2026
Volume 6
Article 71
https://doi.org/10.20851/ll.v6.71

Navigating complexity in STEM education: An editorial

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Complexity is a defining feature of contemporary STEM education, where learners, technologies, curricula, industries, and policies interact in ways that resist simple cause-and-effect explanations. This special issue examines what it means to design for such learning conditions by adopting a complexity perspective that treats educational settings as adaptive systems. In these systems, the central challenge is creating conditions for learning by aligning roles, artefacts, and feedback mechanisms, with coordination emerging as the critical difficulty due to shared responsibility, distributed decision-making, and complex information flows. We frame coordination across three interconnected levels (individual, team, and governance) and argue that effective STEM education depends on orchestration across these levels so that teaching and assessment decisions reinforce rather than contradict one another. The contributions in this issue provide concrete examples of how such orchestration can be achieved in practice, alongside shareable artefacts and design patterns that educators can adapt to their own contexts. By examining diverse cases of coordination in action, this special issue aims to advance research-informed design principles for navigating complexity in STEM ecosystems, offering both theoretical frameworks and practical guidance for educators, researchers, and policymakers working in multifaceted learning environments.

Keywords: academic integrity; adaptive learning; assessment design; complexity; cognitive engagement; experiential learning; feedback architectures; GenAI literacy; industry partnerships; project-based learning

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Recommended citation: Gamage, S. W, & Abadia, R. (2026). Navigating complexity in STEM education: An editorial. *Learning Letters*, 6, Article 71. https://doi.org/10.20851/ll.v6.71

Introduction

STEM education increasingly unfolds within systems characterised by interdependence, uncertainty, and continual change. Adopting a complexity perspective, we treat learning settings as adaptive systems and focus on creating conditions for learning by aligning roles, artefacts, and feedback over time (Davis & Sumara, 2006). In such systems, the central challenge is coordination: how information flows, how responsibilities are shared, and how decisions are made across the educational setting.

Coordination operates at three interconnected levels. At the individual level, educators need sound ways to infer cognitive engagement rather than rely on activity traces alone. Frameworks such as Interactive, Constructive, Active, Passive (ICAP) help distinguish passive observation from active construction (Chi & Wylie, 2014). At the team level, feedback quality and error detection improve when norms of openness and voice are established, what Edmondson (1999; 2018) terms psychological safety. At the governance level, course and program structures determine who hands what to whom, when, and with what responsibility. Drawing on coordination theory adapted to higher education, effective handovers depend on accountability, predictability, and common understanding (Okhuysen

& Bechky, 2009). We therefore emphasise orchestration across all three levels so that teaching and assessment decisions reinforce rather than contradict one another.

This special issue brings together seven research papers that illustrate how such orchestration can be achieved in practice. Readers will find school–industry partnerships, course-level feedback architectures, project-based learning in technical contexts, a "guard railed" GenAI task that assesses process, a behavioural-engagement intervention using planning prompts and personalised feedback, and a longitudinal institutional analysis of GenAI-related academic-integrity trends. Collectively, these papers surface research-informed shareable teaching artefacts and illustrate orchestration patterns that others can adopt, including multi-level feedback routines, ICAP-aligned indicators, process-visible assessment, and concise change logs. We conclude with a research–practice agenda that prioritises assessment redesign, portfolios of evidence combining feasibility and targeted learning indicators, capacity building for ecosystem orchestration, and open sharing of artefacts.

Navigating complexity

Our journey into adaptive and experiential learning began well before this special issue. Working across STEM programs at the University of South Australia (a foundation university of Adelaide University), we have seen first-hand how small design moves can shift whole learning ecosystems. Roles change, tools evolve, and contexts continually shift. What remains constant is our commitment to evidence-informed iteration and the ethics of teaching: transparency, consent, and fairness. We present seven research papers that offer practical approaches others can adapt.

“Promoting school–industry collaborations in STEM: Insights and implications from two case studies” (Vieira et al.): Drawing on two diverse case studies, including the STEM Girls Academy, this paper illustrates how problem-based learning (PBL) can function as a complex system to sustain industry relevance. The authors emphasise the necessity of "boundary brokers"; intermediaries who align authentic industry briefs with curricular goals to ensure feasibility. The study offers a practical "playbook" featuring iterative feedback routines, such as the "two stars and a wish" model, while addressing real-world constraints like timetabling and intellectual property.

“A complexity-informed, feedback loop approach for systems analysis IT education at undergraduate and postgraduate levels” (Darzanos et al.): This conceptual study frames the IT classroom as a complex adaptive system (CAS) where students, staff, and technologies act as interconnected agents. The authors propose a "whole-of-course" architecture that orchestrates feedback across four levels: learner, instruction, staff, and system. Shareable artefacts include OneDrive repositories for visible progress and OnTask+ nudges for personalised reminders. The study reports a reduction in non-submission rates and demonstrates how interventions were staged and coordinated, supporting responsible reuse and alignment between team routines and course-level governance.

“Capturing students' cognitive engagement using the ICAP framework: A scoping review” (Jayasinghe et al.): Providing a theoretical anchor for this issue, this scoping review of 42 articles examines how the ICAP framework is used to map observable behaviours to cognitive depth. The review identifies a recurring emphasis on constructive and interactive modes in sampled studies and reveals a methodological shift toward automated and machine learning approaches, such as natural language processing and log analysis, to measure engagement at scale in digital environments.

“Lessons from practice: Implementing project-based learning in a water engineering course”

(Wella Hewage et al.): Set in a standards-intensive water engineering context, this study provides a grounded account of replacing traditional exams with a scaffolded PBL model. To ensure individual accountability and protect academic integrity against GenAI shortcuts, the authors implemented an individual viva voce (oral exam). This "process-visible" assessment allowed instructors to probe student reasoning and design assumptions that written reports might mask, while providing rubrics and question templates immediately useful to other course teams.

“A case study of solving a complex genetics problem to develop generative AI literacy in health science” (Della Vedova et al.): This case study addresses the rise of generative AI (GenAI) by integrating a "guard railed" task into a health science genetics course. Instead of assessing only the final answer, marks were awarded for the process, specifically, student prompting strategies and critical analysis of GenAI outputs. Results showed that, while overall marks remained stable, there was a strong correlation between the quality of a student's critique and their problem-solving success. By assessing the process we value, we can foster GenAI literacy without compromising integrity.

“Enhancing behavioural engagement and academic performance in a web-based platform through personalised feedback and planning prompts” (Papageorgiou et al.): This study investigates the impact of fortnightly planning prompts and personalised feedback on behavioural engagement in a web-based mathematics course. Using theory-driven log-type indicators, researchers found that planning prompts reliably increased student attempt rates. However, the effectiveness of personalised feedback was moderated by value beliefs; students who highly valued the task showed more consistent practice regularity. The authors conclude that engagement interventions must be tailored to motivational fit rather than applied as universal solutions.

“Beyond the algorithm: A longitudinal study of academic integrity trends in the context of AI in STEM education” (Ulpen et al.): Using institutional case records across 13 study periods (2021–2025), this paper contrasts STEM and non-STEM patterns in GenAI-related investigations and penalties. Essay-style and programming tasks account for most cases. Notably, Turnitin is used sparingly in IT and engineering despite many GenAI-related penalties, and reported GenAI-percent scores have declined over time, reinforcing caution with detection tools. The contribution is descriptive yet decision-relevant: it supports assessment redesign toward process-visible, in-class, or oral components, and advocates for a balanced approach to policy, pedagogy, and detection.

Looking ahead

We see three priorities for advancing both practice and research. First, there is a need for redesign and study assessment that makes learning processes visible. This requires developing tasks that are harder to outsource yet easier to audit, paired with simple analytics that educators can use routinely. The integrity study in this issue (Ulpen et al.) underscores the need to prioritise design over detection. Future research should examine which assessment formats best reveal student thinking, how process-visible tasks affect learning outcomes, and what governance structures support fair and consistent implementation.

Second, we must adopt portfolios of evidence rather than single outcomes. Researchers should report concise studies combining feasibility, usability, and targeted learning indicators while developing common measures for cross-context comparison. This allows the field to build cumulative knowledge about what works, for whom, and under what conditions, moving beyond isolated case studies toward generalisable principles.

Third, we need to build and investigate capacity for orchestration across individual, team, and governance levels. Practice priorities include establishing feedback systems that encourage psychological safety, designing ICAP-aligned tasks, fostering industry-community partnerships, and embedding ethical AI-aware practices. Research should explore how orchestration scales across contexts, which coordination mechanisms prove most robust, and how shared artefact libraries (briefs, rubrics, prompt banks, moderation guides, change logs) support adaptation and innovation.

The goal is not a single method but sustained capacity to coordinate people, artefacts, and feedback over time, enabling continuous learning and improvement.

Conclusion

These contributions argue that navigating complexity in STEM education is less about discovering a perfect method and more about building adaptive capacity through usable theories, iterative designs, and actionable evidence. Across these papers, complexity is not a problem to be overcome but a condition to be worked with thoughtfully. The most durable gains come from transparent designs, iterative feedback, and assessments that make process visible. Our hope is that the artefacts and arguments gathered here prove responsive to local constraints, attentive to ethics, and open to discussion. We invite readers to test, refine, and build on these ideas in their own STEM learning contexts.

About the authors

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