

DESIGNING HUMAN-CENTRED ENGINEERING AND DESIGN EDUCATION: ANALYSING STUDENT ENGAGEMENT PATTERNS TO ENHANCE LEARNING EXPERIENCES

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ABSTRACT

This paper applies human-centred design principles to engineering education by investigating the relationships between student academic performance, online engagement metrics, and assessment strategies. By analysing datasets spanning three academic years (2021-2023) across 57 modules and 1,157 students, the study provides actionable insights to enhance learning experiences and inform curriculum design as an educational product-service system. Key findings reveal that higher online engagement strongly correlates with better academic performance, with distinct patterns emerging across levels of study and assessment types. Postgraduate students achieve higher marks with lower engagement levels, suggesting more efficient learning strategies that could benefit undergraduates through structured mentoring. Mixed assessment approaches generate highest engagement but lowest marks, indicating potential challenges in balancing diverse requirements. The findings demonstrate how data analytics can inform the design of responsive educational experiences that adapt to diverse student needs and engagement patterns—a core principle of human-centred design that students can directly experience through their learning journey.

Keywords: Human-centred education design, product-service systems, learning analytics, assessment strategies

1 INTRODUCTION

Data analytics has gained significant traction in higher education, offering insights that can enhance teaching practice and improve student outcomes [1, 2]. The design of educational experiences shares many parallels with product-service systems design. Both require a deep understanding of user needs, patterns of engagement, and the factors that contribute to satisfaction and success. As engineering and design education evolves to incorporate more digital components, it increasingly resembles a product-service system where traditional teaching (service) is blended with digital platforms and resources (products). Understanding how students interact with these educational systems is essential for designing more human-centred learning experiences that respond to diverse needs and preferences. This approach aligns with the broader shift towards human-centred design, where understanding user behaviour is fundamental to creating successful products and services.

Recent studies have established links between engagement and academic achievement. Newman-Ford *et al* [3] carried out a large-scale study and demonstrated a significant relationship between attendance and attainment, while Leino *et al* [4] showed that online engagement can be just as important a predictor for academic success as attendance. Similarly, You [5] found that the number of times students accessed course content and the regularity of their online learning environment logins were significant predictors of final grades. However, Conijn *et al* [6] noted that results vary considerably across courses, suggesting a need for targeted approaches for different course types.

This paper examines the relationship between student engagement metrics and performance specifically on engineering and design modules by addressing the following questions:

1. What differences exist between online engagement activities for different levels of study?
2. How does student performance vary when comparing modules with different numbers and types of assessments?

3. How does online engagement differ between students on different module attempts and performance levels?

2 METHODOLOGIES

2.1 Data Sources and Analysis

Three main types of datasets were provided relating to student engagement and attainment for three academic years (2021-2023) of four BEng and integrated MEng engineering courses at a UK university with specialisms in mechanical, aerospace, automotive, electrical and electronic engineering ranging from foundation/preparation year (level 0, also called level 3) up to master's degree (level 7). The three datasets were anonymised prior to analysis and these datasets included: student outcomes data, module assessment details, and student online engagement data from Blackboard (the institution's virtual learning environment, or VLE). The online engagement metrics included course accesses, time spent in course, interaction counts, and submission counts across 10,453 module records across 57 modules for 1157 students.

After pre-processing and clean-up, a range of statistical approaches were employed. Exploratory data analysis (EDA) using scatter plots, histograms, and box plots explored distributions and relationships between variables. Spearman's correlation coefficient was used to explore the correlation between engagement metrics and grade outcomes. The Kruskal-Wallis test was used for comparing groups since the data was not normally distributed, with pairwise Wilcoxon rank sum post-hoc tests determining which specific groups had different medians.

3 RESULTS AND ANALYSIS

3.1 Relationship Between Online Engagement and Academic Performance

Initial exploratory data analysis revealed a consistent pattern across all engagement metrics, where higher activity strongly correlated with higher marks. Course accesses ($\rho = 0.388$), and time in course ($\rho = 0.353$) emerged as the metrics most strongly correlated with overall marks and were selected as the primary metrics for subsequent analyses (Figure 1).

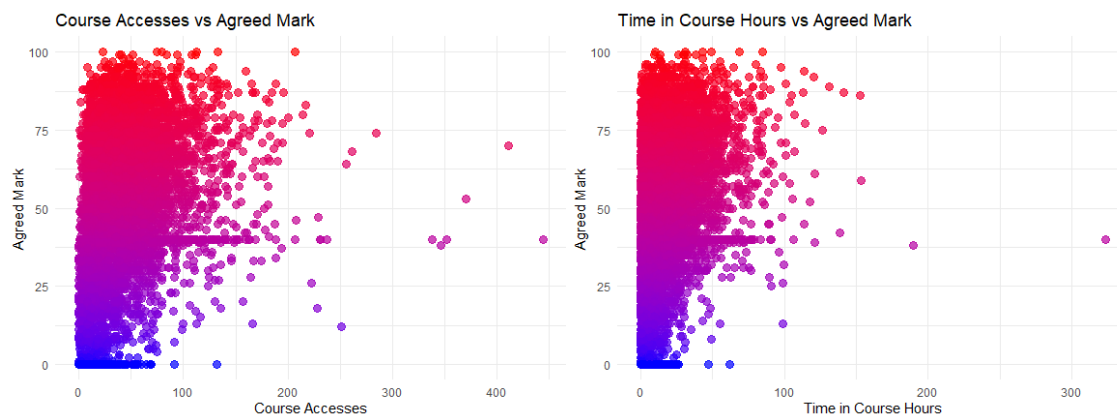


Figure 1. Scatter plots showing the agreed marks plotted against the most strongly correlated online engagement metrics (course accesses and course hours)

3.2 Differences Across Levels of Study

The analysis revealed statistically significant differences in both module marks and online engagement across different levels of study ($p < 0.001$). A notable trend emerged where Level 7 (postgraduate) marks were significantly higher than other levels, while their online engagement levels were significantly lower as shown in Figure 2.

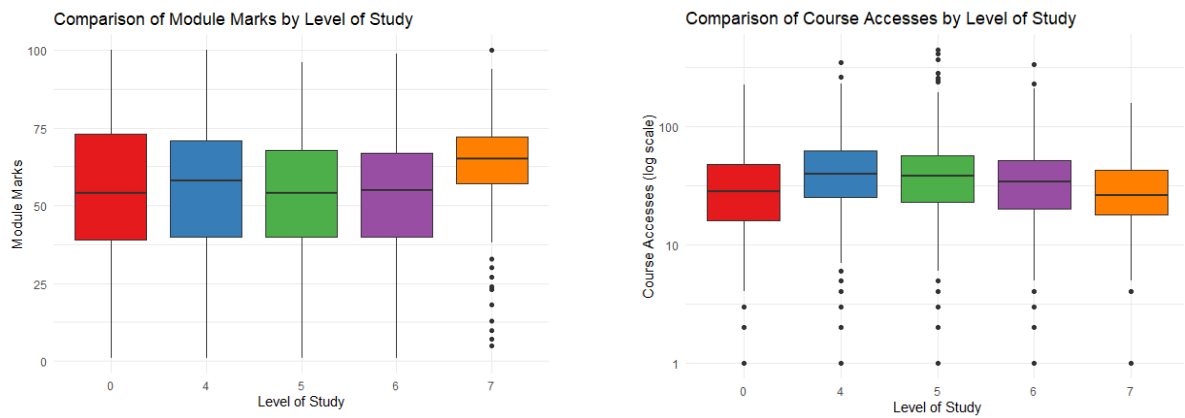


Figure 2. Comparison of marks and course accesses for the various levels of study with Level 7 (postgraduate) marks being significantly higher than other levels, while their online engagement levels were significantly lower ($p < 0.001$)

This suggests that postgraduate students may have developed more efficient study habits and a deeper understanding of the subject matter, allowing them to achieve higher marks with less need for frequent online engagement. This efficiency may stem from prior knowledge of fundamental concepts, further experience with self-directed learning, enhanced metacognitive skills, and greater motivation from career relevance.

3.3 Impact of Assessment Strategies

Significant differences were found between student performance and engagement when comparing both the number and types of assessments. The general trend indicated that modules with more assessments had higher overall marks and higher levels of online engagement ($p < 0.001$) as shown in Figure 3.

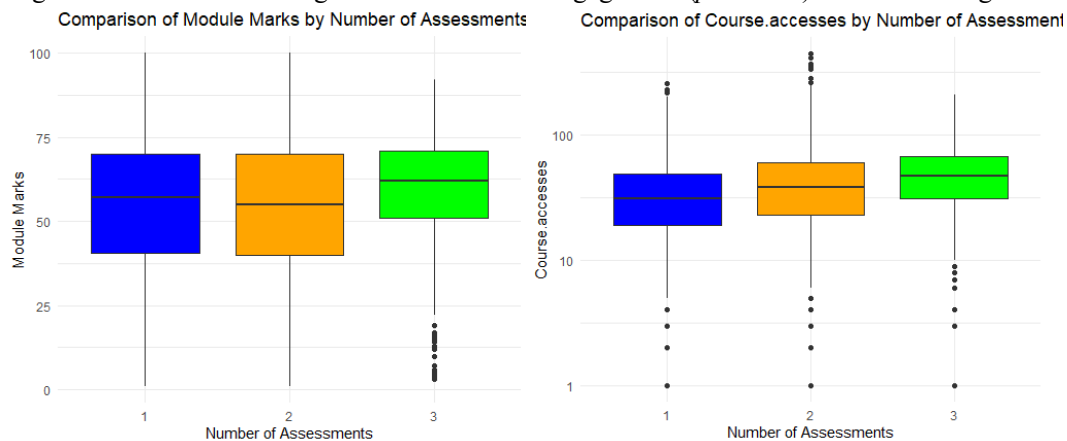


Figure 3. Box plots showing a comparison between how marks and course accesses were distributed across the number of assessment tasks

When examining assessment types, modules with coursework-only assessment had the highest marks but lower online engagement compared to modules with mixed assessment approaches (Figure 4). Interestingly, modules with mixed assessment had the highest engagement levels but the lowest overall marks. This seems counterintuitive and suggests that students may struggle with balancing diverse assessment requirements, potentially leading to a division of focus and less depth in each assessment area. Time management challenges and assessment anxiety may also contribute to this pattern, with students accessing resources frequently but perhaps less strategically than in coursework-only modules.

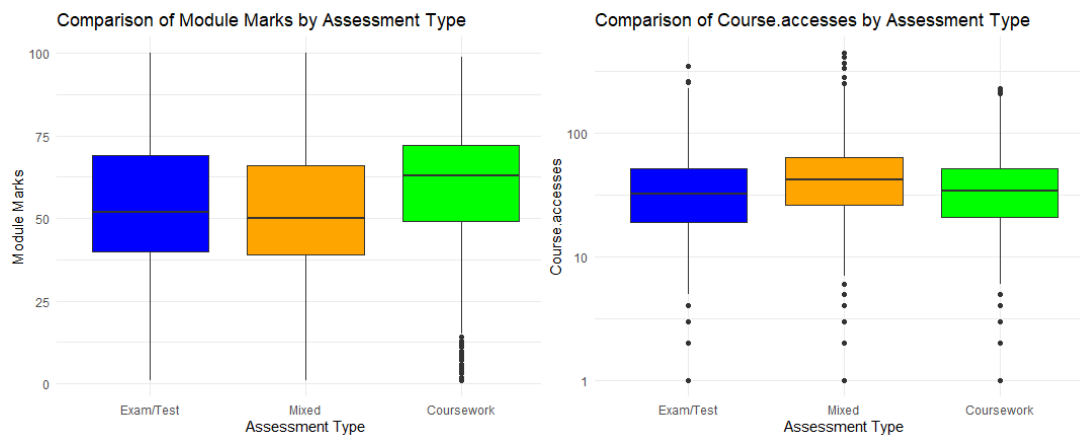


Figure 4. Student performance and engagement by assessment type

This seems to suggest that while more frequent assessments may encourage regular engagement with online resources, potentially leading to improved learning outcomes, the type of assessment also plays a crucial role in how students interact with learning materials.

3.4 Module Attempt Numbers and Performance Bands

Students on their third attempt at a module showed significantly lower engagement than those on their first or second attempts ($p < 0.001$). This pattern (Figure 5) suggests that students retaking modules may experience reduced motivation or confidence, leading to disengagement from online resources.

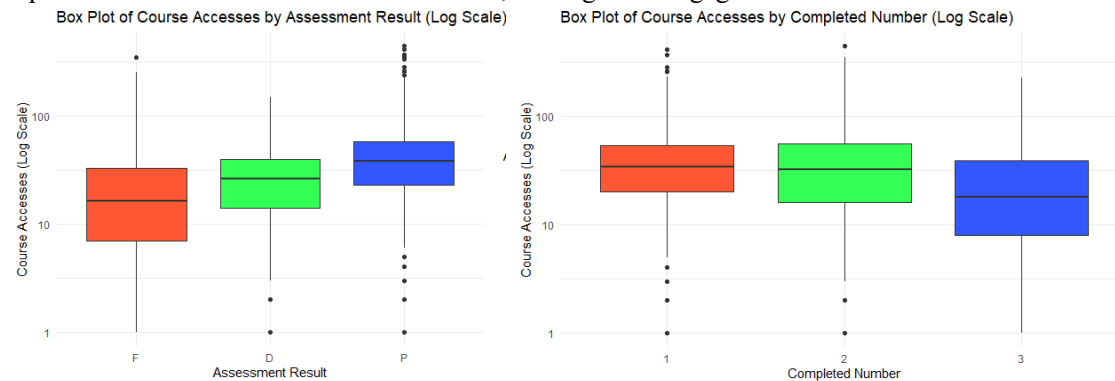


Figure 5. Comparison between the online engagement levels of students who fail (F), are referred/deferred (D) and who passed (P) – left, and for students on their first (1), second (2) and 3rd and final attempt (3) – right

When categorising students into performance bands (low: $< 40\%$, middle: $40-59\%$, high: $\geq 60\%$), significant differences in online engagement were observed ($p < 0.001$). Students in the high-performance band demonstrated substantially higher engagement levels than those in the middle or low bands (Figure 6). Based on the analysis of these engagement patterns across performance bands, we have established some recommended minimum thresholds for online activity that correlate with successful outcomes in engineering modules (Table 1). These engagement benchmarks have now been implemented as transparent guidance for students within course documentation and the VLE, serving as achievable targets that encourage productive learning behaviours while allowing instructors to identify and support at-risk students who fall significantly below these thresholds.



Figure 6. Comparison for course accesses and time in course for various grade bands (top) and comparison between the marks and online engagement (bottom)

Table 1. Recommended minimum levels of online engagement

Performance level	Recommended course accesses	Recommended time in course (hours)
Pass (40-59%)	26	9
Higher ($\geq 60\%$)	36	12

4 IMPLICATIONS FOR HUMAN-CENTRED DESIGN EDUCATION

The approach and findings of this study have significant implications for human-centred design education in engineering and design. They demonstrate the importance of understanding user patterns and behaviours in designing effective systems—a core principle of human-centred design that students can directly experience through their own learning journey. When students observe how their educational experience is being designed and refined based on engagement data, they witness human-centred design principles in action. The varying engagement patterns across different assessment types and levels of study highlight the need for product-service systems to adapt to different user needs and contexts. This mirrors the challenges students will face when designing products and services for diverse users with varying levels of expertise and engagement. By experiencing how educational offerings can be tailored to different needs, students gain first-hand experience with the benefits of human-centred approaches. The integration of data analytics into educational design also models how educators can apply the same human-centred principles we teach, incorporating user feedback and behavioural data to enhance service delivery—a key concept in modern product-service systems.

The findings also suggest opportunities to involve students as co-designers of their learning experiences, sharing insights from engagement data with them and collaboratively developing strategies to enhance their learning. This collaborative approach mirrors modern product-service system development practices where users are increasingly involved as co-creators rather than passive consumers.

5 RECOMMENDATIONS FOR PRACTICE

Breaking down assessment into smaller, more frequent components appears beneficial for engagement and performance. However, the observation that coursework-only modules had high marks despite lower engagement suggests these modules may facilitate deeper, project-based learning. The balance of assessment types in mixed-assessment modules should be carefully considered, as students may struggle to divide their efforts effectively. The significant drop in online engagement for students on their third attempt highlights a need for targeted interventions, such as structured re-engagement plans with specific online activity targets, regular check-ins, peer mentoring, and modified resources emphasising different learning approaches. Level 7 students' ability to achieve higher marks with lower engagement suggests they have developed more effective learning strategies. One suggestion here is to implement mentoring programmes where postgraduate students share study habits with undergraduates and develop guidelines for efficient online engagement based on successful postgraduate practices.

These findings, while valuable, are specific to one UK engineering department and may vary in different contexts. Online engagement metrics also capture only one dimension of learning behaviour. Future work should also include qualitative data to understand student motivations and test these findings across diverse educational settings.

6 CONCLUSIONS

This study demonstrates how applying data analytics to understand student engagement patterns can inform the design of more human-centred educational experiences in engineering and design. The findings confirm that higher levels of online engagement are consistently associated with better academic performance, but with important variations across different student groups. These differences highlight the importance of designing contextualised approaches that respond to diverse user needs—a core principle of human-centred design.

Approaching education as a product-service system can enable more responsive learning experiences. The identified engagement thresholds have provided us with practical guidance for nudging students towards productive behaviours, mirroring how product-service systems are designed to encourage specific user interactions.

This human-centred approach to educational design can serve as a model for how students should approach their own design work, reinforcing the importance of understanding user behaviour and designing responsive systems that adapt to diverse needs. The methods employed offer a framework for similar human-centred analyses in other educational contexts, contributing to the broader application of user-centred design principles in higher education.

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