Performance metrics on a generative learning approach in a studio and flipped classroom setting for increased learning outcomes in mechatronics

Sebastian Oberst (1)

(1) Centre for Audio, Acoustics and Vibration, School of Mechanical and Mechatronic Engineering, Faculty of Engineering and IT, University of Technology Sydney, Australia

ABSTRACT

This paper presents a four-year longitudinal study of the subject "Embedded Mechatronic Systems," which has been redesigned using Generative Learning Theory (GLT) within a flipped classroom model, supported by studio and project-based learning. The subject aims to teach students principles of physical computations, including digital circuit design and embedded systems, to efficiently control sensors and actuators, including MEMS microphones, accelerometers, stepper motors, LEDs, and buzzers, and associated fundamentals of digital signal processing. To better integrate theoretical and practical components, a group project was introduced, transforming previously disconnected laboratory exercises into cohesive, collaborative experiences. Students now produce reflective reports and demonstration videos, fostering deeper understanding through self-explanation and peer interaction.

To monitor the effectiveness of these pedagogical changes, both qualitative and quantitative performance metrics have been systematically tracked across four academic years. These data reveal that hands-on, face-to-face learning environments, especially those emphasising self-testing and collaborative problem-solving, consistently yield higher learning outcomes compared to previously employed remote or isolated learning modes during C19. In response to these findings, a structured assessment framework was introduced, including a 'Competency Threshold' to ensure foundational understanding and a 'Mastering Threshold' to recognise advanced proficiency. These thresholds provide clearer learning targets and support differentiated student progression. The students' engagement with acoustic and vibration sensors, as well as their exposure to applied signal processing, prepares them for work in subsequent subjects, including Vibration and Control, Embedded Mechatronics Studio, or in other, more discipline-specific subjects such as Environmental Noise. Sensors used are implemented using industry-relevant microcontroller platforms such as the STM32 Nucleo series, with direct input and collaboration from industry partners. This integration follows foundational instruction in Digital Circuit Design, ensuring students are equipped with the necessary theoretical and practical skills to engage with modern embedded systems.

This paper outlines the evolution of the subject, the impact of pedagogical innovations, and future directions for further improving learning outcomes in mechatronic engineering education, and the introduction of vibration and acoustic sensors. The results demonstrate that combining flipped learning, GLT strategies, and real-world technology applications not only enhances student engagement but also bridges the gap between academic learning and industrial practice.

1 INTRODUCTION

Modern engineering education increasingly calls for a shift from lecture-based delivery to student-centred, active learning that reflects the complexity of real-world problem-solving. In embedded systems within mechatronics, a field combining mechanical and electrical engineering with computer science, this shift is especially vital. Mechatronics relies heavily on experimental work and practical experience, requiring both theoretical knowledge (e.g., digital logic, control theory, signal processing) and hands-on skills in implementing and debugging hardware-software systems with sensors and actuators (accelerometers, microphones, infrared, stepper motors, piezos).

Over the past five years, including the time through COVID-19, the core subject *Embedded Mechatronic Systems (EMS)* at the University of Technology Sydney in the Mechatronics stream in the School of Mechanical and Mechatronic Engineering has undergone a major pedagogical transformation. This paper outlines the design, implementation, and evaluation of a revised structure based on Generative Learning Theory (GLT), delivered through flipped classroom teaching (FCT), and integrated with studio and project-based learning (PBL) to enhance learning outcomes. The changes are required to increase learning outcomes and to strengthen the independent character of learning and the explorative nature of engineering problem-solving.

In this context, GLT assumes that deep learning occurs when students actively organise, integrate, and elaborate on new information (Fiorella & Mayer, 2016). It involves four key cognitive processes: attention, motivation, memory, and information generation (Wittrock, 1974), each linked to distinct neural functions (Hanke et al., 2012). Constructivism, a related concept, emphasizes learners constructing knowledge through authentic experiences, mostly lab-based and practical, which had already been implemented in the subject design. Teaching strategies aligned with GLT promote exploration, collaboration, and problem-solving.

FCT reverses traditional instruction by shifting content delivery outside the classroom, allowing in-class time for interactive, problem-solving activities. Students engage with materials at their own pace before class, enabling deeper learning during face-to-face sessions. Studies show FCT significantly improves academic performance in STEM fields (Lo & Hew, 2019; Zhang et al., 2021). In the flipped model, online lectures precede class, freeing time for generative tasks like circuit design, sensor calibration, and collaborative debugging. This structure better reflects realistic learning environments and supports improved outcomes. The main aspect of this concept is to prepare students and to increase the sensitivity of students to understand that out-of-classroom learning is the most important part, simply because of the time constraints imposed, and to empower them by providing materials and advice to do so.

PBL engages students in solving real-world problems through critical thinking, collaboration, and inquiry (Kokotsaki et al., 2016; Krajcik & Shin, 2014). It integrates core concepts with scientific practices and cognitive tools, enhancing engagement and understanding. Studio-based learning complements PBL, especially in large cohorts, but requires a shift in mindset for both students and educators (Tekmen-Araci et al., 2020).

Both FCT and PBL align with GLT's emphasis on active knowledge construction. FCT prepares students for deeper in-class engagement, while PBL fosters understanding through authentic problem-solving. These methods support core generative processes but are often difficult to measure through traditional assessments, which focus on surface-level achievement. Moreover, students may find these approaches challenging, especially when guidance is limited and creativity through constructivism is required.

In the context of EMS, the involvement of FLT and PBL in a studio and workshop setting has been shifting passive lecture consumption to active work outside the classroom through online materials and early exposure to assignments and using in-class time for generative tasks: circuit design challenges, code walkthroughs, sensor calibration exercises, and system-level debugging activities. These activities have been trialled in being supported by project-based learning strategies that promote collaborative exploration and contextual problem-solving, known to enhance both student engagement and cognitive retention (Prince & Felder, 2006; Hmelo-Silver, 2004). The goal was to shift the laboratories into the centre, and to make their assessment, Pareto-paribus, more difficult. Therefore, an initial exponential distribution of marks is expected to become more normally distributed. Further, more assessment items, especially project-based assessments and viva-voce, have been introduced to replace final exams or quizzes and to increase transparency and detailed focus. During this process, it is expected that overall marks distribution improves, but that student SFS scores drop temporarily, until increasing again with subject reputation. The subject had been packed with content at the beginning, providing more support and guidelines through online materials and videos, which relaxed over the following weeks, emphasising the focus on the explorative character of the learning process, and fostering independence of the learners, required for all later stages in their degree and profession of engineers as problem solvers. Students learn further through active reflection and documentation, and peer interaction as evaluated through reflection reports, laboratory books, and peer assessment (Ahammed, 2019).

2 METHODS

2.1 General information about the cohort

The study was conducted across six consecutive years (2020-2025), with annual enrolments ranging between approximately 140 and 225 students. Data for the years 2022 to 2025 is complete, while some data for other years are missing. Newer data were extracted from the UTS *Student360* analytics system, which provided demographic details (domestic/international status, gender distribution, prior academic performance) and anonymised assessment results. Prior data was documented from Excel sheets, also anonymised.

2.2 Assessment items over the years

The diagram in Figure 1 presents a longitudinal overview of the EMS course structure across five academic terms AUT21, SPR22, AUT23, AUT24, and AUT25, highlighting the evolution of teaching methods, assessment formats, and learning activities; the first term (2021) served as the baseline. It categorises activities into lab work, group and individual projects, workshops, and exams, while also mapping these against pedagogical approaches: Traditional (blue), Generative Learning (yellow), Constructivism (green), and Flipped Classroom (pink).

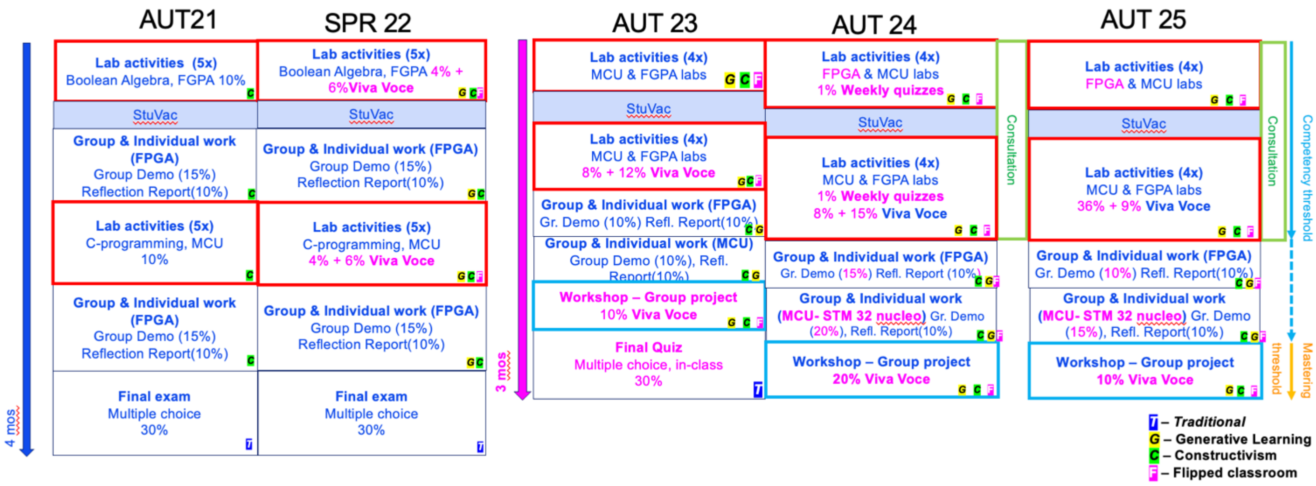


Figure 1. Changes over the years. While the overall subject was already designed to follow some constructivism, the key innovation was the full introduction of generative learning within a flipped classroom format and PBL delivered in a studio/workshop-based environment. At the same time, the goal was to enhance learning outcomes by introducing more and novel components, growing the explorative and research character of the subject, the rigour of the subject aimed to have a student cohort classified as ‘Competent’ and ‘Mastering’.

In AUT21, the course follows a traditional structure with a strong emphasis on lab activities using Boolean Algebra on FPGA (DCD- digital circuit design), and C programming with MCU, each contributing 10% to the final grade. Group and individual work are assessed through demos and reflection reports, totalling 50% across both domains. A multiple-choice final exam accounts for 30%, indicating a conventional summative assessment model. The teaching approach here is predominantly *Constructivism,* focusing on content delivery and individual performance with creative and constructive elements, but little assessment thereof. The subject consisted of a range of lectures, which were contained in a workshop held before the computer labs took place. The computer labs had tasks, the students were advised to complete, and which were only lightly assessed on completion. The two projects, one in DCD and the other using an Arduino Uno, had a practical component, which made use of all computer lab content and a reflection report; these components were kept in the following years. Some old components got a slight shift and related more to the new concepts (e.g., reports) and to include peer-review components (Spark Plus), and remained otherwise identical. Assessment items were evaluated as being only weakly assessed, and students could spend a minimum of time resolving the tasks given.

By SPR22, the course begins to incorporate Generative Learning strategies. Lab activities now include viva-voce assessments, adding an oral component to the evaluation. The structure remains similar, but the inclusion of StuVac (study vacation) suggests a shift toward encouraging independent study. The assessments are slightly redistributed, maintaining the multiple-choice exam but integrating more interactive and reflective components, such as group demos and reports. The workshop became interactive and had extra components such that we introduced a crash course on C programming, a module on how to write a proper engineering report, and an excursion in academic integrity.

In AUT23, the course transitions further into *Constructivist* and *Flipped Classroom* methodologies. Weekly quizzes are introduced to reinforce continuous learning, and project work becomes central, especially in the MCU domain. Assessment is diversified with multiple group demos, reports, and reflection tasks. A workshop-based group project included an in-class multiple-choice test, emphasising collaborative and applied learning. This term reflects a pedagogical shift toward student-centred learning and formative assessment. MCU and DCD content was alternated, starting with MCU to give students more time with microcontroller content, which was more practical but also more abstract with regard to logic implementation etc.

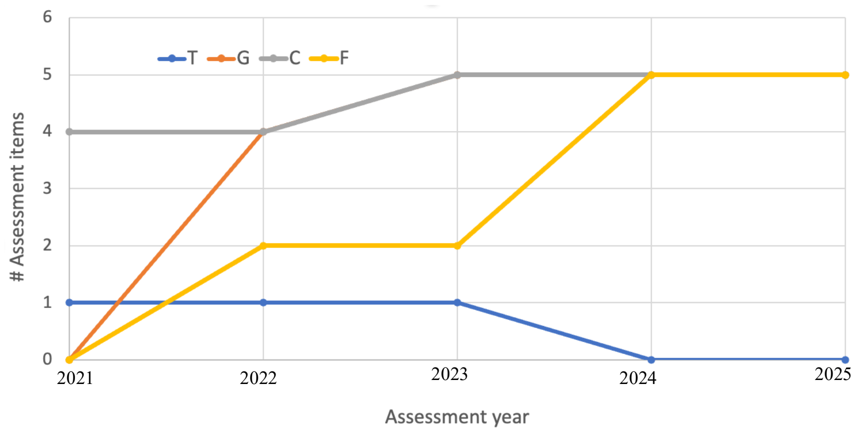


Figure 2. Assessment items over the years. T- traditional methods decreased, whereas G-generative and F-Flipped mode teaching methods were increased. Constructivism was left at approximately the same level. Overall assessment numbers and rigour increased (year 1 = 2021)

A notable structural change occurs in AUT24 where the Arduino UNO platform is swapped against a STM32 Nucleo microcontroller board. DCD component (FPGA) remained theory-heavy while the MCU component became more practical and project-based, with unnecessary confusing content being removed. In AUT25, this course content had been more heavily front-loaded into the first eight weeks, down from being uniformly distributed between the usual twelve. This adjustment provides students with a more intensive early learning phase, allowing the final four weeks to be dedicated to mini-projects and deep learning, following the problem-solving agenda of the advised subject. The mini- projects serve dual purposes: students can either complete the FPGA/DCD (Digital Circuit Design) and MCU projects to meet a competency threshold or engage in an additional workshop project aimed at achieving a mastery threshold which was reserved for the top 10% of the class who had to been assessed successfully on all computer labs and passed overall, including the viva with a score greater than 85%. As a basis for the workshop project, students could select from different sensor boards and integrate different functionalities including proximity/ranging sensing, sound sensing, human presence sensing, electrical (current) sensing, gas sensor, and environmental sensing (magnetic field), and build a project on those sensing capabilities. Changes shown in Figure 2 indicate the increasing component of generative learning, constructivism, and flipped-mode teaching over the years.

The restructured timeline not only supports differentiated learning outcomes but also gives students autonomy in how they demonstrate their understanding. By offering pathways to both competency and mastery, the course design in AUT25 reflects a mature and flexible educational model that values depth, application, and learner agency.

2.3 Evolution of the course structure

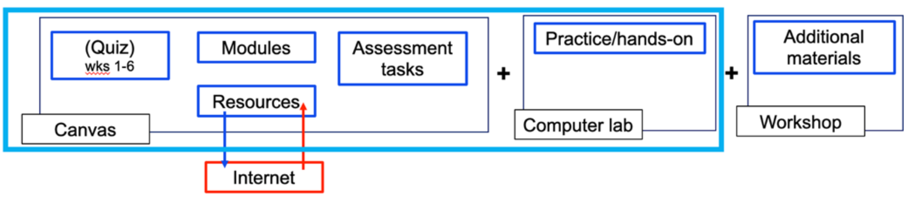


Figure 3. Materials to work with and how to learn for the subject - recommendations to students/process of learning. Work on Canvas, with provided materials, formed the basis of learning, so that student can start right away to work on their assessments; after that, part still unclear components can be fixed in the computer lab. If questions arise (an extension can be requested), and open points are addressed in the following weeks' workshop, which also provides additional materials.

To learn effectively for the subject EMS (Engineering Mechatronic Systems), Figure 3 outlines a structured approach that begins with understanding the available learning materials. These include quizzes from weeks 1 to 6, modules, assessment tasks, and additional resources such as workshops and hands-on practice in computer labs. All these materials are accessible via Canvas, and the internet serves as a supplementary tool for further exploration. Figure 3 emphasises the importance of engaging with both theoretical and practical components to build a comprehensive understanding of the subject.

Figure 3 also highlights the importance of developing a personal learning strategy. Emphasis is laid on self-learning and explorative approaches. Students, however, have never really learned how to do that. Hence, the tutors were instructed to assist in defining clear goals every week and to maintain a lab book to document their work to be able to deal with increased assessment tasks. From lab book, an engineering diary is later on extracted to track progress and reflect on learning outcomes (Fig. 3 in 'Practice/hands-on'). The practice of documenting not only helps in organizing thoughts but also prepares students for assessments by consolidating their understanding of key concepts and processes.

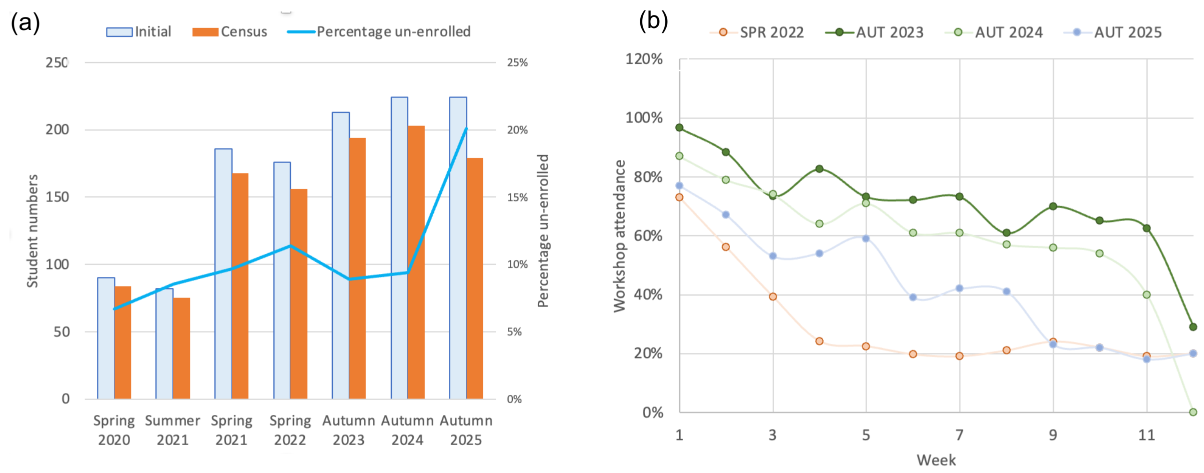


Figure 4. (a) Enrollment numbers initial and after census date, as well as percentage of unenrolled students. (b) workshop attendance over the years.

In the week before the assessment (Week N-1), the diagram in Fig. 3 recommends a three-step approach: first, quickly review quizzes to grasp basic terminology and content, which is the "what" of the subject. Second, study at home using the provided PDFs and videos to understand the "why", the underlying principles, and rationale. Third, engage in laboratory assessments to practice the "how", the application of knowledge in practical scenarios. During this phase, students are encouraged to ask questions and participate in online discussions via Canvas and ED, fostering a collaborative learning environment.

Finally, in the week of the assessment (Week N), the focus shifts to active participation. Students should attend workshops, collaborate with peers, and continue engaging in online discussions. The diagram stresses the importance of attending computer labs, where assessments take place, and learning through interaction with others. This phase is about applying what has been learned, receiving feedback, and refining understanding through real-time engagement. By following this structured timeline, students can approach EMS with confidence and clarity, ensuring a balanced and effective learning experience.

Figure 4 presents student enrollment numbers and engagement in EMS. Figure 4 (a) tracks enrollment patterns across seven sessions, showing both initial and post-census numbers alongside the percentage of students who un-enrolled. Initial enrollment increases steadily, and the percentage of un-enrolled students generally remains below 20%, with a spike in AUT25. This suggests that while interest in the course is consistent, retention may be affected by factors such as course structure or student readiness. Figure 4 (b) illustrates workshop attendance across four semesters, revealing a trend of increasing consistency and participation over time. AUT 2023 shows the most stable and high attendance, indicating successful adjustments in course delivery and student engagement strategies, which then is dropping. A note: For AUT25, the attendance after week eight becomes very low. Not all years have been monitored, only starting in 2022. Also, it should be noted that the cost-of-living crisis played a role, and intensified after 2022, which likely made students attend fewer than usual workshop sessions as they tend to work more to make ends meet.

2.4 Assessment outcomes

In the following, some key assessment outcomes are reported on. Figure 5(a) provides the mark distribution after 50% of computer labs were completed as a key benchmark of the difficulty of the subject (Lourdusamy and Magendiran, 2021), changing the average mark from 85.5% in 2020 to 63.7% in 2025. The trend over five semesters (SPR 2021 to AUT 2025) shows a decline in HDs from 75% in SPR 2021 to just 23% in AUT 2025. Meanwhile, fail rates (F) and low-performance categories (<25% and 0 marks) increase, particularly in AUT 2024 and AUT

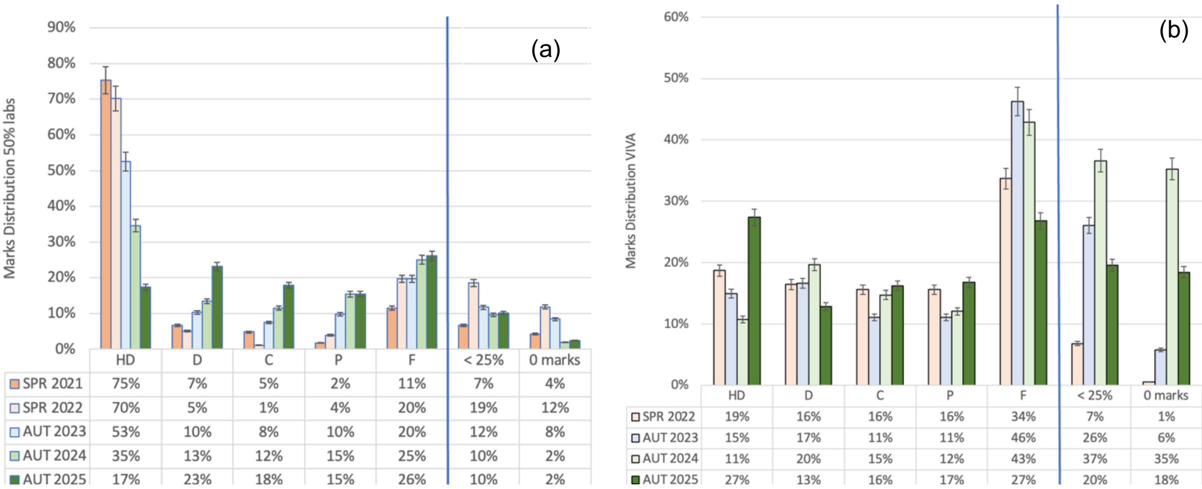


Figure 5. (a) Marks distribution after 50% of the labs, indicative of the lab performance at around census date (~week 5); and (b) marks distribution of a viva-voce, based on all lab assessments.

2025, where combined low scores exceed 30%. This suggests growing challenges in lab-based assessments, due to increased in-built complexity and lab exit viva assessments. The goal was to move the formerly exponential distribution to a more Gaussian distribution, which was eventually achieved in 2025. As an outcome, assessments were fairer, and it is assumed that learning outcomes have improved. Also, we observed over time a better preparedness of students, and for in-class learning, a guided class structure was helpful, consisting of work alone, group work, and in-class presentation. Figure 5(b) focuses on viva-voce performance across four sessions, occurring after the computer labs. Here, the distribution is more balanced, but Fail (F) rates remain high, especially in AUT 23/24, where 46% and 44% of students received less than 50% of the marks, and 6% and 35% received 0 marks. HD rates decrease for this assessment item from about 19% in 2022 to 11% in 2024 and then increase in 2025 to about 27%. The high proportion of students scoring below 50% across all sessions (2022-2025) indicates that oral assessments may be particularly challenging for students, possibly due to gaps in conceptual understanding or communication skills, but it's a good way of assessment in times of AI. Overall, the figure highlights a declining trend in high achievement and the increase in difficulty due to increased assessment items and much more rigorous assessments with the purpose of increasing learning outcomes. In 2025, the trend could be reversed, mainly due to making the subject more engaging in the beginning and simultaneously communicating with students that their presence is required to properly learn and get support for the subject.

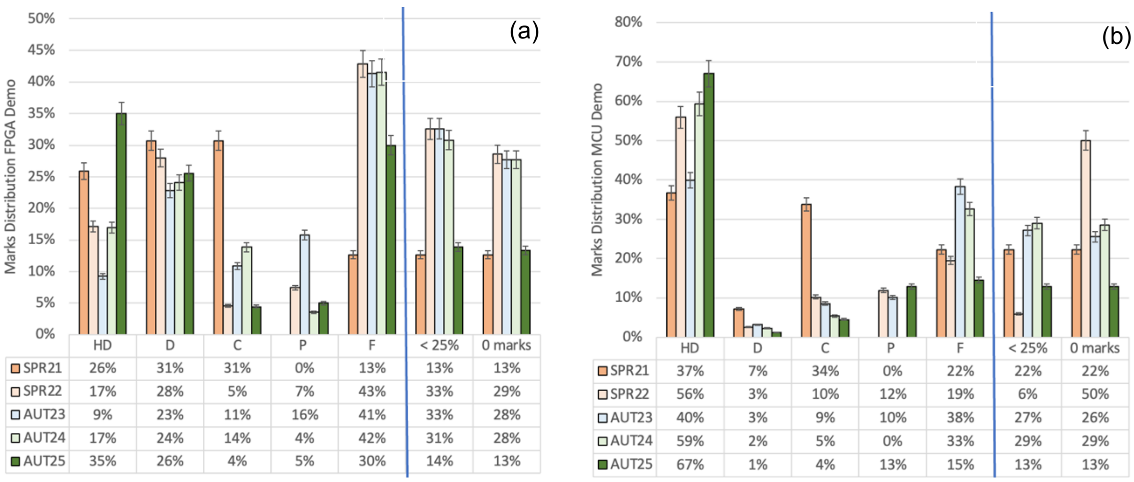
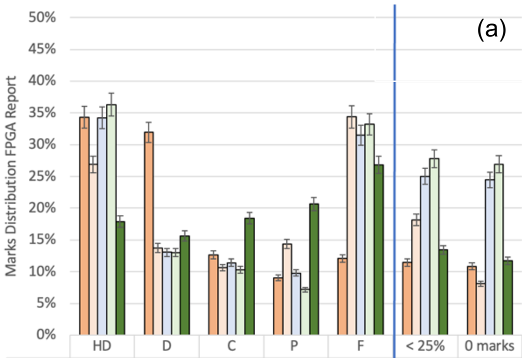
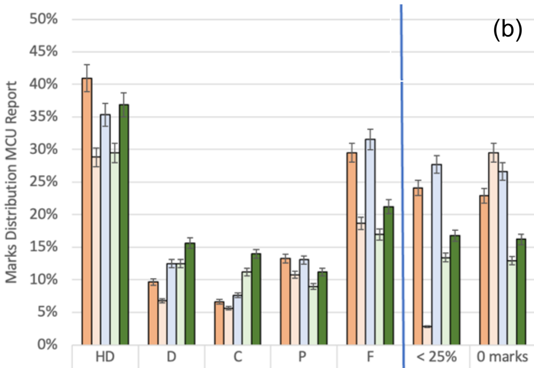


Figure 6. Marks distribution (a) after the FPGA (DCD) demo, and (b) after the MCU demo projects. Main difference consistently observed is the performance increase of students during the MCU project, which has significantly higher HD across all sessions monitored, with an increasing trend.

Figure 6 compares the marks distribution for FPGA (DCD) and MCU demos across five semesters, revealing distinct trends in student performance. In the FPGA Demo (Figure 6a), early semesters like SPR21 and SPR22 show a concentration of grades in the D and C range, with SPR21 having the highest D rate at 31%. However, AUT23 marks a significant drop in performance, with 33% of students scoring below 25% and 28% receiving 0 marks, indicating possible challenges in content delivery or assessment design. By AUT25, performance improves, with 35% of students achieving HD, though 30% still fail, suggesting a polarised outcome where some students excel while others struggle. In the MCU Demo (Figure 6b), SPR21 starts strong with 37% HDs, which is increasing over the session. However, over the years, a consistently high Fail rate was observed, which is opposed to the high HD number. Overall, the graphs suggest that while FPGA (DCD) assessments remain more challenging, MCU demos have seen notable gains in student achievement over time. Since the MCU assessments are toward the end of the session, many students decide not to participate as they have already achieved the 50% (pass) mark, as indicated by a competency threshold. Also, it was increasingly difficult to monitor individual students' performance, and while group work is seen as beneficial to the development of students to become engineers, the fundamentals cannot be properly assessed.



	HD	D	C	P	F	< 25%	0 marks
SPR21	34%	32%	13%	9%	12%	11%	11%
SPR22	27%	14%	11%	14%	34%	18%	8%
AUT23	34%	13%	11%	10%	32%	25%	24%
AUT24	36%	13%	10%	7%	33%	28%	27%
AUT25	18%	16%	18%	21%	27%	13%	12%



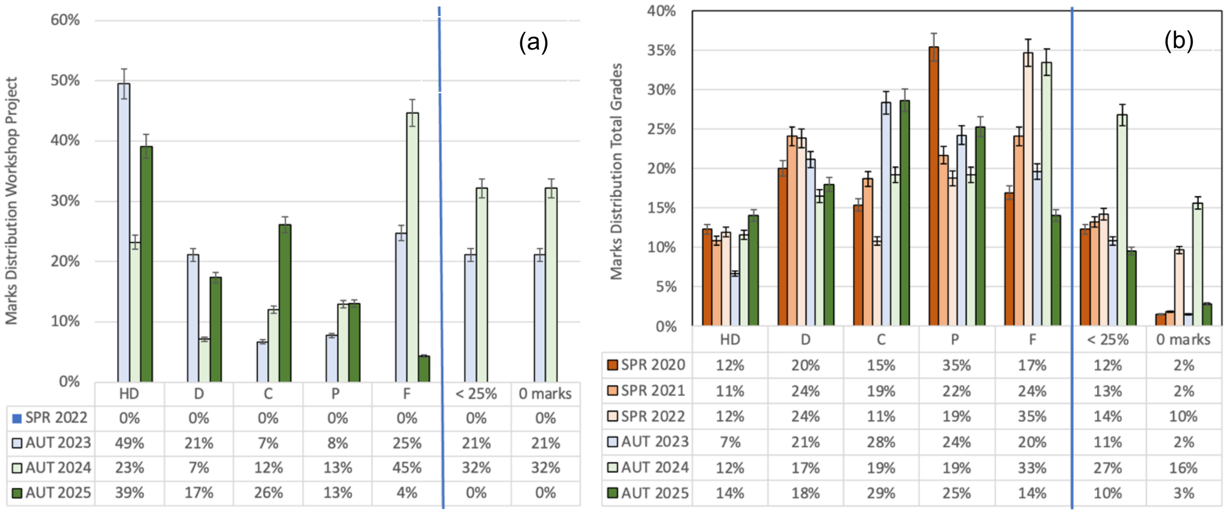
	HD	D	C	P	F	< 25%	0 marks
SPR21	41%	10%	7%	13%	30%	24%	23%
SPR22	29%	7%	6%	11%	19%	3%	30%
AUT23	35%	13%	8%	13%	32%	28%	27%
AUT24	29%	13%	11%	9%	17%	13%	13%
AUT25	37%	16%	14%	11%	21%	17%	16%

Figure 7. Mark's distribution of (a) FPGA Report and (b) MCU Report. The report was the most consistent element throughout the sessions and shows similar performance.

Figure 7 presents a comparative analysis of mark distribution for FPGA and MCU Reflection reports across five sessions, highlighting shifts in student performance and grading outcomes. In the FPGA report (Figure 7a), some sessions, such as SPR21 and AUT24, show relatively strong performance, with HD rates of 34% and 36% respectively. However, a slight decline is shown with in SPR22 and AUT25, where HDs drop to 27% and 18%, and marks concentrate more evenly across the D, C, and P bands. The proportion of students scoring below 25% increases throughout the sessions 2021-2024, before dropping again to the pre-2022 level in AUT2025, after all adjustments have been made, indicating a successful implementation of changes applied to the subject assessment structure. In the MCU report (Figure 7b), performance trends are more positive. AUT25 shows a strong recovery with 37% of students achieving HD, up from 29% in AUT24. The fail rate stabilises at 17% in AUT24 and AUT25, down from a peak of 30% in AUT23. The percentage of students scoring below 25% and receiving zero marks also declined in AUT25, suggesting improved student understanding or assessment design. Interestingly, the report was the most unchanged document throughout the years. While the tasks remained the same, students learned according to a template how to write engineering reports, how to avoid plagiarism, and how to properly write and submit a document that can be understood as a report with a deep reflection of the tasks, paired with peer review. So, while the tasks have been almost the same, the outcomes here were quite significant. However, while the MCU project and report seem to be confirmation of what students learned, it can also be assumed that the plagiarism rate is higher and marking of code, project outcome and report requires significant resources, which will likely not be able to be justified in the future.

Figure 8 illustrates student performance in the EMS course across several semesters, with a focus on workshop project outcomes and total grade distributions. When considering the recent pedagogical enhancements, namely generative learning, flipped mode learning, project-based studio learning, and keeping constructivism, the data reveal a meaningful shift in how students engage with and perform in the course. While the workshop project was only introduced as an additional mini project in 2023, Figure 8(a), shows a clear improvement in outcomes for AUT 2025, with a significant proportion of students achieving High Distinctions. The workshops' mere existence and the improved performance suggest that the introduction of project-based studio learning, with GL/ constructivist approaches and PBL, has had a positive impact on students' ability to master complex tasks. These methods encourage active engagement, peer collaboration, and iterative problem-solving, all of which are conducive to deeper learning. Generative learning strategies, such as teaching others, likely helped students consolidate their understanding, while the flipped classroom model provided more time for in-class application and feedback. Together, these approaches appear to have created a learning environment that supports high achievement in project work.

Figure 8(b) presents the total grade distribution across all course components. HD level students remain almost steady, with a slight increase in the 2025 cohort. The most noticeable change can be seen in the Fail (F) rate, which is decreasing by 2025.



	HD	D	C	P	F	< 25%	0 marks
SPR 2022	0%	0%	0%	0%	0%	0%	0%
AUT 2023	49%	21%	7%	8%	25%	21%	21%
AUT 2024	23%	7%	12%	13%	45%	32%	32%
AUT 2025	39%	17%	26%	13%	4%	0%	0%

	HD	D	C	P	F	< 25%	0 marks
SPR 2020	12%	20%	15%	35%	17%	12%	2%
SPR 2021	11%	24%	19%	22%	24%	13%	2%
SPR 2022	12%	24%	11%	19%	35%	14%	10%
AUT 2023	7%	21%	28%	24%	20%	11%	2%
AUT 2024	12%	17%	19%	19%	33%	27%	16%
AUT 2025	14%	18%	29%	25%	14%	10%	3%

Figure 8. Indicative grade distribution (percentages) for (a) after the workshop project (Mastering level), and (b) Final grade distribution. The results, especially in 2025, indicate that more students have been able to pass the subject, irrespective of its increasing difficulty through more assessments.

3 DISCUSSION

Modern engineering education is shifting from traditional lectures to student-centred, active learning that mirrors real-world problem-solving. In embedded systems and mechatronics, this shift is vital due to rapid advances in AI, edge computing, and IoT, all of which rely on microcontrollers and integrated sensors. These fields demand both theoretical knowledge (e.g., digital logic, control theory, signal processing) and hands-on skills in implementing and debugging hardware-software systems.

At the University of Technology Sydney, the core subject *Embedded Mechatronic Systems (EMS)* has undergone a major transformation over four years. Grounded in Generative Learning Theory (GLT), the course now uses a flipped classroom teaching (FLT) model combined with studio and project-based learning (PBL). GLT emphasizes deep understanding through active engagement, organizing, integrating, and elaborating on content (Fiorella & Mayer, 2016). In EMS, this means replacing passive lectures with pre-recorded content and using class time for generative tasks like circuit design, code walkthroughs, and system debugging. FLT increases learning time and efficiency, and increases significantly independent learning, which students can then apply in PBL.

The curriculum introduces students to physical computing through a staged approach, starting with digital logic and microcontroller basics, then progressing to signal processing using real-world devices like MEMS microphones, accelerometers, and stepper motors. Labs now use STM32 Nucleo microcontrollers instead of Arduino UNO, aligning with industry standards and providing experience in bare-metal programming. This change was made in consultation with industry partners in robotics, acoustics, and intelligent systems.

A key innovation is the integration of labs into a semester-long group project, replacing previously isolated exercises. This fosters collaboration and reflection through technical videos and structured reports, using GLT techniques like self-explanation and peer instruction (Chi et al., 1994; Crouch & Mazur, 2001). The flipped model has made computer labs central to the subject, supported by rigorous assessments and a clear, front-loaded structure.

While not all students achieve high distinctions due to increased difficulty, many do, indicating strong support for engaged learners.

Outcomes have been tracked over four years using both qualitative (reflections, tutor feedback) and quantitative (scores, surveys) data. The average marks across subject outcomes suggest an increase in subject difficulty and assessment quality from 2022 onwards. This is evidenced by a decline in average marks from 62.1% in 2020 and 61.2% in 2021, to 54.1% in 2022 and 55.8% in 2023, followed by a partial recovery to 66.2% in 2024 and 63.7% in 2025. These changes coincided with curriculum and assessment modifications that required greater student engagement. Student Feedback Survey (SFS) scores during this period averaged 3.00 ± 1.16 (n = 4; max = 4.00, min = 2.34), indicating a trend of reduced satisfaction, likely attributable to increased workload rather than lower academic performance. This effect appeared more pronounced among lower-achieving students, who are typically the focus of targeted teaching strategies aimed at improving progression from Fail to Pass, or from Pass to Credit.

This pattern highlights a characteristic feature of the Mechatronic Engineering student cohort at UTS, which appears to be bifurcated into a group of academically driven students (aiming for Distinction and High Distinction) and a larger group primarily focused on achieving a passing grade. While student appreciation of the subject content may also influence satisfaction, this variable was not assessed in the current analysis. Further, results show that hands-on, collaborative environments outperform passive models, especially during periods of online learning. Studio-style teaching, which mimics real-world workflows, has proven effective (Mitchell et al., 2017). An added workshop project on STM32 programming further developed industry-relevant skills and tested research problem-solving, which increased both satisfaction and learning outcomes. Projects selected by students included a smart home security system (human presence, proximity sensor), EchoPass- safe pedestrian crossing tool (MEMS microphone, human presence sensing), Smart Home System- room occupancy detection/light switch (2xMEMS microphone, human presence), Theremin (proximity sensor), and Smart Fire Rescue System (CO gas sensing, proximity sensor), and were paired actuation using buzzers, servo motors and or LED-lights. These projects exposed students to practical experience with different sensors, including microphones, and fundamental concepts such as determining a sampling rate, frequency, and amplitude, as well as modulation, for the first time. The metrics used here to measure increased learning outcomes are i) increasing the number of assessments, and ii) including the difficulty of assessments. While these are qualitative, objectively, it can be agreed that if these conditions are met, and the overall marks remain the same, the learning outcome of the cohort should be increased. To support diverse learners, two performance thresholds were introduced: a Competency Threshold for foundational skills and a Mastering Threshold for advanced achievement. These are embedded in rubrics to promote self-assessment and targeted growth. Sensor integration, especially MEMS devices, serves both technical and pedagogical roles, preparing students for future subjects like Vibration and Control and Environmental Noise. Their real-world relevance boosts motivation and strengthens the link between theory and practice, reinforced by ongoing industry collaboration.

In conclusion, EMS's pedagogical redesign has improved project outcomes and supported excellence among engaged students. While grade variability persists, it reflects the rigor of the course and the demands of constructivist learning. The focus remains on maintaining high standards and helping students develop the skills needed to succeed in this dynamic field.

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