

BRIDGING MATHEMATICAL DIVIDES: DESIGNING INCLUSIVE LEARNING ENVIRONMENTS FOR ENGINEERING STUDENT SUCCESS

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Abstract: Level 4 engineering students arrive with vastly different mathematical backgrounds, yet traditional teaching assumes a uniform level of preparedness in developing problem-solving abilities and quantitative knowledge. This research examines how thoughtful design can reduce achievement gaps and help all learners achieve Level 4 learning outcomes through the SADRAS+ (Student Academic Development Research Associate Scheme) intervention. A three-pronged approach diagnostic testing, structured peer collaboration, and digital (Canvas & AI) tools provides individualized assistance for those with varying abilities. Diagnostic assessment identifies each student's starting point, enabling targeted interventions that build their knowledge base and problem-solving skills. Randomly formed peer groups foster teamwork while maintaining confidentiality. The study investigates which strategies are most effective and examines staff views on inclusive practice and their professional development needs. Findings from 180 participants in the Engineering Mathematics module (EG4017) from the Mechanical and Robotics departments, including those with disclosed special educational needs, demonstrate how personalized pathways within group learning help diverse learners achieve Level 4 outcomes. The findings show that when instruction anticipates different starting points, all can develop the mathematical knowledge, analytical skills, and autonomy required at this level. This presentation offers actionable strategies for STEM educators to design environments in which success is an intentional outcome of inclusive, differentiated guidance.

Keywords: inclusive pedagogy, mathematical preparedness, diagnostic assessment, peer collaboration, engineering education

Introduction

This paper presents an ongoing educational research project funded by Kingston University London's SADRAS+ (Student Academic Development Research Associate Scheme) scheme. SADRAS+ supports

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staff-led initiatives aimed at enhancing student outcomes and closing attainment gaps, particularly for underrepresented groups. Our project, titled “Specialized Teaching Approaches: Implementing Inclusive Education for Students with Special Needs”, explores inclusive pedagogical strategies within mechanical engineering education. Led by Dr.-Ing. Siva P. R. Muppala (Principal Investigator) and Dr. Payam Khazaeinejad (Co-Investigator) from the Faculty of Engineering, Computing and the Environment, the project seeks to develop and evaluate targeted teaching interventions that improve engagement, accessibility, and academic success among students with special educational needs. Mathematics forms the essential foundation for all engineering education, and this is particularly critical for first-year students in Mechanical Engineering and Robotics programmes. Without solid mathematical understanding, students cannot engage meaningfully with any core engineering content. For Mechanical Engineering students, mathematics provides the analytical language for statics, dynamics, materials behaviour, thermodynamic systems, and fluid mechanics. For Robotics students, mathematical competence underpins control theory, kinematics, sensor signal processing, and programming logic. Every subsequent module in these programmes assumes mathematical fluency—students who struggle with foundational mathematics find barriers compounding as they progress through their degree. The Kingston University Level 4 descriptors make explicit what is expected of students at this stage. Students must demonstrate broad understanding of the knowledge base and its terminology, showing awareness that areas of knowledge are open to ongoing debate. They should show ability to collect information from authoritative sources to inform solutions to standard problems in familiar contexts and begin developing ability to judge reliability of data using predefined techniques. Level 4 requires students to identify principles and concepts underlying theoretical frameworks and begin identifying their strengths and weaknesses.

Level 4 also requires students to operate with limited autonomy under direction, taking responsibility for the nature and quality of their outputs. They must develop interpersonal skills to work effectively with others, recognising factors that affect team performance with empathy and social awareness. Students should show awareness of their own capabilities in key areas and engage in development activity through guided self-direction, demonstrating resilience and self-criticality in their learning. Communication skills must enable effective expression through oral, written, numerical and visual mediums. These are demanding expectations that build throughout the engineering programme, and students who arrive with weak mathematical foundations find themselves struggling to meet them from the outset, with difficulties compounding in subsequent levels. The motivation for this project came from direct classroom observation. In my teaching of engineering mathematics, I noticed that students with special educational needs (SoSNs) tend to be less integrated with other students in the cohort. They often sit separately in lectures, hesitate to ask questions in front of peers, and struggle to keep pace with students who have stronger mathematical

backgrounds. The School currently provides limited direct support beyond extra time allowances for assessments. I felt we could do more. Research by Pete Quinn Consulting found that only 33% of disabled students in UK universities received the support they needed. Meanwhile, disabled student numbers have increased 50% over five years. The population is diversifying but support has not kept pace. At Kingston, our engineering courses attract students from genuinely diverse mathematical backgrounds - some with strong A-levels, others through access courses or foundation programmes with significant gaps.

The project draws on a framework model I developed through previous classroom research (Muppala and Chandramohan, 2020). This framework uses iterative processes of diagnostic assessment, targeted intervention, and formative evaluation to measure and improve student learning. The approach treats learning enhancement as a systematic, evidence-based process rather than ad hoc responses to perceived difficulties. Additional mathematics support is embedded within the core module delivery, with formative assessments providing immediate feedback on learning progress. The core research questions are: Can diagnostic assessment identify individual mathematical weaknesses early enough to enable targeted intervention? What teaching approaches best support diverse learners in developing the knowledge, understanding, and skills that Level 4 requires? How effective are peer collaboration and AI-enhanced learning tools? And what are staff views on inclusive practice and professional development needs? The theoretical framework draws on Florian and Black-Hawkins (2011) on inclusive pedagogy, Morris et al. (2021) on formative assessment, and El-Sabagh (2021) on adaptive learning environments.

Materials and Methods

The study is conducted within EG4017 Engineering Mathematics at Kingston University London, a core Level 4 module serving both Mechanical Engineering and Robotics students across the Faculty of Engineering, Computing and the Environment. Total enrolment is approximately 180 students, including several with disclosed special educational needs encompassing specific learning difficulties, sensory impairments, mental health conditions, and neurodevelopmental differences. The module runs across both semesters with eleven two-hour lectures each semester and corresponding tutorial sessions split between analytical problem-solving approaches and MATLAB computational practice.

For Mechanical Engineering students, mathematics provides the analytical tools required for understanding statics and dynamics, materials science and behaviour under stress, and energy systems including thermodynamics. For Robotics students, mathematical competence is absolutely essential for control theory and system stability analysis, kinematics of manipulator arms, and programming algorithms. The Kingston University Level 4 descriptors specify that students should demonstrate ability to identify principles and

concepts underlying theoretical frameworks, collect information from authoritative sources to inform solutions, and undertake practical tasks that may be complex and non-routine while engaging in self-reflection on their performance. They must also show creativity and innovation in approaching problems, testing unfamiliar concepts and evaluating outcomes. Without mathematical fluency providing the foundation, students simply cannot meet these demanding expectations.

Ethical approval was obtained through KUREOS. I completed GDPR Essential and GDPR with Researchers certifications before data collection. All participation is voluntary with no bearing on grades.

The intervention approach applies a framework model developed through my previous classroom research. This model uses iterative cycles of assessment and intervention - what I term Process 1, Process 2, through Process n - to systematically identify and address learning gaps. The approach embeds additional mathematics support within the core module, using formative assessments to provide immediate feedback and measure learning progress. The framework treats each assessment cycle as data informing the next intervention, accumulating evidence about what works for which students. The first component is diagnostic assessment at module commencement through Canvas, covering probability, decimal operations, percentages, fractions, ratios, and basic statistics. The purpose is identifying weaknesses early. Of 140 available students, 48 completed the diagnostic test.

The second component is structured peer collaboration. Groups of five students work collaboratively throughout the module. This size derives from my earlier research showing it enables meaningful participation without passive observers. Following the Level 4 descriptor emphasis on interpersonal skills and team performance, we adopt cyclic leadership rotation - each student takes turns facilitating discussions, building communication skills alongside subject knowledge. Grouping is anonymous regarding special educational needs. SoSNs are included but never identified within groups. This prevents stigmatisation while enabling participation as equals. The Level 4 descriptors emphasise working effectively with others with empathy and social awareness - anonymous integration supports this while protecting vulnerable students. The third component is AI-enhanced digital learning through Pearson MyLab integrated with Canvas (Pearson Education, n.d.). The platform provides randomised questions, unlimited practice, compulsory pre-quiz learning activities, and immediate feedback. This supports the Level 4 requirement that students engage in development activity through guided self-direction, showing resilience in their learning.

Beyond structured components, I provide direct one-to-one support for SoSN students. In Foundation module FX3005, I have six SoSN students with different requirements - ADHD, visual impairment, hearing

difficulties, schizophrenia, unspecified needs, and multiple disabilities. Each receives individually timetabled 30-minute sessions supplementary to regular teaching. Students report feeling more comfortable asking questions in this setting. Data analysis examines diagnostic scores at item level, quiz results, and individual versus group performance comparisons. Statistical analysis includes descriptive statistics, paired t-tests, and correlation analysis with significance at $p < 0.01$. The framework model approach means each data collection informs subsequent intervention design in an iterative improvement cycle.

Results

The diagnostic test was completed by 48 students from the 140 enrolled at the time of administration, representing a 34% response rate that exceeds established benchmarks for classroom research (Brookfield, 2017, p. 111). The cohort achieved an average score of 81% with a standard deviation of 7.65 percentage points. Average completion time was 33 minutes, suggesting the assessment length was appropriate for the content covered. These aggregate numbers initially suggest reasonable foundational skills across the cohort, but closer examination of the distribution reveals a considerably more complex and concerning picture.

Scores cluster heavily in the 90-100% range - students who demonstrate the broad understanding of the knowledge base that Level 4 descriptors require. However, a distinct cluster also appears in the 0-10% range. The distribution is bimodal. We have two populations: students ready to operate in varied but predictable contexts using specified techniques, and students who lack the prerequisite knowledge base entirely. Drilling into individual questions, probability emerged as the major weakness. Only 60% answered the dice probability question correctly - fifteen percentage points below any other topic. Wrong answer analysis showed 21% chose 2/36 and 8% chose 3/12, indicating conceptual confusion about sample spaces and counting outcomes. These errors reflect inability to collect information systematically to inform solutions - a core Level 4 skill. Decimal multiplication was the second problem area. Only 75% correctly multiplied 0.02 by 0.003. A quarter of incoming students cannot reliably track decimal place values. The Level 4 descriptors require ability to judge reliability of data using predefined techniques - students who cannot perform basic decimal operations will struggle with any quantitative judgment. Both probability and decimals require abstract reasoning without concrete real-world anchors. When problems have clear structure and familiar context, students demonstrate the expected ability to apply underlying concepts - 83-92% accuracy on percentages, fractions, ratios, and statistical measures. The difficulties concentrate where Level 4 conceptualisation and critical thinking skills are most needed. Four students selected "No Answer" repeatedly across unrelated questions - suggesting disengagement rather than topic-specific difficulty. The Level 4 descriptors emphasise awareness of own capabilities and engagement in development activity. These students need individual support to develop the self-direction expected at this level.

Regarding peer collaboration, the framework model approach generated encouraging preliminary data that warrants careful interpretation. When we compared individual quiz performance with scores achieved on equivalent collaborative group tasks, individual and group performance showed a moderate positive correlation of 0.57. A paired t-test confirmed this difference reached statistical significance ($t = 3.04$, exceeding the critical value of 2.947 required for $p < 0.01$). This finding aligns with results from my earlier classroom research investigating group work dynamics in large engineering cohorts, suggesting the pattern is robust rather than an artifact of this particular cohort. Critically, the benefits of group work were not uniformly distributed across students of different abilities. Students who struggled on individual assessments showed markedly greater improvement in collaborative settings than stronger students demonstrated. Group work particularly benefited those who need most support to meet Level 4 expectations - precisely the students this SADRAS+ project aims to help. The Level 4 descriptor emphasis on developing interpersonal skills and understanding team performance appears validated by these findings - structured collaboration simultaneously develops both subject knowledge and the working-with-others capabilities that the descriptors explicitly require for Level 4 achievement. Pearson MyLab feedback has been positive. Students value unlimited practice supporting self-directed development. Staff appreciate reduced marking burden. Time saved enables developing richer explanatory materials - contextual analogies that help students build the broad understanding of the knowledge base that Level 4 requires. One example: for complex numbers, I created the analogy "What would i say to another i? Join me and I will take you to the realm of real numbers" - referring to i^2 equalling negative one. Students remember such contextualisations longer than formal definitions.

Students with disclosed special educational needs report improved confidence under the combined approach. The framework model's iterative structure means support can be adjusted based on evidence rather than assumptions about what students need.

Discussion

These preliminary findings carry direct implications for curriculum design aligned with Kingston University Level 4 expectations. The diagnostic data reveals that probability and decimal operations require fundamentally different pedagogical handling than more procedural mathematical topics. Both demand the conceptualisation and critical thinking that Level 4 descriptors explicitly specify - the ability to identify principles underlying theoretical frameworks, to judge reliability of data and information using predefined techniques and criteria. Students struggle precisely where these higher-order cognitive skills are required rather than straightforward procedural application.

The framework model approach suggests concrete pedagogical responses to these identified difficulties. Additional scaffolding for abstract mathematical topics is indicated - explicit worked examples that make reasoning processes visible to students, visual representations of sample spaces for probability problems, connecting decimal operations to real engineering measurement contexts where small quantities have tangible meaning. The iterative Process 1 through Process n structure embedded in the framework model means such interventions can be systematically tested and refined based on subsequent formative assessment data, building cumulative evidence about what approaches work for which categories of student difficulty.

The bimodal score distribution confirms that assuming uniform preparation fails students at both ends. Some arrive demonstrating the broad understanding Level 4 expects; others lack prerequisites entirely. The framework model's diagnostic-first approach identifies who needs what, enabling differentiated support rather than teaching to an imagined average. The peer collaboration findings align with Level 4 descriptor emphasis on interpersonal skills and team performance. Students must develop ability to work effectively with others, recognising factors affecting team dynamics. Structured group work with rotating leadership provides practice in exactly these capabilities while simultaneously supporting subject learning. Anonymous integration of SoSN students enables full participation with the empathy and social awareness the descriptors mention.

The framework model's iterative structure proves particularly valuable for inclusive practice. Rather than one-size-fits-all intervention, each assessment cycle generates data informing the next. Students requiring more support receive it; those progressing well move forward. This aligns with Level 4 expectations that students operate with limited autonomy under direction, taking responsibility for output quality while receiving appropriate guidance. AI-enhanced platforms like Pearson MyLab support the Level 4 requirement for self-directed development. The literature supports this - Aljohani et al. (2024) found 59% of adaptive learning studies reported improved performance. McKinsey (2020) estimated technology could handle 20-40% of routine teacher tasks. Our experience confirms this. Time saved on marking enables developing the contextual, engaging materials that help students build genuine understanding rather than surface memorisation. Liu (2025) argues that future engineering education should pursue human-AI partnerships leveraging AI's personalization alongside human strengths in inspiration and ethics to reimagine inclusive pedagogy.

From curriculum development perspective, this project provides evidence for several changes. Diagnostic testing should become standard at module start - the framework model depends on accurate initial data. Probability and decimal work need explicit early attention with scaffolding appropriate to abstract reasoning

demands. Peer collaboration specifications belong in module descriptors with guidance on inclusive group formation. Adaptive platforms warrant institutional investment as core infrastructure. The UK Curriculum and Assessment Review (2025) emphasises high standards for all, noting persistent attainment gaps. The SADRAS+ framework model offers one practical, evidence-based approach - not separate provision but responsive teaching within shared spaces where diverse students can develop the knowledge, skills, and autonomy that Level 4 requires.

Conclusion

This paper has presented preliminary findings from an ongoing SADRAS+ project investigating inclusive approaches to engineering mathematics education at Kingston University London. The work addresses a fundamental challenge facing engineering educators: ensuring that all first-year Mechanical Engineering and Robotics students can achieve Level 4 learning outcomes in mathematics, regardless of their starting points or disclosed special educational needs. The Kingston University Level 4 descriptors establish clear and demanding expectations - students must demonstrate broad understanding of the knowledge base and its terminology, show ability to collect information from authoritative sources to inform solutions to standard problems, develop interpersonal skills for effective teamwork, and engage in self-directed development with resilience. Without solid mathematical competence, students simply cannot meet these requirements or progress successfully to advanced engineering study in subsequent years.

The diagnostic assessment revealed specific weaknesses in probability and decimal operations - precisely the areas requiring conceptualisation and critical thinking skills that Level 4 demands. The bimodal score distribution confirmed that uniform teaching assumptions fail our diverse cohort. The framework model approach, with its iterative cycles of assessment and targeted intervention, provides systematic methodology for identifying and addressing individual learning gaps.

Structured peer collaboration with anonymous integration of SoSN students proved effective. Statistical evidence shows benefits for struggling students. This approach simultaneously develops subject knowledge and the interpersonal, team-working capabilities that Level 4 descriptors explicitly require. Pearson MyLab supported self-directed practice while reducing staff marking burden, enabling time reallocated for this project has provided consistent visual identity across dissemination activities, reinforcing project coherence.

For curriculum development, we recommend embedding diagnostic pre-assessment as standard practice - the framework model requires accurate baseline data. Evidence on probability and decimal weaknesses justifies restructuring early content with explicit scaffolding for abstract reasoning. Peer collaboration

specifications should appear in module descriptors with inclusive formation guidance. Adaptive learning platforms warrant investment as core educational infrastructure supporting self-directed development. This research remains a work in progress. The project continues through its twelve-month timeline with activities still to complete. Staff questionnaires on inclusive practice and professional development needs are being analysed. Systematic feedback from SoSN students about intervention experiences is being gathered. The complete dataset will inform the final SADRAS+ report and subsequent journal paper.

The findings presented here are preliminary, representing partial data from ongoing intervention. As more evidence accumulates through the framework model's iterative cycles, our understanding will deepen. We presented initial work at the Kingston Festival of Learning and now share these conference findings at ICEDU, gathering international feedback to strengthen our final analysis. What emerges clearly even from preliminary data is that thoughtful inclusive design makes a measurable difference. When we diagnose student needs systematically, structure collaboration to include everyone, and deploy technology to support practice while freeing staff for enriched teaching, more students achieve the Level 4 learning outcomes their programmes require. Success becomes intentional outcome of evidence-based educational design rather than accident of prior preparation.

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Declaration of Interest Statement

The authors declare that they have no conflict of interests.

References

- Aljohani, N.R. et al. (2024) 'Personalized adaptive learning in higher education: A scoping review', *Heliyon*, 10(21).
- Department for Education (2025) Curriculum and Assessment Review Final Report. London: DfE.
- El-Sabagh, H.A. (2021) 'Adaptive e-learning environment based on learning styles', *International Journal of Educational Technology in Higher Education*, 18, Article 53.
- Florian, L. and Black-Hawkins, K. (2011) 'Exploring Inclusive Pedagogy', *British Educational Research Journal*, 37(5), pp. 813-828.
- Liu, C. (2025) 'A comprehensive review of applications of AI technologies in higher engineering education', *Discovery Education*, 4, p. 528. Available at: <https://doi.org/10.1007/s44217-025-00954-0>.
- McKinsey and Company (2020) How Artificial Intelligence Will Impact K-12 Teachers.
- Morris, R. et al. (2021) 'Formative assessment and feedback for learning in higher education: A systematic review', *Review of Education*, 9(3).
- Muppala, S.P. and Chandramohan, V. (2020) 'Classroom Research in Large Cohorts: An Innovative Approach Based on Questionnaires and Scholarship of Teaching and Learning on Multiple-Intelligences', *Journal of Education and Learning*, 9(3), pp. 106-115.
- Nguyen, T.T. and Habok, A. (2023) 'Automated evaluation systems in higher education', *Education and Information Technologies*, 28.
- Pearson Education. (n.d.). MyLab Math (Version [e.g., 2025]). <https://www.pearson.com/mylab.html>