293-0051

Use of Technology	Automated tools risk providing impersonal or superficial feedback Poorly integrated or glitchy platforms disengage learners'
Clarity & Actionability	Generic or vague comments often go unused. Learners struggle if feedback doesn't clearly indicate next steps
Valuing Feedback	Varying or low-quality peer feedback if rubrics are unclear Learner may lack skills or confidence to evaluate others meaningfully
Learner Agency & Engagement	Even well-crafted feedback can fail if learners aren't motivated or don't know how to act on it.
Integration with Curriculum	Feedback often isolated within a course or assessment item. Disconnected tasks reduce opportunities for sustained learning

Abundant Feedback

The provision of feedback has previously been a resource constraint. Typically, instructors are allocated a set amount of time per assignment to provide as much feedback as they can within that window of time. This instructor-led scarcity model prioritises efficiency over depth, resulting in feedback that may be brief, generic, or focused more on justification of grades than on supporting learning. Learners are rarely given the opportunity to engage meaningfully with feedback, and consequently, they do not develop the feedback literacy skills needed to interpret, reflect on, and apply it effectively.

To address the challenges from Table 1, we propose the concept of abundant feedback, enabled by GenAI. GenAI is particularly suited to tasks such as summarising content, evaluating structural components, interpreting syntax and inferring contextual details across tasks. These tools can be used to generate conversational, personalized feedback directly to students, without the traditional limitations, as such they introduce the potential for feedback to become abundant.

Abundant feedback is the opposite of the scarcity paradigm, where instead students have access to a (theoretically) infinite supply of feedback. While it takes vast resources to develop GenAI models, they have a near-zero marginal cost for each instance of providing feedback to students. It is this feature that makes GenAI the enabling technology to truly offer feedback at scale. It introduces the potential for providing students feedback continuously as they iterate and refine their work. More importantly, the concept of abundance introduces the possibility of different models of engagement with feedback. Much like how an all-you-can-eat lunch buffet offers more variety, options and opportunities than a single large meal, the abundance of feedback that GenAI can provide will allow students to engage very differently with feedback on their work. Abundant feedback is therefore defined as a multi-dimensional concept which maintains the features of traditional feedback whilst also providing an abundance in volume, availability, relevance and character through the use of GenAI models (Figure 1). Each dimension is derived from the issues documented in Table 1, as such it is proposed solution to existing challenges.

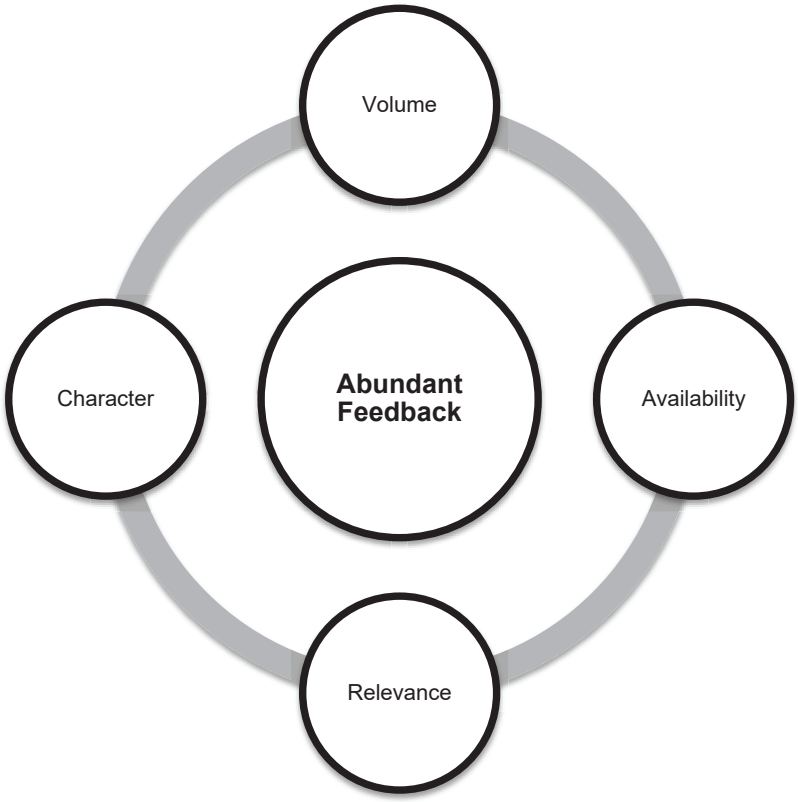


Figure 1: The dimensions of abundant feedback

Volume

Unlike traditional feedback models, abundant feedback is not constrained in volume – the marginal cost of providing more feedback is zero. In doing so, feedback is no longer constrained to what can fit within the instructor's resource envelope, such as only addressing the most common errors with pre-prepared comments. Learners are able to seek deeper feedback on their work, to seek feedback on more aspects of their work, and to seek alternative versions of feedback if they do not find the first feedback helpful to them.

Availability

Abundant feedback is potentially available 24/7 and on-demand. Instant feedback clearly addresses the issue of timeliness in feedback, eliminating the delays inherent in traditional models. Furthermore, on demand feedback allows learners to request feedback at any stage of a learning task, rather than only at the designated feedback points within the task. This gives learners the opportunity to seek formative feedback as required throughout their learning, rather than limiting feedback to a retrospective summative mode.

Relevance

Relevance in the context of abundant feedback refers firstly to the ability to tailor feedback so that it reflects both the discipline expertise of the domain, and the significance of the feedback to the learner or the task at hand. Learners are provided with feedback that is meaningfully connected to the specific concepts, practices, and expectations of their field of study, are now able to filter and further explore knowledge by specifying further relevance related to interconnected aspects of their work e.g. by requesting further feedback into specific technical aspects of a larger system.

https://doi.org/10.52202/086293-0051

Character

Tone, structure and style are all important characters of feedback which can impact the learners ability to comprehend and/or trust the feedback they receive. It can be characterised based on what the leaner wants it to be (e.g. encouraging, direct, funny or supportive), what they need it to be (e.g. corrective, developmental or instructional), or what it should be from an instructor's perspective (e.g. aligned assessment task).

This dimension also includes the ability to change the format of how feedback is provided (eg text, images, audio), and the persona that is providing the feedback. Some learners may benefit from a clear and concise list of what needs to be improved, whereas others may benefit from dialogic feedback with embedded reflection or commentary. This level of flexibility can play a powerful role in improving feedback practice by shaping how learners perceive, engage with, and act on feedback. It also further refers to the ability to adapt feedback to its intended purpose, for instance, whether the feedback should be instructive, facilitative, descriptive, or evaluative, depending on the pedagogical intent.

The Enabling Technology

The concept of abundant feedback represents a significant departure from traditional instructor-led feedback models that often rely on isolated, summative comments delivered at the end of an assessment. In contrast, abundant feedback allows feedback to be reframed as a continuous, integrated process that is learner-centred and central to learning. This paradigm shift has far-reaching implications for learner engagement and teaching practices.

Example of Applying Abundant Feedback

In engineering education, learners frequently engage with complex tasks and projects. Traditionally, the feedback provided on these assessments often arrives late, is restricted in depth due to instructor constraints, and may lack sufficient detail for meaningful learner engagement. The concept of abundant feedback, enabled by GenAI, presents a significant shift in this scenario by providing immediate, extensive, contextually rich, and interactive feedback to learners, fundamentally altering the educational landscape.

The abundant feedback model, powered by GenAI, significantly expands the traditional feedback paradigm across four clearly defined dimensions: volume, availability, relevance, character, and learner agency. In a typical assessment scenario, GenAI has the potential to autonomously analyse students' submissions in real-time, immediately identifying and flagging syntactic and logical errors, offering detailed suggestions for correction, and relating these corrections explicitly to engineering principles and best practices. While this may not always directly align with the learning outcome, the abundant feedback model can be considered as a shared reference point for educators to guide more coherent and purposeful integration of GenAI feedback in education. The opportunity is that feedback can be delivered in a personalised, adaptable format that is tailored to the learners' educational context and preferred learning styles, actively engaging students in iterative processes of learning, revision, and self-regulation.

Learner Engagement, Feedback Literacy and Agency

Feedback is most effective with metacognitive learners, those who have a deep understanding of how feedback actually works and how to use it. Developing agency, the capacity to take ownership of learning and engage proactively with feedback, is essential.

Abundant feedback makes this possible. As an enabling technology, it allows for the integration of frequent, on-demand, formative, and personalised feedback throughout the curriculum. This responsive and inclusive approach not only supports learning but also deepens students' understanding of feedback itself, fostering both feedback literacy and agency. The ability to make feedback abundant represents a critical shift in academic practice, from the challenge of delivering feedback to empowering students to engage with it. In this model, the limiting factor

is no longer the educator's capacity to provide feedback, but the student's ability to interpret and act on it.

Abundant feedback also drives learner agency by enabling students to select, interpret, and apply feedback aligned with their goals. Learners move beyond passively receiving feedback to actively seeking it out and using it to guide their learning.

Teaching Practice

Although abundant feedback is proposed as a conceptual reference point rather than a prescriptive framework. It addresses one of the most persistent challenges in education: the cost and timeliness of meaningful feedback at scale. In doing so, it precipitates a shift in teaching practice, from feedback being the final step in the assessment cycle to embedding it as a continuous, dialogic element of the learning process. This means instructors are no longer the sole providers of feedback. Instead, they become designers of feedback-rich learning environments, orchestrating the integration of AI-generated, peer, and self-assessment feedback into their teaching practice. Rather than just adding more feedback, educators can adopt the dimensions of abundant feedback by reconfiguring existing practices or reimagine learning task design. Iterative work with broader range of artefacts (e.g. written, verbal, performative) and multiple feedback checkpoints, as well as opportunities for dialogue, revision and reflection are now possible. This contributes to higher fidelity and authenticity in the learning experience, by mimicking the iterative, collaborative and dynamic nature of professional practice. As such the concept of abundant feedback can act as a guide for institutions in balancing efficiency with quality and supporting purposeful integration of emerging technologies to ensure feedback practices remain sustainable and learner-centred.

Potential Risks and Rewards

Providing abundant feedback, particularly with GenAI, is not without its risks. It is important to acknowledge that learners are already beginning to use Gen AI systems to provide feedback on their work. Intellectual property and data security have always been risks that are associated with the use of external third-party software or tools to deal with confidential data such as student assignments. Appropriate training for students and academics is important to ensure that the use of external tools aligns with institutional polices. The use of locally provided tools can address these concerns, however GenAI is a rapidly advancing field, and students will have access to newer, more powerful tools that operate outside the university's control.

Feedback is more than just data transfer, and the way in which feedback is provided can sometimes be more important than the feedback itself. Moving to an abundant feedback paradigm removes the constraints on providing feedback, but it risks removing other critical elements as it does so. Our proposed framework helps to crystallise these issues, and a non-exhaustive set of examples are discussed below.

For example, provision of feedback with abundant volume and/or relevance may risk learners becoming lost in a flood of information. In this aspect, it is critical that educators refocus their approaches towards developing learners' feedback literacy, particularly aspects of "meaning-making". There are also obvious concerns about the ability of AI systems to provide correct information, and although this can be considered as simply a (potentially) soluble technical problem, rather than a conceptual issue, an increased focus on evaluative judgement of feedback would also help to address this.

In the short term, feedback with abundant character carries potential risks of students being exposed to feedback that is harmful if Gen AI feedback systems are not appropriately developed. However, this is also possible in current human feedback processes, and if systems take this possibility into account, there is potential for improvement over the status quo. In the longer term, learners may not develop the skills to interpret feedback from different sources, preferring to receive feedback only in some ways rather than others, harming their long-term development of the ability to work in varied contexts and multidisciplinary teams. It

https://doi.org/10.52202/086293-0051

will be important for educators to moderate (limit abundance of) these systems and introduce them into their courses in a thoughtful manner.

In a similar vein, while giving students abundant availability and agency empowers them to seek and interrogate feedback during their formal education, it is important for students to learn to work without abundant feedback, and to be comfortable with uncertainty where needed, in order to work in areas where quality abundant feedback is not available. Abundant feedback may provide the early scaffolding to enable learners to reach this point faster, particularly in areas of technical knowledge that are well-established, but the point of education in a world of Gen AI must be to enable students to do things that Gen AI cannot do itself.

As can be seen from the above discussion, feedback literacy is a critical component in the successful deployment of abundant feedback. It is important that the abundant provision of feedback information by Gen AI systems does not see the realm of feedback more generally being dismissed as a "solved problem" by staff and institutions. However, if appropriately harnessed, abundant feedback becomes an enabler of feedback literacy, as well as an important tool in feedback literacy research. Which is why defining abundant feedback as within this paper provides a conceptual reference point for guiding more coherent and purposeful integration in education. However, it does not in itself address pedagogical impacts or applications. GenAI is a fast-paced emerging technology, the dimensions of abundant feedback may need to adapt as new tools reshape practical settings and contextualised scenarios. Future work should therefore explore how the concept can be applied within established models such as e.g. CDIO design-based cycles to inform practice.

Conclusion

Feedback remains a cornerstone of effective learning, yet its traditional delivery has been constrained by time, scale, and educator workload. Generative AI is opening up the opportunity to make feedback abundant by lowering the marginal cost of providing that feedback. This in turn opens many opportunities that go beyond simply the benefits of “more feedback”. Ultimately, abundant feedback will shift our mindset and approach to student engagement, as well as learning and assessment design. Abundant feedback is a potential enabler of feedback literacy, while improved feedback literacy of learners is important to mitigate potential risks of abundant feedback.

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