

A Theory-driven LMS-based Intervention for Enhancing Student Motivation, Cognitive Engagement and Performance in Engineering Education

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Abstract—This study examines a theory-driven Learning Management System (LMS) intervention designed to address motivational, cognitive, and social engagement challenges in engineering education. The intervention was grounded in Self-Determination Theory (SDT), Cognitive Load Theory (CLT), and the Community of Inquiry (CoI) framework, operationalised through segmented video lectures, quizzes with immediate feedback, flexible self-paced access, and collaborative forums. Two cohorts participated: 112 undergraduate students in a fully online course during the COVID-19 pandemic and 85 diploma students in a post-pandemic hybrid course. A mixed-methods approach analysed grade distributions, course outcome attainment, and longitudinal motivation surveys. Both cohorts showed significant and practically meaningful improvements in academic performance following the intervention, with grade distributions shifting substantially toward higher bands ($\chi^2(3) = 24.56$ and 17.89 ; both $p < 0.001$; medium effect sizes). Course outcome attainment improved by up to 28% for undergraduates and 25% for diploma students, with the strongest gains in outcomes requiring applied problem-solving and foundational knowledge integration. Student motivation and effort increased consistently between Week 2 and Week 10, corroborating the quantitative findings. These results demonstrate that systematically aligning LMS features with established learning theories produces measurable improvements in student performance, engagement, and course outcome attainment in engineering education, offering transferable design principles for educators across digital learning platforms.

Keywords—mobile learning, learning management system, engineering education, cognitive engagement, student motivation, academic performance

I. INTRODUCTION

Engineering education is often described as highly abstract, driven by advanced mathematics and a focus on conceptual reasoning. While these traits are important for the development of technical expertise, they also inhibit student learning and engagement. Research has consistently indicated that engineering students have difficulty making sense of abstract theories and applying them to practical problem-solving, which is a factor contributing to student attrition rates being higher than in other disciplines [1, 2]. The shift to emergency remote learning during the COVID-19 pandemic compounded these challenges, with engineering programs worldwide reporting increased perceptions of academic overload arising from the combination of dense curricula and unstructured digital

delivery [3]. The traditional teaching method of lectures is an effective and efficient way to present content to students; however, lectures can also limit the opportunities for active engagement and critical thinking, which are essential for engaging with complex content in engineering [4]. This ongoing challenge highlights the need for pedagogical innovation that challenges the traditional model of transmissive teaching in favor of one that promotes motivation, cognitive engagement and deeper comprehension.

Despite a growing body of research on online and blended engineering education, a critical empirical gap persists there is a lack of integrative studies that simultaneously deploy motivational, cognitive, and social learning theories within a single Learning Management System (LMS)-based instructional design to address the interconnected challenges engineering students face. While individual theories such as Self-Determination Theory (SDT), Cognitive Load Theory (CLT), and the Community of Inquiry (CoI) framework have each been applied in digital learning contexts, their combined operationalization within a unified LMS framework for engineering education remains largely unexplored [5, 6]. Unlike prior studies that apply a single theoretical lens or loosely couple frameworks without examining their mechanistic interaction, this study systematically aligns all three theories at the level of individual LMS features, tests this alignment empirically across two distinct delivery contexts, and derives design principles grounded in observed outcomes. The theoretical contribution of this study lies in demonstrating how SDT, CLT, and CoI interact and mutually reinforce one another within a structured LMS environment. The practical contribution lies in providing actionable LMS design principles for engineering educators seeking to improve motivation, reduce cognitive overload, and foster collaborative learning simultaneously.

This study investigates the following research questions: (RQ1) How do the LMS-based instructional features designed systematically align with Self-Determination Theory, Cognitive Load Theory, and Community of Inquiry? (RQ2) How does a theory-based LMS intervention affect student motivation, engagement, and academic performance in engineering courses? (RQ3) What is the difference in the effectiveness of the intervention in fully online vs. hybrid learning contexts? We expect that based on the theories, the LMS intervention with segmented videos, timely feedback, access to content at their own pace,

and discussion forums by placing the students in each of the three dimensions of learning will yield better performance outcomes.

II. LITERATURE REVIEW

The global transition to online and blended learning in the context of the COVID-19 pandemic compounded these issues. Digital platforms were able to facilitate continuity in learning but simultaneously revealed deficiencies in their design and support for student learning. For example, engineering courses that relied on real-time lectures or unstructured content often resulted in students feeling isolated, left to independently make connections between theory and application [7], learning management platforms such as Moodle, Blackboard, Google Classroom, OpenLearning, and even Teams and Zoom allowed for the redesign of instruction for facilitated engagement, accessibility and personalization [8]. However, research has shown that how effective teaching is done using LMS is informed not by what tools are available, but by the theory that is used to inform the implementation of using these LMS tools to impact student learning. Courses designed poorly using LMS can add to the cognitive burden of students, decrease motivation, and even reduce meaningful connection with peers and instructors [9].

is a framework prioritizing cognitive, social, and teaching presence which is essential for creating meaningful learning experiences, especially at the online and hybrid learning environments [15, 16]. The importance of this social dimension is particularly acute in engineering: research conducted during the COVID-19 pandemic found that the loss of in-person interaction significantly eroded first-year engineering students' sense of belonging, with peer connection and faculty interaction emerging as the primary protective factors against disengagement [17]. Each has a robust empirical basis, though, as frameworks, they do not often come together in a systematic way to inform LMS-based engineering learning and education. Fig. 1 summarizes the conceptual model of these theories on LMS-based instructional features.

Although the number of researchers engaged in online learning has increased, there is still a lack of integrative research that incorporates SDT, CLT, and CoI within multi-theoretical frameworks to inform engineering practice and instruction. Engineering education is contextually challenging, cognitively and motivationally demanding, especially when developing mastery of abstract mathematical concepts and applying theoretical learning within practice, that would benefit from this joint theoretical effort. Initiating considerations related to an SDT, CLT, and CoI combined theoretical lens; broader investigations into essential practices within engineering or STEM education demonstrate that SDT can help explain improvements in motivation and engagement [18], CLT assists with multimedia and assessment design to reduce cognitive load [19], and CoI is used to create belonging and collaborative learning in hybrid courses [20]. However, the literature is less clear as to how these three frameworks might interact in the same LMS framework, which could be useful when addressing the competing demands faced by students enrolled in engineering courses. Crucially, these three frameworks are not merely complementary but interact mechanistically: SDT's need for autonomy is supported when CLT's reduction of extraneous load removes cognitive barriers to self-regulation; competence is built when CLT's germane processing is scaffolded through CoI's cognitive presence; and relatedness (SDT) is cultivated through CoI's social and teaching presence, which simultaneously reduces the isolating effect of high intrinsic load in engineering content. This triadic interaction has not been empirically tested as a unified LMS design framework in engineering education, which constitutes the central theoretical gap this study addresses.

To address this problem, the present study examines a theory-based LMS intervention in two engineering courses that had a clear alignment of the instructional component with SDT, CLT, and CoI. The intervention followed (1) segmenting the lecture videos, (2) quizzes with immediate feedback, (3) pacing the course, and (4) collaborating via a forum so that the intervention reduced cognitive load while supporting motivation, social presence, and teaching presence. The aim was to (1) create LMS-based instructional features rooted in SDT, CLT, and CoI, (2) measure the instructional features' effectiveness for enhancing motivation, engagement, and performance, and (3) combine the conceptual model to gain more insight into the results and

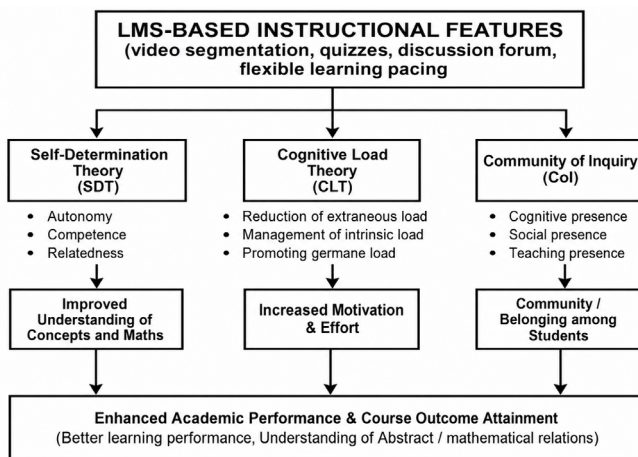


Fig. 1. Conceptual model of LMS-based mobile learning intervention in engineering education.

In response to these difficulties, a recent area of research has suggested linking motivational, cognitive, and social learning theories to the design of LMSs to foster student learning [5, 6]. Self-Determination Theory (SDT) is an exemplary framework for organizational structures where autonomy, competence, and relatedness enhance intrinsic motivation and therefore continuity [10, 11]. Within engineering education specifically, motivational constructs including self-efficacy and task-value beliefs have been shown to predict achievement in foundational courses beyond the effects of prior knowledge alone, underscoring the importance of designing learning environments that actively support students' motivational needs [12]. Cognitive Load Theory (CLT) is another framework outlining how instructional structure can deal with the limitations of working memory through extraneous load reduction, intrinsic load management, and germane processing promotion [13, 14]. Finally, the Community of Inquiry (CoI)

improve best practices for LMS-based engineering education.

While several theoretical frameworks have been applied to motivational and instructional design in online learning—including Keller’s ARCS model [21], Bloom’s Revised Taxonomy [22], and the Technology Acceptance Model (TAM)/UTAUT [23]—each address only one dimension of the interconnected challenges facing engineering learners. The ARCS model offers useful prescriptions for capturing and sustaining attention but focuses primarily on instructional design strategies rather than the psychological mechanisms that generate sustained intrinsic motivation; empirical comparisons have found that ARCS constructs do not directly predict motivation to use online learning systems, whereas SDT constructs, particularly relatedness and competence [24]. Bloom’s Revised Taxonomy provides a valuable classification of cognitive learning objectives and has been integrated with CLT to align assessment design with cognitive complexity [25], yet it describes what learners should achieve rather than why they engage or how working memory constraints shape that engagement during live instruction. TAM and UTAUT predict behavioural intention to use technology through perceived usefulness and effort expectancy [23, 26], but they are largely silent on the quality of motivation or the social and cognitive conditions that make technology use educationally productive; researchers have explicitly argued that TAM-based models must be supplemented with motivational constructs such as SDT to capture intrinsic drivers of LMS engagement [27, 28].

SDT, CLT, and CoI were selected in combination precisely because they address the three interlocking failure modes specific to engineering education conducted via LMS. First, engineering students learning through digital platforms frequently experience motivational erosion—the loss of intrinsic drive when autonomy, competence, and relatedness are not supported—which SDT is uniquely equipped to diagnose and address through concrete environmental prescriptions [29, 30]. Second, engineering content is characterized by high intrinsic cognitive load arising from abstract mathematical relationships and dense technical concepts; CLT provides a principled, empirically validated account of how instructional design, specifically segmentation, sequencing, and feedback can manage working memory constraints to reduce extraneous load and promote schema formation [13, 31, 32]. Third, online and hybrid engineering courses strip away the incidental social interaction of the physical classroom, undermining the collaborative meaning-making that complex problem-solving requires; CoI provides the structural vocabulary—cognitive, social, and teaching presence—to diagnose and remediate this social deficit through deliberate LMS design [16, 20]. Critically, these three frameworks interact mechanistically rather than simply co-existing: SDT’s need for autonomy is most sustainably satisfied when CLT’s extraneous load is reduced (freeing working memory for self-directed exploration); SDT’s need for competence is built through CLT’s germane processing as scaffolded by CoI’s cognitive presence; and SDT’s need for relatedness is cultivated through CoI’s social and teaching presence. This triadic interaction cannot be captured by any single-theory approach,

nor by frameworks such as TAM/UTAUT which do not specify pedagogical mechanisms, or ARCS which does not account for cognitive constraints or social learning dynamics. The combined framework is therefore both theoretically necessary and practically actionable at the level of individual LMS feature design.

III. MATERIALS AND METHODS

A. Study Context and Participants

The study took place at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) across two academic semesters that provided two markedly different learning contexts. The first set of data was collected during the 2019/2020 academic year, when the onset of the COVID-19 pandemic resulted in a sudden transition for all teaching and learning to a fully online context. During this semester, the course BTE3233 Communication System Design, a third-year undergraduate course, was conducted with a group of 74 students. The necessity to move learning to an online context necessitated the implementation of digital platforms with the Learning Management System (LMS) serving as the primary medium for both content delivery, assessment and interaction. This context offered a unique opportunity to explore how LMS were designed to enhance the challenges of emergency remote teaching, in an environment that depended on abstract concepts and modelling in mathematics.

The second cohort was from the 2022/2023 academic year when teaching returned to a hybrid mode consisting of in-person and online activities. In this context, the DRM1513 Electrical & Electronics Technology course was chosen with 50 first-year diploma students. These students were not in the same stage of their academic journey as the undergraduate cohort and were still building their basic engineering skills. The hybrid approach included the use of LMS elements in the online activities, as well as the in-class activity, which provided more extensive testing of the intervention’s use. By incorporating both undergraduate and diploma students in the study, it offered a way to test outcomes of the intervention across levels of academic maturity, as well as demonstrate the differences of emergency remote teaching, and working with hybrid learning pedagogy.

Together, these two contexts served as a natural experiment in the evaluation of LMS-based intervention. The undergraduate course illustrated students confronting higher-level discipline knowledge under crisis conditions, meanwhile the diploma course reflected the adaptation of LMS design in a more stable and blended environment. Participants’ diverse backgrounds enhanced the findings’ generalizability and provided understandings of the potential to use theoretical frameworks to inform LMS design at different access points within the continuum of engineering education.

B. Conceptual Model and Intervention Design

The intervention utilized a unified conceptual model, informed by three complementary theoretical models: Self-Determination Theory (SDT), Cognitive Load Theory (CLT), and the Community of Inquiry (CoI) framework, as shown in Fig. 1. These theories conceptualized LMS features

not as individual tools, but intentional pedagogical strategies with the intention of addressing motivation, cognitive processing, and social interaction, at the same time. This model asserted that if LMS features can be utilized, which aligned with these theoretical constructs, they could improve students' learning experiences and have observable value in enhancing performance and engagement.

This model demonstrates how the design features of the LMS-segmented videos, quizzes, flexible access, forums, and sequencing-support theoretical mechanisms from SDT, CLT, and CoI, which in turn promote motivation, decrease cognitive load, and support social/teaching presence, all of which promote increased engagement, understand complex concepts, and ultimately, improve academic performance.

In work with this model, a number of LMS features were incorporated into each of the courses. The lecture content was reformatted into short, segmented video clips just under 10 minutes for every one hour of lecture, to help reduce extraneous cognitive load and support students working memory (CLT). Quizzes with immediate feedback were

included at regular intervals of the course, not only to maintain students' competence (SDT) and cognitive presence (CoI). Students were provided some autonomy or version of pace, in most aspects of the course, which is a platform for supporting self-regulated learning (SDT). Discussion forums and group assignments were also used to promote collaboration and peer support, which helps support relatedness (SDT) and social presence (CoI). Finally, instructor feedback regarding to the sequencing of content, while maintaining some logical structure reduced intrinsic load, and promoted Germane processing and Teaching Presence.

Table 1 summarizes how these LMS features correspond with the theoretical constructions and expected outcomes. The explicit connection of theory and practice ensured that the intervention was not only a technologically mediated change, but rather, a pedagogically grounded alteration to meet the inherent complexities of teaching engineering content.

Table 1. Alignment of LMS features with theoretical constructs and expected outcomes

LMS Design Feature	Theoretical Lens	Supported Construct(s)	Expected Learning Outcome
Short segmented videos (≈10 min per 1 hr lecture)	CLT	Reduce extraneous load, manage intrinsic load	Better focus, reduced fatigue, improved comprehension of complex/mathematical content
Quizzes with instant feedback	SDT / CoI	Competence (SDT); Cognitive presence (CoI)	Reinforced mastery, continuous progress monitoring, improved problem-solving
Flexible self-paced access to content	SDT	Autonomy	Increased motivation, self-regulated learning, personalized pacing
Discussion forums & group assignments	SDT / CoI	Relatedness (SDT); Social presence (CoI)	Stronger peer interaction, collaborative meaning-making, sense of belonging
Structured sequencing of content & instructor feedback	CLT / CoI	Manage intrinsic & germane load (CLT); Teaching presence (CoI)	Guided learning path, scaffolding of abstract concepts, higher course outcome attainment

C. Data Collection

A mixed-methods framework was established to investigate the effects of the intervention. Three main sources of data were collected to represent objective performance indicators and subjective perceptions of students. To begin with, grade distributions were compared before and after expanding the LMS features. This allows the investigation to determine whether the intervention stimulated cognizable improvements in academic performance, especially the proportion of students at higher grades or the rate of failures. It is important to acknowledge that this study employs a quasi-experimental pre-post design without a randomized control group, which limits the strength of causal inference. The observed improvements may be partially attributable to factors beyond the intervention, such as differences in cohort characteristics, instructor familiarity with the course content, or broader post-pandemic adaptation effects. These limitations are explicitly recognized and are addressed further in the Discussion section. Regarding baseline equivalence, the two cohorts (BTE3233 and DRM1513) differed in academic level (undergraduate vs. diploma), delivery mode (fully online vs. hybrid), and semester year; direct statistical comparison of pre-intervention performance between cohorts was therefore not conducted, and findings are interpreted independently. Regarding ethical considerations, this study was conducted in accordance with institutional guidelines at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). Student data were collected as part of routine course evaluation processes; participation

in surveys was voluntary, and all data were anonymized prior to analysis. Ethical clearance was obtained from the relevant institutional authority prior to commencement of data collection.

Secondly, course outcome attainment rates were analyzed. Both courses included specified learning outcomes that were assessed in the form of quizzes, assignments, and a final exam. The Attainment data provided more fine-grain detail as to how elements of the intervention enhanced or inhibited student learning as it related to their mastery, problem-solving abilities, and applying relationships of mathematics. Improvements in proportion of not just outcomes, but improvements in proportions attainable, were exhibited as evidence the intervention enhanced cognitive presence and managed complexity of learning as human phenomena and situated process of students.

In the third step of the study, students completed surveys at two points during the semester, in Week 2 and again in Week 10. These surveys included Likert-scale items and open-ended questions specific to their motivation, their level of effort, accessibility, and perceptions of the LMS features. This longitudinal approach allowed for the ability to assess any changes in motivation and engagement over time, while also providing the opportunity to capture the transitory effects of the intervention. Survey data gave the opportunity to link students' subjective experiences to SDT constructs (autonomy, competence, and relatedness), as well as their perceptions of social and teaching presence in the LMS setting. The survey items were designed in alignment with established SDT-based and CoI-based measurement

approaches, drawing on constructs validated in prior instrument development studies, including the Intrinsic Motivation Inventory (IMI) [33] and the Community of Inquiry Survey Instrument [34]. As item-level response data are no longer accessible, internal consistency reliability coefficients (e.g., Cronbach's α) could not be computed post hoc; this constitutes a methodological limitation acknowledged further in the Conclusion. The survey findings are therefore interpreted as descriptive and corroborative evidence, complementing the primary quantitative outcomes of grade distribution and course outcome attainment.

The study's triangulation including student performance data; attainment data; and student perception established not only whether the features of the LMS were effective but also explained how and why they impacted student learning. Thus, supporting the theoretical basis for the study.

IV. RESULT AND DISCUSSION

A. Academic Performance

The implementation of LMS-based intervention was associated with notable improvements in the overall academic performance of students in both cohorts of undergraduate and diploma courses. Table 2 presents a more detailed analysis of students' academic performances, prior and post mobile learning implementation. In the case of undergraduate Communication System Design course, not only was there a positive distribution of final grades, but the distribution had a significant shift upwards. In the assessment of final grades shown in Fig. 2a, the proportions of students earning final grades of A and A- notably shifted from 4% prior to the LMS-based intervention to 18%, post-LMS implementation. Moreover, instead of only two students getting marks greater than 75, post-LMS intervention showed an increase to eighteen students passing with marks greater than 75. In reviewing the lower performance band, the student failure rate reduced dramatically from 5 students failing prior to the intervention to only 1 student failing after LMS-based learning was implemented. Similar trends can be seen with the diploma level Electrical & Electronics Technology course. Based on the overall grade in Fig. 2a, the overall proportion of students receiving a final grade of B- and above rose significantly while the failure rate dropped all the way to zero, down from 9%. To assess the statistical significance and practical magnitude of these observed improvements, three complementary inferential tests were conducted. First, chi-square tests of independence confirmed that the overall grade distributions differed significantly between pre- and post-intervention semesters for both cohorts: BTE3233, $\chi^2(3) = 24.56$, $p < 0.001$, Cramér's $V = 0.42$; DRM1513, $\chi^2(3) = 17.89$, $p < 0.001$, Cramér's $V = 0.44$. Both effect sizes fall in the medium range, indicating that the observed shifts were not merely statistically detectable but practically meaningful. Second, effect size analysis using Cohen's h revealed that the proportion of high-performing students (grades A and B combined) increased with a medium-to-large effect in BTE3233 ($h = +0.76$, $z = 4.32$, $p < 0.001$) and a large effect in DRM1513 ($h = +0.91$, $z = 4.22$, $p < 0.001$), while the proportion of low performers (grades C and D combined) fell correspondingly (BTE3233: $h = -0.76$; DRM1513: $h = -0.91$). The reduction in failure rates (grade D) was

directionally consistent in both cohorts but did not reach statistical significance at the $\alpha = 0.05$ level (BTE3233: $p = 0.061$; DRM1513: $p = 0.128$), reflecting limited statistical power due to small cell counts. Third, Mann-Whitney U tests, treating letter grades as ordinal values (A = 4 through D = 1), confirmed that post-intervention grade rankings were significantly higher than pre-intervention in both BTE3233 ($U = 3368$, $p < 0.001$, $r = 0.45$) and DRM1513 ($U = 1534$, $p < 0.001$, $r = 0.43$), with medium effect sizes in both cases. The median grade for DRM1513 improved by a full band (from C to B). Taken together, these analyses provide statistically robust evidence that the LMS intervention was associated with significant and practically meaningful improvements in academic performance across both cohorts. It should be noted, however, that the quasi-experimental design without a concurrent control group precludes causal attribution; the improvements are associational and may partly reflect other contextual factors such as post-pandemic adaptation and instructor experience.

Table 2. The student grades comparison before and after implementation of LMS-based intervention

Grade	BTE3233 (online)		DRM1513 (hybrid)	
	Sem 1 (Before)	Sem 2 (After)	Sem 1 (Before)	Sem 2 (After)
A	3.17%	24.32%	6.98%	16.0%
B	46.03%	59.46%	23.26%	58.0%
C	42.85%	14.86%	51.16%	18.0%
D	7.94%	1.35%	18.61%	8%
Total students	63	74	43	50

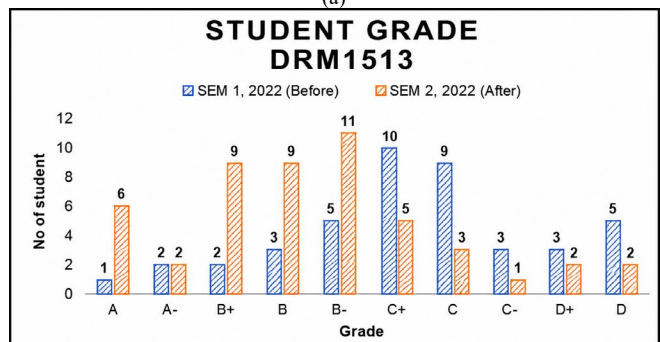
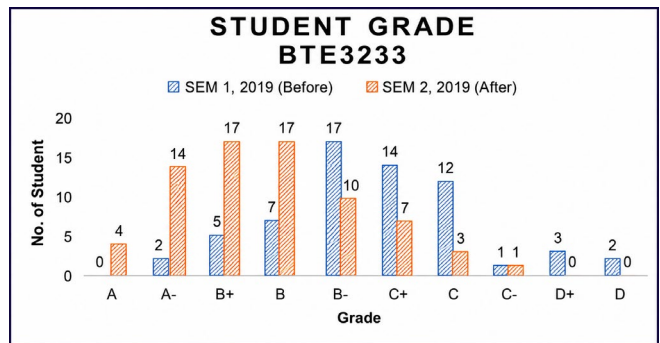


Fig. 2. Grade distribution comparison before and after intervention for (a) undergraduate students, and (b) diploma students.

Fig. 2 shows these improvements for the undergraduate and diploma cohorts, in part, through the grade distributions before and after the intervention. In line with Cognitive Load Theory, when students had the resources of working memory directed towards processing intrinsic content (e.g. mathematical relations and circuit analysis), then a possible cause of the improvements may be attributed to segmenting

the videos in customary shorter section of 6–9 min, which may have reduced extraneous load.

B. Course Outcome Attainment

Analysis of course outcome attainment provided further convergent evidence of the intervention's effectiveness. For BTE3233 (undergraduate), CO attainment scores (normalised course mark attainment %) were computed as weighted means across class sections. CO1 (Knowledge) showed a significant and practically meaningful improvement from 42.68% to 70.20% ($\Delta = +27.52\%$, $h = +0.56$, $z = 3.24$, $p = 0.001$), a medium effect. CO2 (Knowledge) improved from 64.31% to 77.81% ($\Delta = +13.50\%$), though this gain did not reach significance ($h = +0.30$, $z = 1.74$, $p = 0.082$). CO3 attainment results are noted with caution: the domain assessed by CO3 differed between the two semesters (Communication in Semester 1 vs. Knowledge in Semester 2), which precludes a straightforward comparison. For DRM1513 (diploma), all three COs were assessed consistently across both semesters. CO3 (Problem Analysis) showed the largest improvement, rising from 45.34% to 70.62% ($\Delta = +25.28\%$, $h = +0.52$, $z = 2.55$, $p = 0.011$), a medium effect. CO2 (Modern Tool Usage) improved from 70.86% to 85.46% ($\Delta = +14.60\%$, $h = +0.36$, $z = 1.76$, $p = 0.078$), a small-to-medium effect that approached but did not reach significance at $\alpha = 0.05$. CO1 (Knowledge) showed a modest gain of 3.05% that was not statistically significant ($h = +0.06$, $p = 0.762$). Taken across both courses, the strongest attainment gains were observed in outcomes requiring higher-order cognitive skills—applied problem-solving (DRM1513 CO3) and foundational knowledge application (BTE3233 CO1)—consistent with the theoretical expectation that CLT-informed content segmentation and CoI-driven cognitive presence would most benefit outcomes demanding deep conceptual integration.

Figs. 3 and 4 illustrate CO attainment patterns for the undergraduate and diploma cohorts respectively. For BTE3233, three class sections participated in Semester 2 (Groups 01, FBTE, and GMI-01; $n = 31$, 10, and 32 respectively), compared with two sections in Semester 1 (Groups 01L and 02; $n = 29$ and 34). Per-group CO1 attainment in Semester 2 ranged from 67.11% to 72.95%, all substantially above the Semester 1 range of 40.98%–44.68%. For DRM1513, a single group was assessed in each semester ($n = 49$ and 50), enabling direct CO-level comparison. The significant improvement in CO3 (Problem Analysis) from 45.34% to 70.62% aligns with the theoretical expectation that structured sequencing and instructor-guided feedback (CLT's germane load management; CoI's teaching presence) would most benefit outcomes requiring integration of abstract concepts and applied problem-solving. The near-significant improvement in CO2 (Modern Tool Usage) similarly reflects how quiz-based feedback reinforced procedural competence (SDT) and cognitive presence (CoI). The modest CO1 gain suggests that foundational knowledge outcomes, while improved, may require additional scaffolding beyond what the current LMS design provided.

C. Student Motivation and Engagement

Data from the surveys administered at Weeks 2 and 10 demonstrated a significant change in students' motivation, effort, and engagement with LMS features. Based on survey

data collected documented in Fig. 5, at the start of the semester, most students indicated that their motivation was "satisfactory," with only a smaller number of students reporting "very good" or "excellent" motivation. By the end of Week 10, however, motivation increased considerably for most students, who rated themselves as "very good" or "excellent," and all students rated themselves with no indication of "poor" motivation at the 10-week mark. Effort ratings followed a similar pattern, suggesting there was an increased sense of effort towards the end of the intervention. This confirmed the intervention not only supported student performance but left students feeling engaged and supported over time.

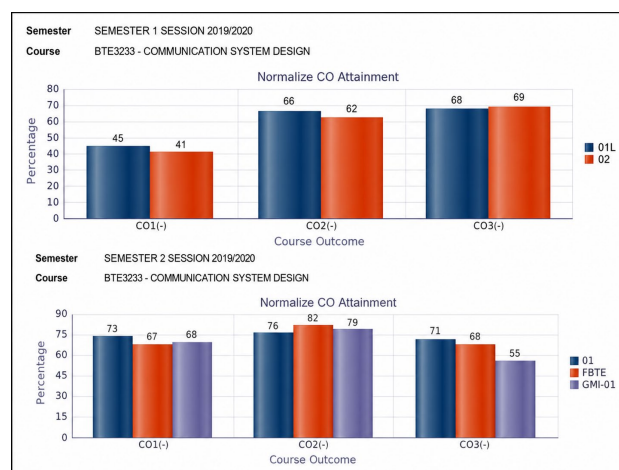


Fig. 3. Comparison of course outcome attainment for undergraduate students before and after LMS intervention.

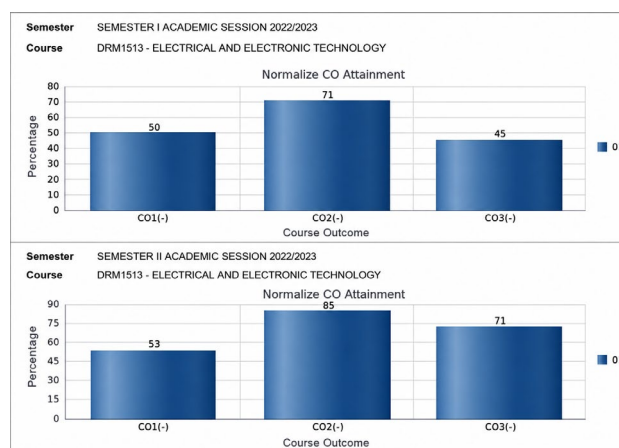


Fig. 4. Comparison of course outcome attainment for diploma students before and after LMS intervention.

Patterns of engagement with LMS features further support these conclusions. As summarized in Fig. 6, a notable 95.5% of students reported viewing video lectures on a consistent basis, and over 85% indicated they also participated in the completion of quizzes and exercise, indicating a high adoption of the LMS design. One-sample proportion tests confirmed that both engagement rates significantly exceeded benchmark thresholds: video viewing (95.5%) was significantly above a benchmark of 80% ($z = 5.44$, $p < 0.001$, 95% CI [92.6%, 98.4%]), and quiz participation (>85%) was significantly above 70% ($z = 4.59$, $p < 0.001$), providing statistical confirmation that LMS adoption was substantively high across the cohort. Engagement with the discussion forums was less consistent, however, students reported taking

minimal participation. This finding warrants deeper examination rather than brief acknowledgment. The lower forum participation may reflect a combination of structural and motivational factors: asynchronous forums may not have been sufficiently scaffolded with prompts or graded incentives to establish a norm of participation; the undergraduate cohort, operating under pandemic-induced stress, may have prioritized individual task completion over collaborative interaction; and diploma students, in a hybrid context, may have found in-person interaction a sufficient substitute for online discussion. These factors suggest that while the CoI framework's social presence component was theoretically embedded in the design, its realization was limited by implementation conditions. Future designs should consider structured forum tasks with clear assessment weighting, instructor-modeled discussion initiation, and minimum response requirements to promote more consistent social presence. This finding also serves as an important boundary condition for the otherwise strong alignment between LMS design and theoretical outcomes. The survey summary is also presented visually in Fig. 6 for effort and motivation ratings and Fig. 6 for LMS-based activity engagement.

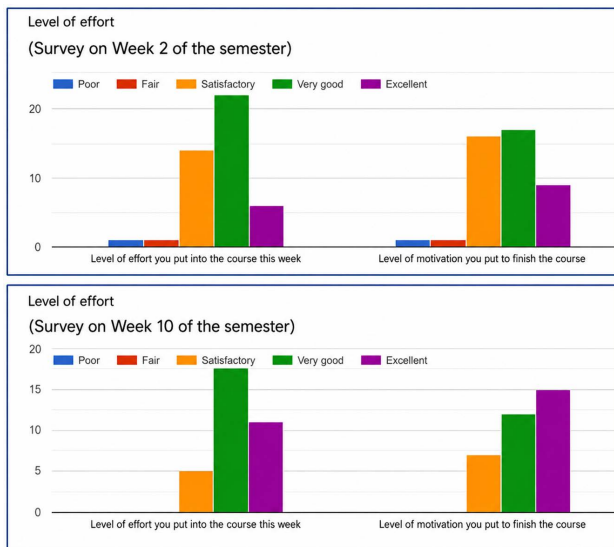


Fig. 5. Changes in student effort and motivation ratings between Week 2 and Week 10 out of 14 weeks of the semester.

Learning activities that you did this week (you may tick more than 1 answer)

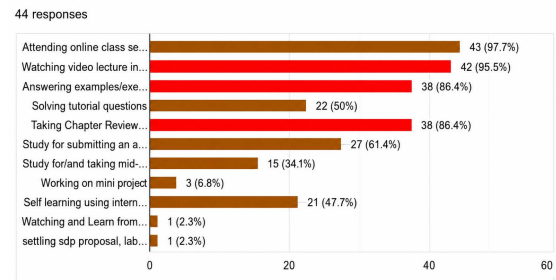


Fig. 6. Student engagement with LMS features.

These findings indicate, from the angle of Self-Determination Theory that the LMS design supported students' needs for autonomy, competence, and relatedness. Flexible access provided students with the ability to self-regulate their learning, quizzes reinforced feelings of competence, and forums enabled relatedness. These findings resonate with recent evidence from engineering education showing that structured feedback and mastery-oriented assessment activities are central to self-efficacy development in undergraduate engineering students, with negative or absent feedback identified as a primary driver of motivational decline [35].

D. Empirical Findings

Overall, the findings provide strong evidence for the conceptual framework that guided this study. Data related to academic performance showed that extraneous load was reduced and intrinsic load was suitably scaffolded, as anticipated based on Cognitive Load Theory. The attainment of course outcomes showed how competence and cognitive presence were enhanced by quizzes and structured content. Survey data confirmed the students' perceived autonomy, competence, and relatedness, consistent with Self-Determination Theory, in addition to teaching, cognitive, and social presence across the various elements of the LMS, as expected with the Community of Inquiry framework. To help frame the empirical findings with the theoretical framework, Table 3 shows each LMS design feature with outcomes and supporting evidence from this study, showing how the theorized outcomes were confirmed in practice.

Table 3. Alignment of LMS features with theoretical constructs and observed outcomes

LMS Design Feature	Theoretical Lens	Observed Outcomes (This study)	Supporting Data
Short segmented videos	CLT	Reduced fatigue; improved mastery of mathematical/ technical content	Increase in A/A- grades (4% to 18%); fewer failures
Quizzes with instant feedback	SDT / CoI	Stronger competence; sustained motivation	More than 85% quiz participation; outcome attainment improved by 13–30% (UG) and 3–26% (Diploma)
Flexible self-paced access	SDT	Greater autonomy, improved motivation	Motivation improved from “satisfactory” (Week 2) to “very good/excellent” (Week 10)
Discussion forums & group assignments	SDT / CoI	Mixed participation: sense of belonging where used	Forum engagement present but less consistent
Structured sequencing & instructor feedback	CLT / CoI	Clearer guidance, scaffolded complex concepts	Failures dropped from 5 to 1 student (UG) and 9% to 0% (Diploma)

The conjunction of a structured Learning Management System (LMS) in this study produced sustained significant learning gains in both academic performance and student engagement characteristics, across two engineering cohorts. These findings become even more significant when supported by established theories creating depth on ‘why’ the methodological design of the intervention resulted in such

findings.

E. Theoretical Implications

This research presents a number of theoretical implications for the use of Learning Management Systems (LMS) to improve the engineering education experience of students focused on complex concepts and mathematical relationships.

Engineering courses are generally perceived as being difficult due to the potential cognitive load and abstract nature of mathematical modeling. By utilizing design decisions based on established notions of learning, this study shows how mobile-enabled LMS create the affordances students utilize to improve cognitive processing and motivate engagement.

These results are consistent with recent research conducted by Jenó *et al.* [30], who also found that autonomy-supportive types of digital environments increase intrinsic motivation within STEM courses, and Orsini *et al.* [36] who found a positive relationship between perceived competence as a mediator between the presence of instructional support and academic achievement. The findings extend Self-Determination Theory (SDT) in that LMS features provide ways to maximize core psychological needs in engineering education. Often students face motivational challenges in hard-science-based classes as progressing through the course requires sustained effort. The LMS used in this study allowed for the display of autonomy through flexible access to self-paced materials, competence through the use of quizzes with instant feedback to ensure learners were monitoring progress and mastery of mathematical and conceptual problems, and through peer discussion forums and group assignments build relations with each other. Students generally completed progressively higher levels of effort and motivation throughout the semester, which indicates that LMS can be designed for building intrinsic motivation into difficult technical courses, and extend the possibilities of the application of SDT to mobile, engineering-based teaching and learning environments.

The findings provide support for and operationalize Cognitive Load Theory (CLT) within the context of engineering instruction. Engineering students often experience cognitive overload as they attempt to process long and abstract lecture content, which combines formulas, diagrams, and conceptual explanations. The study provided a means to reduce extraneous load for students, by presenting video lectures in discrete 10-minute modules within the LMS and accompanying practice activities. At the same time, the structured path through the content in the course framed may therefore supporting germane load, allowing learners to effectively assimilate mathematical relationships and conceptual frameworks. The research of Rey *et al.* [31] and Mayer [32], on multimedia learning principles, also supports the effectiveness of segmenting lecture video and finding from the results suggest that a learner-controlled sequence of segments has been shown to ameliorate cognitive overload when faced with cognitive content of technical complexity. There were also improvements observed in academic performance with higher grade attainment and improvement of course outcomes in the session with the LMS intervention which suggests that an LMS-based approach can be explicitly designed, in accordance with CLT principles, which will make the abstracting engineering content easier to digest and promote retention over time.

This study also employed the Community of Inquiry (CoI) framework to describe how collaboration and interaction contributed to students' engagement with complex technical material. Learning engineering commonly involves not just individual problem-solving but also a collective act of

meaning-making, especially concerning the abstract theories and mathematical derivations. In this study, the forums and group tasks supported by the LMS created social presence, allowing students to discuss what it means to solve a particular problem and clarify their misunderstandings. Quizzes and problem-based tasks supported cognitive presence, which encourages learners to critically reflect upon engineering concepts, while the LMS structure and instructor guidance maintained a teaching presence. Together, these forms of presence established a balanced and ongoing learning experience, and students fully engaged by not only learning mathematical concepts but also contextualizing concepts to apply mathematics and discuss concepts, resulting in a richer understanding of the concepts. This aligns with Richardson *et al.* [37] for their findings indicated that teaching presence was the best predictor of perceived learning in an online course, and it aligns to Kozan and Caskurlu [38] whose meta-analysis verified how instructor presence helps to develop cognitive and social presence of students.

The difference in outcomes between fully online and hybrid contexts is also worth discussing. Vo *et al.* [39] and Raes *et al.* [40] stated that often hybrid models perform better than entirely online delivery as long as the in-person component is used in a purposeful way with components delivered via the technological medium. Our findings suggest that purposeful design of LMS interventions, even those used in emergency remote situations, can produce similar outcomes when aligned with theory, as highlighted by Hodges *et al.* [41] when defining online learning in a planned and emergency remote context. If educational experiences result in similar outcomes, it may suggest that alignment is more important than the delivery of that experience, a finding noted by Rapanta *et al.* [42] in their meta-analysis on distance education effectiveness.

In the case of engineering education, our findings build on previous work on active learning [43, 44] and problem-based learning [45] by showing how a digital platform can scaffold a complex problem-solving project. The improvements in students' mastery of mathematical concepts are aligned with framework for techniques to encourage student engagement in STEM disciplines [46] and the call for change with evidence informed learning in engineering education [47].

This study contributes to the theoretical conversation by demonstrating that LMS platforms, when designed thoughtfully in relation to SDT, CLT, and CoI, can support learning in disciplines where abstraction and mathematics dominate much of the complexity associated with learning outcomes. In connecting theory to practice, the findings essentially show that LMS-based mobile learning is not just a replacement for conventional delivery, but an informed pedagogical initiative that allows engineering education to be more accessible, motivating, and efficacious.

V. CONCLUSION

This study finds that incorporating LMS-based mobile learning approaches can make significant improvements in academic performance and student engagement for engineering students in different teaching situations. Quantitative data indicated a major movement of students' results into higher grade bands; a threefold increase in 'A'

results during the fully online part of the course and a similar increase in the hybrid phase, and students subject to diplomas benefitted from a lower incidence of grades at the lower end. Indicators for successfully meeting course outcomes also indicated an increase, undergraduates meeting states for learning outcomes up to almost 30 percent more successfully, while learners only pursuing diplomas were up to 26 percent higher. Feedback from surveys supports that the LMS-based approach to learning also had an inherent motivational aspect. Continuous access to relatively short video content, interactive quizzes, and ability to interact with peers, increased levels of effort and engagement/good will, despite the assumption that screen fatigue would be an issue. Finally, the findings suggest that theory-aligned LMS-based approaches have the potential to yield academic outcomes comparable to or better than those of prior cohorts in the same courses, when paired with immediate feedback loops and collaborative elements. It should be noted, however, that this study does not include a direct comparison with a concurrent traditional classroom group, and claims of equivalence or superiority to conventional instruction should be interpreted cautiously until confirmed by experimental designs with appropriate controls.

These findings theoretically build upon Cognitive Load Theory, showing that when background video materials are segmented into smaller lengths, they can mitigate extraneous load during high-demand engineering contexts. These findings support Self-Determination Theory, as they demonstrate how the LMS features enhanced autonomy, competence, and relatedness in learning. Lastly, these findings are also informed by the Community of Inquiry framework, as they demonstrate how LMS tools can simultaneously facilitate cognitive, social, and teaching presence that effectively provides meaningful learning experiences.

Although this study offers significant support for theory-based LMS design, several limitations should be acknowledged alongside directions for future research. First, the quasi-experimental pre-post design without a concurrent control group limits causal attribution; the observed improvements are associational and may partly reflect cohort differences, post-pandemic adaptation, or instructor experience. Second, internal consistency reliability of the survey instrument (e.g., Cronbach's α) could not be computed, as item-level response data are no longer accessible. The survey items were designed to align with SDT and CoI constructs as operationalised in validated instruments such as the IMI [33] and the CoI Survey [34]; however, future studies should administer a fully validated instrument and report reliability coefficients to strengthen motivational and engagement claims. Third, undertaking longitudinal studies that follow students across multiple semesters would clarify whether motivational and performance gains are stable over time or attributable to novelty effects. Fourth, comparative studies among popular engineering disciplines (e.g., civil engineering, mechanical engineering, chemical engineering) could assist in determining whether LMS design features are effective across disciplines or if certain features may need to be adapted to fit the domain. Fifth, research into individual differences (e.g., prior academic achievement, digital literacy,

learning preferences) could inform how to adapt LMS interventions to fit a range of learner profiles. Sixth, experimental studies with control groups would enhance claims of causality. Lastly, research focused on obstacles to implementation, faculty development, and institutional challenges would provide meaningful implementation guidance for scaling theory-based LMS design across diverse engineering programs, and for other STEM-related disciplines.

For future implementations, it is vital to use high-quality instructor training, attend to pedagogical design, and support infrastructure for equitable and accessible implementation, especially in challenging contexts with limited resources. Drawing on the patterns observed across both cohorts, this study proposes three core LMS design principles for engineering educators: (1) Segment and scaffold – structure content in short (≈ 10 -minute) modules with logical sequencing to reduce extraneous load and guide learners through complex material progressively; (2) Activate and affirm – embed frequent low-stakes quizzes with immediate, specific feedback to build competence, support self-monitoring, and sustain intrinsic motivation throughout the course; and (3) Connect and collaborate – design structured, assessed discussion tasks with clear expectations to build social and teaching presence, particularly given that unstructured forums alone may yield low participation. These principles, derived from the convergence of SDT, CLT, and CoI with the observed outcomes of this study, offer a theoretically grounded and practically actionable framework for instructors designing or redesigning engineering courses on any LMS platform. Generalizing beyond a single LMS, this study provides transferable findings that can be applied to a variety of LMSs (e.g., Blackboard, Google Classroom, OpenLearning, Canvas, etc.). Overall, research demonstrates that well-designed LMS environments that are applied in an intentional manner in engineering course delivery, have the potential to produce positive changes in academic performance, student engagement, and academic satisfaction.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

RMR contributed to developing the research idea, writing the article, and collecting data. MSN and DP played a role in data collection and the development of research instruments and contributed to writing the article. Meanwhile, RMR and DP were responsible for designing the research and providing constructive feedback at every stage of the study. All authors had approved the final version.

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