28TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
2 – 4 SEPTEMBER 2026, UNIVERSITY OF BRISTOL, UNITED KINGDOM

STRATEGIC USE OF FORMATIVE ASSESSMENT IN NEURODIVERSE CLASSES WITHIN ENGINEERING

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ABSTRACT

The proportion of neurodiverse students in STEM subjects, especially engineering, is significant. Evidence from literature consistently shows higher rates of disadvantage in neurodiverse students' grades. Nonetheless, researchers found that neurodiverse students showed higher rates of creative problem-solving ability. The reasons behind lower performance are often attributed to time-management issues, task avoidance, implicit requirement ambiguity, executive functioning overload, and cognitive fatigue. These challenges represent a non-comprehensive list of day-to-day difficulties students face, but they cover some of the issues this study focuses on. Within engineering education, the strengths of neurodiverse students can play a significant role in achieving positive outcomes. The approach of this study involves functional formative assessments and structured gradual learning of skills to tackle some of the main stressors in neurodiverse students. The structure follows a progressive and practical learning framework to allow flexible, paced learning, and a set of formative assessments to provide practical feedback for an equivalent task in summative assessment. The addition of formative assessments marked a positive shift in mean grades and a normal distribution with reduced presence of low-range outliers. The introduction of in-person weekly tutorials in addition to the reinforced formative assessment resulted in further positive shifts in grades and learning outcome fulfilment. A survey of neurotypical and neurodiverse students showed positive engagement with both learning structure and assessment. The study shows how introducing a practical approach to learning and realistic trialling of assessment structure for students improved learning outcomes and relieved stress in neurodiverse students.

Keywords: Neurodiversity, formative assessment, Universal Design for Learning, inclusive pedagogy

1 INTRODUCTION

The representation of neurodiverse individuals in STEM fields is garnering increasing scholarly attention. Neurodiversity, a term encompassing Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), dyslexia, dyspraxia, and other neurological variations, is increasingly recognised as natural human cognitive diversity rather than a deficit to be corrected [1]. Hamilton and Petty [1] argue that neurodiversity challenges stigmatising accounts of neurodevelopmental differences, advocating for the creation of contexts in which neurodivergent individuals can thrive. Within the engineering students specifically, prevalence rates of neurodivergent conditions have been reported at levels exceeding those found in the general population [2]. This higher representation presents both opportunities and challenges for educators seeking to maximise learning outcomes for all students.

Despite notable strengths in creative problem-solving, pattern recognition, and systems thinking [3], neurodiverse students consistently demonstrate lower academic performance when measured through traditional assessment mechanisms [4]. The reasons for this disparity are multifactorial and well-documented in the literature. Chief among these is time management, task avoidance behaviours triggered by ambiguous or implicit task requirements, functioning overload when confronted with complex multi-step assessments, and cognitive fatigue resulting from sustained attention demands [5], [6]. Importantly, these difficulties often reflect a mismatch between assessment environments and cognitive profiles of neurodiverse learners, rather than an absence of understanding or capability.

The Universal Design for Learning (UDL) framework provides a pedagogical foundation for addressing these challenges [7]. UDL advocates for multiple means of engagement, representation, action and expression, creating learning environments that are accessible to the widest possible range of learners without the need for individual accommodations. Laurillard [8] frames teaching as a design science, proposing that pedagogical patterns should be systematically constructed to support learning through

technology and structured activities. Her framework emphasises the iterative alignment of learning objectives, activities, and assessment, a principle directly informing the intervention in this study.
The creative and iterative nature of engineering aligns well with cognitive strengths associated with neurodivergence. However, the assessment of engineering competencies frequently relies on summative assessments that demand sustained performance under time pressure, which disproportionately disadvantages neurodiverse students [9]. The gap between a student's capability and their ability to demonstrate that capability under assessment conditions represents a significant equity concern. This study addresses this gap by presenting an intervention based on the introduction of functional formative assessments and a structured, progressive learning framework within an engineering design module. Drawing on Wiliam's [10] conception of embedded formative assessment, the formative tasks were designed to be integral to the learning process rather than merely preparatory exercises. The progressive learning structure was designed to break complex design tasks into manageable stages, reducing executive functioning load and providing clear, explicit expectations at each step. The motivation for this study is twofold. Firstly, it seeks to quantify the benefit of additional formative assessments prior to summative evaluation in terms of improved learning outcome achievement. Secondly, it aims to explore the potential of such interventions to reduce stress levels among neurodiverse students, contributing to a more equitable learning experience. The study is situated within the discourse on inclusive pedagogy in engineering and draws on UDL as its theoretical framework.

2 LITERATURE REVIEW

The engineering student population has been identified as having elevated rates of neurodivergent conditions compared to the general student body. Studies by Wei et al. [2] reported that students with ASD were disproportionately represented in STEM, with engineering being among the most commonly chosen disciplines. Similarly, Sedgwick et al. [11] found that individuals with ADHD demonstrated a preference for applied, hands-on disciplines, which may explain higher enrolment in engineering. The cognitive profiles associated with conditions such as ASD and ADHD, including strong systematising abilities, visual-spatial reasoning, and divergent thinking, align with the demands of engineering problem-solving [3] . However, academic outcomes for these students frequently fall below those of their neurotypical peers. Römhild et al. [4] found that students with learning differences and ADHD achieved lower grade averages despite comparable intellectual ability. The discrepancy is frequently attributed not to lack of understanding but to assessment structures and learning environments that fail to account for the executive functioning of neurodiverse learners [5] . Hamilton and Petty [1] emphasise that the onus is too often placed on neurominority students to find alternative routes to meet neuro-normative expectations, highlighting the need for systemic change towards universal design approaches.

2.1 Challenges faced by neurodiverse learners

Executive functioning, encompassing skills such as planning, organisation, task initiation, working memory, and self-monitoring, represents a core area of difficulty for neurodiverse students [6]. In the context of engineering education, where assignments frequently require management of complex projects over extended periods, deficits in executive functioning can significantly impair performance. Cognitive fatigue, resulting from additional efforts required by neurodiverse students to process information and sustain attention in non-optimised environments compounds these difficulties [12].
Task avoidance is another well-documented phenomenon, particularly when assignments contain implicit or ambiguous requirements [13]. Neurodiverse students struggle to infer unstated expectations, leading to procrastination or disengagement. This effect is amplified in design courses where open-ended tasks, while pedagogically valuable, create uncertainty that triggers avoidance behaviours. Time management difficulties exacerbate these issues, as neurodiverse students often underestimate time required for complex tasks or struggle to allocate effort appropriately across competing demands [5].

2.2 Universal Design for Learning and Pedagogical Design

The UDL framework, discussed by Burgstahler et al [9] [7], provides three guiding principles for inclusive curriculum design: multiple means of engagement (the "why"), multiple means of representation (the "what"), and multiple means of action and expression (the "how" of learning). When applied to engineering education, UDL principles support the creation of assessment structures that are transparent, scaffolded, and offer multiple pathways to demonstrate competence [9]. Laurillard [8] extends this thinking by positioning the design of teaching and learning activities as an evidence-based, iterative process. Her framework for pedagogical design science emphasises the importance of aligning learning activities with desired outcomes through cycles of acquisition, inquiry, discussion, practice, and production. This approach resonates with the interventions in this study, where formative assessments were designed to provide structured practice opportunities that directly mirror the demands of the summative assessment, enabling students to iteratively develop competence.

2.3 Formative Assessment and Feedback Literacy

Formative assessment is a key mechanism through which inclusive pedagogical principles can be implemented. Wiliam [10] argues that formative assessment should be embedded within the fabric of teaching, functioning as a continuous process through which evidence of learning is elicited, interpreted, and used to make decisions. This embedded approach moves beyond the notion of formative assessment as a discrete event and positions it as an integral component of learning. The role of feedback within formative assessment is critical. Nicol [14] advocates for a shift from monologue to dialogue in feedback processes, arguing that effective feedback requires systems that promote student engagement with feedback rather than passive reception. Henderson et al. [15] identify the persistent feedback challenges, that it is frequently perceived by students as unclear, untimely, or disconnected from opportunities for application. The design of the formative assessments in this study sought to address these concerns by providing timely, task-aligned feedback within a structure that allows for immediate application.

The concept of feedback literacy has emerged as a key construct in understanding how students engage with assessments. Hoo et al. [16] demonstrate that self and peer assessment interventions can develop student feedback literacy, enabling learners to make productive use of feedback. Carless [17] situates feedback within a broader educational framework, emphasising that effective feedback processes are those that support students in becoming self-regulated learners. Winstone et al. [18] provide a comprehensive taxonomy of recipience processes, identifying the ways in which learners can exercise agency in their engagement with feedback. Their review highlights that proactive recipience, where students actively seek out, engage with, and implement feedback, is associated with improved learning outcomes. The integration of these perspectives on formative assessment and feedback literacy underpins the design of the intervention examined in this study. By providing structured formative tasks that mirror the summative assessment, students were afforded opportunities to develop both domain-specific competencies and the metacognitive skills necessary to self-regulate their learning.

3 METHODOLOGIES

The study was conducted within an undergraduate engineering design module delivered at a UK university. The module requires students to demonstrate competence in design methodology, computer-aided design, and communication of engineering solutions through technical documentation. Prior to the intervention, the module relied on a single summative assessment to evaluate student learning. The intervention introduced a series of formative assessments designed to provide students with structured opportunities to practice and receive feedback on tasks directly aligned with the summative assessment. Consistent with Wiliam's [10] embedded formative assessment approach, these tasks were integrated within the module's teaching structure rather than treated as standalone preparatory exercises. Each formative task mirrored a component of the final assessment, allowing students to develop familiarity with expectations, format, and standards. The progressive learning structure broke down the overall module competencies into staged learning objectives, with each stage building upon the previous one. This scaffolded approach, informed by Laurillard's [8] design science framework, was designed to reduce executive functioning load by providing explicit structure and clear milestones. The course was structured over 1 semester spanning 12 weeks, with students given 2 weeks for each formative assessment and 6 weeks (including holidays) for the summative assessment.

Feedback on formative tasks was designed to be specific, timely, and actionable, reflecting the principles outlined by Nicol [14] for effective feedback in higher education. The feedback aimed to support students in developing their feedback literacy [16], enabling them to make increasingly independent judgements about the quality of their own work. In subsequent academic years, in-person weekly tutorials were added to the module structure, providing students with additional contact time for guided practice, peer interaction, and individualised feedback. These tutorials complemented the formative assessments by offering real-time support and reducing the isolation that neurodiverse students may experience when working independently on complex design tasks. Formative assessments feedback was given as verbal feedback on a 1-to-1 basis in class, while summative feedback was given as marks with detailed mark scheme and individual written feedback.

3.1 Data Collection and Analysis

Assessment data was collected across multiple academic cohorts: a baseline year prior to the intervention, a year following the introduction of formative assessments, and a subsequent year incorporating both formative assessments and weekly tutorials. Grade distributions were analysed to identify shifts in mean performance, distribution shape, and presence of low-range outliers. A student survey will be administered in further iterations of the study to capture perceptions of the learning structure and assessment approach, with responses collected from both neurotypical and neurodiverse students. Statistical analysis focused on comparing grade distributions across cohorts and examining attendance patterns in formative versus summative assessments. Attendance data was collected to contextualise performance trends, particularly where differential participation in formative activities may have influenced aggregated results.

4 RESULTS

The introduction of formative assessments in the first year of the intervention was associated with a positive shift in the mean grade and a grade distribution that more closely approximated a normal curve with a reduced presence of low-range outliers. This suggests that the opportunity to practise and receive feedback prior to the summative assessment was associated with improved performance in the class, the assumption made was that each first-year cohort was of the same entry level ability as prior years. The subsequent introduction of in-person weekly tutorials alongside the formative assessments resulted in a further positive shift in grades and enhanced fulfilment of learning outcomes. The combination of structured formative practice and regular tutorial support appeared to provide a cumulative benefit, consistent with the scaffolded learning principles of Laurillard [8]. A further positive observation is that the effect remains even with an increased class size, which occurred in the second and third year of data. *Figure* shows the distribution percentage of students obtaining equivalent percentage grades. The data is split over three years of data collected, first without formative, second with a Summative assessment post Formative assessment (SpF) and the third set as SpF with in-person tutorials introduced.

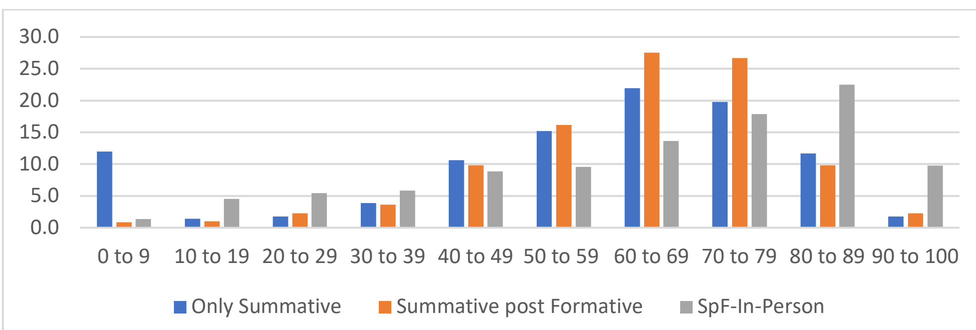

Figure 1. Grade distribution over three consecutive years where data is presented as percentage of class obtaining the grade range in order to normalise the data to account for class size changes

Analysis of attendance records revealed a notable discrepancy between formative and summative assessment participation: the formative assessment attracted only 40% of students in the SpF In-Person year, while the summative 99%. Nonetheless, the result shows that final year with the most available resources enhanced the student outcome regardless of consumed resources by the students. The stress survey will be performed in further iterations of the study to further understand the effects of the learning structure in the student population.

5 DISCUSSIONS

The need for unified yet accessible learning methods that serve both neurodiverse and neurotypical students in engineering education is a pressing concern in contemporary higher education [1]. The results of this study contribute to the growing evidence base supporting the integration of formative assessment and scaffolded learning structures as mechanisms for improving equity in engineering programmes. The positive shifts observed in earlier intervention years align with Wiliam's [10] arguments for the efficacy of embedded formative assessment in enhancing student performance. The reduction in low-range outliers is particularly noteworthy, as it suggests that the intervention may have its greatest impact on students who are most at risk of underperformance, a group likely to include a disproportionate number of neurodiverse learners [4]. The UDL-aligned design of the intervention, which provided structured practice opportunities without requiring students to disclose disability status or seek individual accommodations, represents an inclusive approach consistent with the compassionate pedagogy advocated by Hamilton and Petty[1].

The feedback processes embedded within the formative assessments reflect the dialogue-centred approach advocated by Nicol [14], moving beyond transmission-based models towards a system where feedback serves as a catalyst for student self-regulation. The development of feedback literacy, as conceptualised by Hoo et al. [16] and Carless [17], appears to have been supported through the iterative cycle of formative practice and feedback, though further empirical investigation is required to quantify this effect. The results from the most recent cohort, however, introduce important nuances. The system implemented with the addition of in-person sessions and low formative attendance did not show significant differences in grades in this instance. If the students who attended the formatives were already among the more engaged and higher-performing members of the cohort, the aggregate data may not capture the benefit experienced by those individuals. Conversely, the majority of students who did not attend the formative sessions were assessed solely through the summative, without the preparatory benefit, may still have benefitted by in-person tutorials, further supporting pedagogical theory.

This attendance differential raises important questions about the voluntary nature of formative assessment. While a low-stakes, non-compulsory approach is consistent with UDL principles of learner autonomy [9], it may inadvertently create a self-selection effect in which the students who most need the scaffolding are least likely to engage with it. Henderson et al. [15] identify this as a persistent challenge in higher education feedback systems: the students who stand to gain the most from feedback opportunities are often the least likely to access them. Future iterations of the intervention may benefit from exploring strategies to increase formative attendance, such as integrating formative tasks more tightly into the module schedule, providing incentives for participation, or embedding formative activities within tutorial sessions where attendance may be higher. The variability in results across cohorts also underscores the importance of longitudinal data collection in educational interventions. Single-year results, whether positive or negative, may reflect cohort-specific factors such as baseline preparedness, attendance culture, or external stressors. The overall trajectory of the intervention, viewed across multiple years, remains broadly positive and consistent with the theoretical framework underpinning its design. It is noted that a formal stress analysis has not yet been conducted, which limits the ability to directly quantify the intervention's impact on neurodiverse students' stress levels. The survey data provide preliminary qualitative evidence of reduced anxiety, but future work should incorporate validated stress measurement instruments to strengthen this aspect of the evaluation.

6 CONCLUSIONS

This study evaluated the introduction of functional formative assessments within a structured engineering design module, with the aim of reducing executive overload and clarifying expectations, particularly for neurodiverse students.

Earlier intervention years showed improved mean grades and fewer low-range outliers, with additional gains following the introduction of weekly in-person tutorials; however, the most recent cohort displayed lower engagement with formative sessions and uneven access to their benefits. While still maintaining satisfactory learning outcome levels.

Although later years overall indicate more positively achieved learning outcomes, low attendance at voluntary formative activities remains a challenge, warranting further research into stress, cognitive load, retention, formative engagement, and feedback literacy; nonetheless, the findings support structured formative assessment as an inclusive strategy in engineering design education.

In further iterations of the study a student survey to determine variations of stress between neurotypical and neurodiverse students will be conducted, the results will help determine the effects of formative assessments in stress reduction for summative assessments.

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