THE IMPACT OF TECHNOLOGY-ENHANCED LEARNING ON STUDENT ENGAGEMENT: THE MEDIATING ROLE OF SELF-REGULATED LEARNING AND THE MODERATING EFFECT OF TEACHING PRESENCE

Rui Zhu [1*]
Ziyue Wang [2]
Racha Mahakuntha [3]
Ge Wei [4]
Praphaphan Wunsuk [5]

[1-5] Innovation College, North-Chiang Mai University
[*] **Corresponding Author, E-mail:** rui.zhu@northcm.ac.th

Abstract: This study constructs a core conceptual framework with student engagement as the dependent variable and technology-enhanced learning as the independent variable, by introducing the following demographic variables: gender, age, grade point average (GPA), and internet accessibility. The study attempts to analyze the differences in the mean perception of the independent variable (technology-enhanced learning) and the dependent variable (student engagement) among the respondents grouped by demographic variables, as well as the direct predictive effect of the independent variable on the dependent variable and the indirect effect path. To this end, the study proposes the following research hypotheses: (1) technology-enhanced learning positively predicts student engagement; (2) self-regulated learning mediates the relationship between the two; (3) the sense of presence in teaching moderates the relationship between technology-enhanced learning and student engagement.

This study takes higher education institutions as a case and conducts a survey among their undergraduate and graduate students. A stratified random sampling method was used to determine the sample, and the final sample size was 387. A total of 400 questionnaires were distributed in this study, and the questionnaires were distributed through a combination of online and offline methods. Finally, 387 questionnaires were effectively recovered, with a recovery rate of 96.75%, which is representative and has reliable data.

The main empirical findings of this study are as follows: Gender, age, and GPA grouping show significant differences in the four dimensions of technology-enhanced learning, student engagement, self-regulated learning, and the sense of presence in teaching. High-achieving students have significantly higher mean scores in each variable dimension than low-achieving students. In addition, Internet access also significantly affected students' scores on the above four variables. Students with

stable Internet access had a significantly better learning experience than those with unstable Internet access. In the regression path analysis, technology-enhanced learning significantly and positively predicted student engagement; self-regulated learning played a partial mediating role in the above path; and the moderating effect analysis showed that the sense of presence in teaching significantly moderated the relationship between technology-enhanced learning and student engagement. These results fully support the three hypotheses proposed in this study.

The research contributions of this study are mainly reflected in the following two aspects: First, at the theoretical level, this study combines the self-regulated learning theory (Zimmerman, 2002) and the inquiry community model (Anderson et al., 2001) to propose a comprehensive model that covers technology, psychological strategies and teaching structure. It effectively reveals the direct and indirect path mechanisms of technology-enhanced learning on student engagement, enriches the theoretical construction of the influence path of teaching in the digital learning environment, and expands the new perspective of "sense of teaching presence" as a regulatory mechanism.

Second, at the level of curriculum management and teaching practice, the results of this study provide empirical guidance for the design of online and blended teaching courses. The study suggests that universities should pay attention to teacher support, learner autonomy, and platform design when promoting technology-enhanced teaching. In particular, teacher training and the construction of a sense of presence should be strengthened. In addition, the study also emphasizes the important role of digital infrastructure in educational equity, reminding policymakers that while promoting digital education, they should ensure students' access to the Internet and digital resources.

In summary, this study not only verifies the important relationship between technology-enhanced learning and student engagement, but also provides theoretical and practical support for building a more inclusive and efficient digital learning environment.

Keywords: Technology-Enhanced Learning Student Engagement Self-Regulated Learning Teaching Presence

Introduction

The integration of digital technology into educational settings has transformed how knowledge is delivered and consumed. Known as technology-enhanced learning, this integration includes the use of tools such as learning management systems, interactive simulations, digital assessments, and multimedia content to improve the teaching and learning experience (Kirkwood & Price, 2014). The urgency of digital transformation in education accelerated during the global COVID-19 pandemic, compelling institutions to transition to online and hybrid modalities, which not only challenged existing pedagogies but also exposed infrastructural and instructional gaps (Dhawan, 2020).

While digital learning environments are now widespread, student engagement within these

platforms remains a central concern. Student engagement refers to the level of interest, motivation, and active participation that students exhibit in their learning process, typically conceptualized across behavioral, emotional, and cognitive dimensions (Fredricks, Blumenfeld, & Paris, 2004). Prior studies have shown that while digital tools offer flexibility and accessibility, they do not inherently guarantee student engagement (Martin & Bolliger, 2018). For instance, Al-Fraihat et al. (2020) found that system quality and instructor presence significantly influenced students' satisfaction and engagement in e-learning environments, highlighting the importance of supportive pedagogy.

Two psychological and instructional constructs—self-regulated learning and teaching presence—have emerged as critical to understanding how engagement is facilitated in technology-mediated contexts. Self-regulated learning involves learners' proactive control over their cognitive, motivational, and behavioral processes to achieve learning goals (Zimmerman, 2002). This becomes especially important in online education, where learners often operate with greater autonomy. Concurrently, teaching presence, derived from the Community of Inquiry framework (Anderson et al., 2001), encompasses the instructor's role in designing, facilitating, and guiding learning experiences. Garrison and Cleveland-Innes (2005) argue that teaching presence is a strong predictor of both perceived learning and satisfaction in online education.

In response to the increasing reliance on technology-enhanced learning and the mixed results surrounding its effectiveness, this study is positioned to explore the dynamic interplay between TEL, self-regulated learning, teaching presence, and student engagement. By doing so, it addresses an urgent need in educational research and practice to move beyond technology adoption and into the pedagogical processes that lead to meaningful learning outcomes.

Despite significant advancements in digital education technologies, a growing body of research highlights inconsistent results regarding their influence on actual learning engagement. For example, Bernard et al. (2009) noted in a meta-analysis that while distance education may produce equivalent or better outcomes compared to face-to-face instruction, the presence of active pedagogical elements (e.g., learner control, interaction) mediates success. This highlights a critical limitation in many technology-enhanced learning models, where the focus is often on access to tools rather than the instructional and cognitive processes that foster engagement.

One central gap is the under exploration of self-regulated learning as a mediating mechanism between TEL and engagement. Although the importance of metacognitive strategies and motivational regulation has been acknowledged (Pintrich, 2004), few empirical studies have quantitatively tested how these strategies mediate technology's impact on learner engagement. Without this understanding, technology-enhanced instruction may not adequately support the learners who need it most, particularly those with weaker self-management skills.

A second critical gap pertains to teaching presence as a moderating factor. While research confirms its influence on perceived learning and satisfaction (Shea, Li, & Pickett, 2006), there is

insufficient empirical work assessing how teaching presence moderates the relationship between TEL and engagement. That is, while a robust teaching presence may amplify the benefits of TEL, the mechanisms and extent of that effect remain poorly specified.

Furthermore, most TEL studies have focused on homogeneous student populations or failed to include demographic diversity. Factors such as age, gender, academic performance, and internet access can significantly influence learning experiences and outcomes (González-Gómez et al., 2012). The exclusion of such variables limits the generalizability and applicability of existing models. This study addresses these limitations by incorporating a broader demographic analysis to ensure inclusivity and contextual sensitivity.

Lastly, a fragmented research landscape exists where psychological and instructional constructs are often studied in isolation. Integrated models that include self-regulated learning, teaching presence, and technology-enhanced learning as interdependent elements remain rare. This study proposes a comprehensive framework to address this fragmentation and provide a more holistic understanding of digital engagement.

This study makes the following contributions:

From a theoretical standpoint, this study contributes to the intersection of educational psychology and instructional technology by developing and validating an integrated model based on Zimmerman's (2002) self-regulated learning theory and Anderson et al.'s (2001) Community of Inquiry framework. The model elucidates how self-regulated learning functions as a mediating variable and teaching presence as a moderator in the TEL-engagement relationship. These findings move beyond simple correlations and offer a structural explanation for the variance in student engagement in digital settings.

Empirical support for the mediating role of self-regulated learning advances theoretical understanding of learner autonomy in online contexts. As Broadbent and Poon (2015) argued, self-regulated strategies are especially important for learners in technology-rich but low-structure environments. The findings also substantiate the theoretical claim that engagement is not merely a response to content or technology but emerges through a complex interaction between learner agency and instructional design.

Practically, the study provides direct implications for educators and instructional designers. First, the significance of teaching presence suggests that training programs should equip instructors with skills in instructional facilitation, timely feedback, and social presence development. Teaching presence is not merely about delivering content but shaping the interactional context in which learners construct knowledge (Garrison et al., 2010).

Second, digital course designers are encouraged to embed scaffolding mechanisms that support self-regulated learning. These may include reflective prompts, goal-setting dashboards, and progress monitoring tools—design elements that help learners manage time, track progress, and reflect on

performance.

Third, the study calls for attention to infrastructure inequality. Internet accessibility was found to significantly influence student experiences, underscoring the need for institutional investments in reliable connectivity and device availability. Park and Shea (2020) emphasize that addressing digital equity is foundational to achieving equitable learning outcomes in online environments.

In conclusion, this study offers a comprehensive, evidence-based framework that not only deepens theoretical understanding of TEL but also informs practical strategies for improving student engagement, supporting learner autonomy, and optimizing instructor effectiveness in digital learning contexts.

Research Objectives

The central objective of this study is to examine the complex mechanisms through which technology-enhanced learning influences student engagement in the context of higher education, placing particular emphasis on the mediating role of self-regulated learning and the moderating function of teaching presence. As digital learning environments continue to expand and evolve, understanding the nuanced interplay between technological integration and students' psychological and behavioral engagement has emerged as a critical area of inquiry in educational research. While the integration of digital tools into pedagogical practices has become increasingly widespread, the empirical evidence surrounding their actual impact on learning outcomes remains mixed and context-dependent. This study seeks to address this gap by developing and validating a conceptual model that not only captures the direct effect of technology on engagement but also accounts for the underlying psychological mechanisms and contextual moderators that condition this effect.

The first research objective is to explore the direct impact of technology-enhanced learning on student engagement. This involves assessing whether the use of digital learning tools—such as learning management systems, online quizzes, video-based instruction, and interactive simulations—can significantly enhance students' behavioral participation, emotional investment, and cognitive involvement in the learning process. This objective is rooted in the recognition that technology, when purposefully integrated, has the potential to create more flexible, accessible, and stimulating learning environments that promote student agency and active participation.

The second objective is to analyze the mediating role of self-regulated learning in the relationship between technology-enhanced learning and student engagement. Specifically, this study investigates whether the use of self-regulation strategies—such as goal setting, self-monitoring, time management, and reflective thinking—serves as a key psychological mechanism that explains how and why technology affects student behavior. Drawing on Zimmerman's (2002) theory of self-regulation, the study hypothesizes that students who possess stronger self-regulated learning skills are more likely to capitalize on the affordances of educational technologies and exhibit deeper levels of engagement.

The third objective is to assess the moderating role of teaching presence in shaping the effectiveness of technology-enhanced learning. Teaching presence, as defined in the Community of Inquiry framework, includes the design, facilitation, and direction of learning experiences. This study explores whether high levels of instructor support, timely feedback, and active facilitation enhance or buffer the impact of technology on student engagement. This line of inquiry is crucial for understanding the extent to which the instructor's role in digital settings influences learner outcomes, particularly in asynchronous or blended formats where students may otherwise feel disconnected or unsupported.

The final objective is to offer evidence-based recommendations for educators, instructional designers, and policy makers aiming to improve the quality and equity of digital and hybrid learning environments. By fulfilling these four objectives, the study not only provides an empirically validated model of technology-mediated engagement but also contributes to theoretical refinement by integrating constructs from self-determination theory, self-regulated learning theory, and the Community of Inquiry model. In doing so, it challenges the simplistic assumption that technological integration alone leads to improved educational outcomes and underscores the importance of learner agency and pedagogical support as essential components of effective technology-enhanced learning.

By achieving the above research objectives, the study will construct an explanatory empirical model that reveals the complex and dynamic interactions between teaching technology, learner autonomy, teaching behavior, and student learning outcomes. This will not only help to break down the simplistic thinking of “technology equals effectiveness,” but will also provide more scientific and systematic theoretical guidance for future digital teaching practices.

Literature Review

Against the backdrop of the ongoing development of higher education, the strategic integration of digital technologies has evolved from an auxiliary teaching option to a core teaching method. Technology-enhanced learning (TEL) is not just an update of educational tools; it marks a fundamental shift in the way learning environments are constructed, reshaping the way students interact with learning content and how teachers design teaching. In particular, the rapid rise of blended and fully online learning models, driven by global public health events such as the COVID-19 pandemic, has prompted large-scale investments in digital platforms, virtual learning environments (VLEs), and personalized learning technologies in higher education. However, the effectiveness of these technologies depends not only on their “usability” but also on whether they are closely integrated with teaching strategies and truly support active learning, motivation, and learning engagement.

This study was conducted against the backdrop of this educational transformation. It aimed to explore how technology-enhanced learning (TEL) affects students' engagement, a construct widely recognized in educational psychology as a core predictor of academic success, persistence, and achievement (Fredricks et al., 2004). In the model of this study, technology itself is viewed as an

environmental variable rather than an automatic tool for effectiveness. Its effectiveness is jointly influenced by students' internal learning abilities and teachers' external teaching behaviors. Therefore, this study introduces two key variables: Self-Regulated Learning (SRL) and Teaching Presence. These two variables represent the psychological learning process of students and the supportive teaching behaviour of teachers, respectively, and are hypothesized to be important mechanisms that moderate or mediate the relationship between technology and engagement.

The purpose of this section is to systematically review the theoretical constructs and empirical research progress of the above four key variables – technology-enhanced learning, student learning engagement, self-regulated learning and teaching presence – in the context of higher education.

Technology-enhanced learning (TEL) refers to the purposeful integration of digital technologies into the learning process to improve student learning outcomes, accessibility, interactivity, and engagement. TEL is not only concerned with the delivery of content through digital means, but also aims to reshape learning and the way students cognitively, behaviorally, and emotionally interact with knowledge and teaching (Luckin et al., 2016). TEL goes beyond the provision of online learning materials to include adaptive learning environments, data-driven feedback systems, gamification, and the use of immersive technologies such as virtual and augmented reality. Scholars such as Kirkwood and Price (2014) have highlighted a paradigm shift in educational technology research – from viewing technology as a tool to viewing it as a learning environment and medium. As such, TEL can enable personalization, flexibility in time and place, and continuous formative feedback, which together enhance learner control over the educational process. Empirical evidence supports the effectiveness of technology-enhanced learning environments in improving learning outcomes, especially when they align with sound pedagogical principles (Broadbent & Poon, 2015). Research by Matcha et al. (2019) suggests that learning analytics and dashboards can help students better monitor their own learning trajectories, thereby improving self-regulation and learning efficiency. Similarly, Azevedo et al. (2020) highlight the role of adaptive technologies in responding to students' cognitive load and emotional state, delivering tailored content and interventions based on learner needs.

Despite these benefits, the effectiveness of technology-assisted learning is not automatic. Research warns against deterministic views of technology, emphasizing that its value depends on learners' self-regulation and structured pedagogical support (Ifenthaler & Yau, 2020). Research suggests that without adequate guidance or instructional support, the benefits of technology-assisted learning may be lost or even counterproductive, leading to disengagement or cognitive overload for the learner.

Student engagement is a multidimensional concept that is widely recognized as a key predictor of academic success, learning persistence, and overall well-being (Fredricks, Blumenfeld, & Paris, 2004). It includes three interrelated domains: behavioral engagement (involvement, effort, and persistence), affective engagement (interest, enthusiasm, and emotion), and cognitive engagement

(investment in learning strategies, metacognition, and deep learning approaches). The concept has evolved over time, with scholars such as Kuh (2006) expanding the concept to include student behaviors and the institutional conditions that promote them. Student engagement becomes more complex in digital and blended learning environments. Martin and Bolliger (2018) found that clear instructional design, timely feedback, and opportunities for interaction have a positive impact on students' behavioural and affective engagement. However, Henrie et al. (2015) argue that traditional engagement measurement methods (e.g., self-report surveys) may fail to capture subtle changes in engagement in virtual environments. As a result, learning analytics, clickstream data, and real-time engagement metrics are increasingly used to more accurately measure and predict student engagement. Dixson (2015) emphasizes that affective engagement is often overlooked, but it plays a crucial role in maintaining motivation and perseverance, especially in asynchronous environments. Personalized feedback, immediacy of the instructor, and peer interactions help alleviate the sense of isolation commonly experienced in online learning environments. Affective engagement is particularly important for vulnerable student populations who may have difficulty self-directing or lack social support. Student engagement is also strongly influenced by contextual factors such as academic performance and internet availability. For example, You (2016) and Kahu (2013) both note that students with high academic achievement tend to exhibit more consistent engagement patterns across tasks and time, in part due to their stronger intrinsic motivation and self-regulation. Similarly, limited or unstable internet access has been shown to significantly hinder students' ability to fully engage with online materials, collaborative tasks, and feedback systems.

Self-regulated learning (SRL) refers to the process by which learners actively monitor, manage, and control their own learning behaviors, emotions, and cognitions in order to achieve academic goals (Zimmerman, 2002). It includes elements such as goal setting, strategy use, self-monitoring, self-assessment, and reflection. In a TEL environment, the need for self-regulation becomes even more critical due to the high degree of learner autonomy required in an asynchronous and blended environment. Empirical research consistently shows that students who exhibit higher levels of self-regulated learning tend to perform better academically, are more resilient when faced with challenges, and demonstrate deeper engagement in the learning process (Broadbent, 2017). In TEL environments, the availability of learning dashboards, adaptive assessments, and automated feedback systems has been shown to promote metacognitive awareness and strategic learning behaviors (Matcha et al., 2019; Azevedo et al., 2020).

Moreover, self-regulated learning is not a static trait, but rather a set of skills that can be fostered through instructional design. Winne and Hadwin (2008) suggest that learning environments should include features such as scaffolded tasks, reflective activities, and guided practice to promote SRL. For example, Paris and Paris (2001) highlight the value of “thinking aloud” protocols and modeling to develop students' ability to reflect on and refine learning strategies.

Despite the importance of self-regulated learning skills, there are still differences in abilities among students. Zimmerman and Kitsantas (2005) argue that students with lower self-regulated learning skills are unlikely to benefit from distance learning environments unless they are systematically supported. Researchers therefore advocate embedding self-regulated learning training modules in digital platforms, such as goal-setting prompts, progress tracking tools, and self-assessment checklists (Jangili and Ramakrishnan, 2024).

Pedagogical presence refers to the role of the instructor in designing, organizing, facilitating, and guiding the learning experience to ensure that students achieve meaningful and educationally valuable outcomes (Anderson, Rourke, Garrison, & Archer, 2001). Within the framework of the Communities of Inquiry (CoI), pedagogical presence is considered, along with social presence and cognitive presence, as one of the three pillars of effective online learning. In a distance learning environment, pedagogical presence is not limited to real-time instruction. It also includes elements of instructional design such as course structure, clarity of learning objectives, consistency of assessment, and availability of feedback mechanisms. Shea et al. (2005) found that strong instructional presence can significantly improve student satisfaction, motivation, and learning outcomes. Recent research suggests that instructional presence can be enhanced through technology. Richardson et al. (2017) showed that pre-recorded lectures, timely automated feedback, and personalised teacher responses help to improve instructional presence. However, it is not enough to simply provide content; the quality and consistency of interactions is important. Teachers must employ strategies that promote dialogue, reflection, and cognitive engagement, even in asynchronous formats (Martin & Bolliger, 2018). Instructional presence also varies by discipline and learning environment. Arbaugh (2008) found that conceptual subjects benefit more from high levels of teacher intervention, while technical courses may rely more on direct feedback and performance-based tasks. Cultural expectations further moderate perceptions of teaching presence; in collectivist cultures, instructional behaviors are typically interpreted as supportive, whereas in individualist cultures, learners may prefer autonomous and egalitarian interactions (Joo et al., 2011). Despite its importance, there are still gaps in understanding how to effectively cultivate and sustain teaching presence across different distance learning modalities. The integration of artificial intelligence, affective analytics, and behavioral analytics offers promising avenues for automating some elements of teaching presence while retaining its human-centered core.

This study is based on the following theories:

1. Self-Determination Theory (SDT) proposed by Deci and Ryan (1985; 2000) is a macro theory of human motivation widely used in education. This theory states that individuals will exhibit higher levels of initiative, self-regulation, and sustained learning engagement when their three basic psychological needs are met. These needs are autonomy (a sense of control over one's actions), competence (confidence in one's ability to master and perform a task), and relatedness (the need to connect with others) (Ryan & Deci, 2000). Technology-enhanced learning environments can support

these needs through a variety of features. For example, interactive simulations and multimedia content allow learners to choose their own pace and mode of learning, which can enhance their sense of autonomy and engagement (Kirkwood & Price, 2014). In addition, timely and personalized feedback can enhance a sense of competence, while online discussion platforms and collaborative tools can help strengthen the emotional connection between teachers, students and peers. However, if the technology is not properly designed, it may reduce motivation by reducing interpersonal interaction or limiting learning paths.

The Community of Inquiry (CoI) model proposed by Garrison, Anderson and Archer (2000) provides a theoretical framework for understanding the effectiveness of online and blended learning environments. The model suggests that meaningful learning depends on three key factors: cognitive presence (the ability of learners to construct meaning through continuous reflection and dialogue), social presence (the ability of individuals to express themselves and their emotions in a learning community), and teaching presence (the role of teachers in designing, guiding and directing the learning process). Among these, “pedagogical presence” is particularly critical. In a technological environment where physical interaction is limited, the guiding role of the teacher has a significant effect on maintaining the structure of the learning process and enhancing students' participation and cognitive engagement (Anderson et al., 2001). Previous studies have shown that the higher the pedagogical presence, the higher the students' sense of engagement and satisfaction with the course (Shea et al., 2005).

The research model proposed in this paper is as follows. The model includes path relationships between four core variables: technology-enhanced learning as the independent variable, which indirectly affects students' learning engagement by influencing their self-regulated learning ability; teaching presence as the moderating variable, which is expected to moderate the direct path between technology-enhanced learning and student engagement, enhancing or weakening the strength of the path effect.

Specifically, this study attempts to explore the following three levels:

The main effect path: whether technology enhances learning directly promotes students' engagement behaviors; the mediating path: whether students need to have a certain degree of self-regulation in order to fully unleash the positive effect of technology on learning behaviors; and the moderating path: whether the presence of teaching enhances or weakens the impact of technology on students' learning engagement.

Based on the above conceptual model and theoretical logic, this paper proposes the following three specific research hypotheses:

Technology, as an integrated platform for learning resources and teaching media, can enhance students' perceived freedom, sense of control and individual adaptability in the learning process. These factors together affect learning motivation, which in turn enhances their behavioral, emotional and

cognitive investment. Existing research has shown that in a learning platform with good technical support, students are more likely to exhibit frequent login behavior, higher forum participation, more homework completion rates and more positive learning feedback behavior. Therefore, this paper proposes the following hypothesis:

H1: Technology-enhanced learning has a significant positive impact on student engagement.

Although technology provides students with more learning convenience, not all students can make full use of these resources, especially in the absence of external coercive structures. The learning effect depends largely on individual self-regulation ability. If students can effectively set learning goals, manage their time and continuously monitor their learning progress, they are more likely to turn the "potential advantages" of technology into actual participation. Therefore, this paper proposes that

H2: Self-regulated learning mediates the relationship between technology-enhanced learning and student engagement.

In a technology-dominated learning environment, if there is a lack of effective guidance and emotional support from the teacher, students may feel isolated and helpless, which will affect their motivation to participate. However, when teachers demonstrate an active teaching presence through various means (e.g., personalized feedback, online Q&A, interactive discussions, etc.), students are more likely to feel cared for and supported, thereby enhancing their willingness to invest in learning. Therefore, the teaching presence not only serves as a background variable of the learning atmosphere, but also has the potential to change the strength of the impact of technology on student behavior. Therefore, this paper proposes that

H3: The teaching presence moderates the impact of technology-enhanced learning on student engagement, and the relationship is stronger when the teaching presence is higher.

In summary, this paper takes technology-enhanced learning as the starting point of the study, and combines the two key variables of self-regulated learning and sense of presence to construct a conceptual model that integrates motivational mechanisms, learning behaviors, and instructional design. This model not only helps to gain a deeper understanding of how students can achieve effective learning with the support of technology, but also provides theoretical support for the design of online education platforms and the optimization of teachers' teaching behaviors. The next section will design quantitative research tools and empirical analysis methods based on this model to verify the rationality of the above hypotheses and the applicability of the theoretical model.

Methodology

This study investigates the impact of technology-enhanced learning on student engagement, incorporating self-regulated learning as a mediating variable and teaching presence as a moderating variable. The study is grounded in two well-established theoretical frameworks: the Self-Determination Theory (Deci & Ryan, 1985; 2000), which emphasizes learners' autonomy, competence, and

relatedness, and the Community of Inquiry framework (Anderson, Rourke, Garrison, & Archer, 2001), which conceptualizes meaningful learning as an interaction of cognitive presence, social presence, and teaching presence.

Research Design and Instruments

A quantitative research design was employed to test three hypotheses: (1) technology-enhanced learning positively affects student engagement, (2) self-regulated learning mediates this relationship, and (3) teaching presence moderates the relationship between technology use and student engagement. The data collection instrument consisted of five sections, including four validated measurement scales and one demographic section. All scale items were measured using a five-point Likert scale ranging from strongly disagree to strongly agree.

The Technology-Enhanced Learning Scale (adapted from Kirkwood & Price, 2014) includes 15 items that assess students' perceptions of the utility, interactivity, and ease of digital technologies in supporting academic learning. The Student Engagement Scale integrates behavioral, emotional, and cognitive dimensions based on prior studies by Fredricks et al. (2004), Dixson (2015), and Handelsman et al. (2005), containing 18 items. The Self-Regulated Learning Scale draws from Zimmerman (2002) and Barnard-Brak et al. (2010), covering metacognitive regulation, goal-setting, time management, and self-assessment through 20 items. Lastly, the Teaching Presence Scale (Anderson et al., 2001) includes 13 items assessing students' perceived instructional design, feedback, guidance, and interaction from instructors.

Population, Sample, and Sampling Strategy

The target population includes currently enrolled students in accredited higher education institutions who had experienced at least one course utilizing technology-enhanced instruction. Stratified random sampling was adopted to ensure proportional representation across institutional type, academic discipline, and level of study. The final sample consisted of 387 valid responses from a total of 400 distributed questionnaires, exceeding the minimum required sample size of 384, which was calculated using the standard formula for an unknown population proportion with a 95 percent confidence level and 5 percent margin of error.

Data Collection

Data were collected through an online questionnaire deployed using secure survey platforms. Prior to formal deployment, a pilot test was conducted among 30 students to validate clarity, internal consistency, and accessibility of the survey instruments. Feedback informed minor revisions to enhance usability and comprehension. Ethical protocols were strictly followed, including informed consent, anonymity, voluntary participation, and data security.

To ensure inclusivity and usability across technological constraints, the survey was mobile-optimized, designed with high-contrast interfaces, and avoided multimedia elements that could hinder access on lower-performance devices. Participants had four weeks to respond, and the response rate

was boosted through scheduled reminders and instructor collaboration.

Statistical Techniques

The analytical framework combined descriptive and inferential statistics. Descriptive statistics (mean, standard deviation, frequency) provided a profile of participants' demographic characteristics and variable distributions. Independent-samples t-tests and one-way analysis of variance were used to examine differences across gender, age groups, academic achievement levels, and internet accessibility.

To test Hypothesis 1, a multiple linear regression analysis was conducted with student engagement as the dependent variable and technology-enhanced learning as the independent variable. Hypothesis 2 was tested using mediation analysis based on the Baron and Kenny (1986) causal steps model, followed by a bootstrap analysis (5,000 iterations) to assess the indirect effect of self-regulated learning. Hypothesis 3 was examined using moderation analysis through the PROCESS macro (Model 1), evaluating the significance of interaction terms between technology use and teaching presence.

Reliability and Validity

Internal consistency reliability was assessed using Cronbach's alpha. All four core scales demonstrated high reliability: technology-enhanced learning (.932), student engagement (.874), self-regulated learning (.925), and teaching presence (.914). Construct validity was evaluated through expert panel reviews and statistical validation. The Kaiser-Meyer-Olkin (KMO) value for sampling adequacy was .843, and Bartlett's test of sphericity was significant ($\chi^2 = 1282.931$, $p < .001$), supporting factor analysis suitability.

Results

This study used a variety of statistical methods, including independent sample t-tests, one-way analysis of variance, Pearson correlation analysis, linear regression analysis, mediation effect analysis and moderating effect analysis, to explore the impact of technology-enhanced learning on student engagement and to test the mediating role of self-regulated learning and the moderating role of the sense of presence in teaching. The sample size was 387, the data quality was high, and all scales had good reliability and high internal consistency.

Descriptive statistics and group difference analysis:

The descriptive analysis of the 387 valid questionnaire responses provides a well-balanced and informative profile of the respondents' background characteristics.

In terms of gender distribution, the sample is nearly evenly split, with 49.1% male (n = 190) and 50.9% female (n = 197). This balanced representation helps minimize potential gender bias and enhances the generalizability of the results across male and female student populations.

Regarding the age distribution, the majority of respondents (76.2%) fall within the 18–23 age range. Specifically, 52.7% are aged 18–20, and 23.5% are aged 21–23, reflecting the typical age demographic of undergraduate students in higher education. Smaller proportions were found in the 24–

26 age group (8.8%) and among those aged 27 and above (15.0%). This concentration of younger participants aligns with the study's focus on student experiences in digital learning environments.

For the academic performance variable, measured via current cumulative grade point average (GPA), the sample displays a moderate-to-high academic profile. The largest proportion of students (41.6%) reported a GPA between 2.5 and 2.99, followed by 27.6% with a GPA between 3.0 and 3.49. Additionally, 16.8% fell within the 2.0–2.49 range, and 9.0% had a GPA in the highest category (3.5–4.0). Only a small proportion (4.9%) had a GPA below 2.0, indicating a relatively small low-performance group in the sample.

With respect to internet accessibility, over half of the respondents (54.3%) indicated that their internet connection was stable and fast, ensuring smooth participation in online learning. Meanwhile, 32.6% reported having unstable or slow connections, and 13.2% lacked regular or fixed internet access. These findings highlight the continuing digital divide among students and underscore the importance of equitable technological infrastructure in technology-enhanced learning contexts.

(1) Gender differences

The results of the independent sample t-test showed that there were significant statistical differences between the genders in the four core variables of technology-enhanced learning, student engagement, self-regulated learning, and sense of presence in teaching. This result suggests that female students may have a relative advantage in terms of learning motivation, digital literacy, or classroom perception.

(2) Age differences

One-way ANOVA showed that there were also significant mean differences among the four variables in different age groups. As they grow older, students' learning styles and awareness of the use of teaching resources may gradually increase.

(3) Academic performance (GPA) differences

One-way ANOVA by GPA showed highly significant differences ($p < .001$) between the four variables for different GPA groups. Students with high GPAs scored higher in terms of learning engagement, self-regulation, experience of technology use, and perceived teaching interaction.

(4) Internet accessibility

Under the grouping of network access conditions (high-speed and stable, unstable or no fixed network), there were significant differences ($p < .001$) in the four core variables. Students with good network conditions performed better in terms of technology use, course participation, self-directed learning and perceived teaching support, highlighting the fundamental role of network infrastructure in digital education.

Correlation analysis:

The Pearson correlation analysis showed that there were significant positive correlations between all core variables, and the correlation coefficients are as follows:

Table 1: Correlation Analysis

Variable Pair	r	p-value
Technology-Enhanced Learning & Student Engagement	0.974	< .001
Technology-Enhanced Learning & Self-Regulated Learning	0.952	< .001
Technology-Enhanced Learning & Teaching Presence	0.79	< .001
Student Engagement & Self-Regulated Learning	0.938	< .001
Student Engagement & Teaching Presence	0.804	< .001
Self-Regulated Learning & Teaching Presence	0.801	< .001

(** Significance level 0.01, two-tailed test)

Hypothesis Testing:

H1: Direct Effect of TEL on Engagement

Linear regression demonstrated a strong predictive effect of technology-enhanced learning on student engagement:

Table 2: Regression Analysis

Model Summary	Value
R^2	0.948
F (1, 385)	7069.978
B (TEL → Engagement)	1.033
p-value	< .001

Conclusion: H1 supported. Technology-enhanced learning significantly and positively predicts student engagement.

H2: Mediation by Self-Regulated Learning

Mediation analysis confirmed that self-regulated learning partially mediates the relationship between TEL and engagement：

Table 3: Intermediary analysis

Effect Type	Coefficient	BootSE95%	CI Lower95%	CI Upper	p-value
Total Effect	0.9181	0.0109	0.8966	0.9396	< .001
Direct Effect	0.6368	0.0277	0.5823	0.6913	< .001
Indirect Effect	0.2813	0.0302	0.2242	0.3421	-
Std. Indirect Effect	0.2984	0.032	0.238	0.3624	-

Conclusion: H2 supported. Self-regulated learning significantly mediates the relationship between TEL and engagement.

H3: Moderation by Teaching Presence

Moderation analysis showed that teaching presence positively moderates the effect of TEL on student engagement：

Table 4: Analysis of the moderating effect

Predictor	B	t	p-value95%	CI Lower95%	CI Upper
Technology-Enhanced Learning	0.6221	30.05	< .001	0.5816	0.6625
Teaching Presence	0.2834	12.59	< .001	0.2392	0.3276
Interaction Term (X × W)	0.0312	4.29	< .001	0.0168	0.0455

Conclusion: H3 supported. Teaching presence enhances the impact of technology-enhanced learning on student engagement.

The empirical findings validate the theoretical model proposed in this study. Technology-enhanced learning significantly influences student engagement, both directly and through self-regulated learning. Furthermore, teaching presence strengthens this relationship, highlighting the importance of instructor support in digital environments. The findings suggest that institutional and pedagogical strategies should focus not only on technology deployment but also on fostering self-regulatory skills and strengthening teaching presence to optimize student engagement in digital learning contexts.

Discussion

This study set out to examine the mechanisms by which technology-enhanced learning (TEL) affects student engagement, incorporating the mediating role of self-regulated learning (SRL) and the moderating role of teaching presence. The analysis draws upon Zimmerman's (2002) social cognitive theory of self-regulation and the Community of Inquiry (CoI) framework proposed by Anderson et al. (2001), offering a robust theoretical lens through which to interpret the complex interplay between technology, learner autonomy, and instructional support.

One of the most salient findings is that academic performance (GPA) is a strong predictor of students' digital learning experiences. Students with higher academic achievement consistently scored better on all four dimensions—TEL, SRL, teaching presence, and engagement. This supports Pintrich and De Groot's (1990) assertion that academic success is closely tied to the use of effective self-regulatory strategies. High-performing students appear to be more intrinsically motivated, metacognitively aware, and capable of leveraging digital learning tools to their advantage. These

students demonstrate a greater ability to manage their time, monitor their progress, and engage meaningfully in digital learning environments. Thus, educational institutions must consider differentiated support strategies to ensure equity for lower-performing students.

Equally important is the role of internet accessibility in shaping students' learning experiences. The study found that students with stable and fast internet access reported significantly higher scores across all variables. This reaffirms findings by Park and Shea (2020), who cautioned that the digital divide remains a substantial barrier to equitable learning. Inadequate access not only limits participation but also undermines students' ability to interact with instructors and peers, submit assignments, and receive feedback in a timely manner. Therefore, technological infrastructure should be considered a foundational requirement for implementing effective TEL strategies. Educational administrators should prioritize digital equity by investing in high-speed connectivity, particularly for students from underprivileged regions.

The study also reveals significant inter-variable relationships. Pearson correlation analysis indicated nearly perfect positive correlations between TEL and engagement ($r = .974$), as well as TEL and SRL ($r = .952$). These findings suggest that students who experience higher levels of technological support are also more likely to self-regulate their learning and demonstrate active participation. In alignment with Martin and Bolliger (2018), this study confirms that well-structured digital environments—especially those that include timely feedback, interactive tasks, and autonomy-supportive features—can significantly enhance students' behavioral, emotional, and cognitive investment in learning.

Teaching presence plays an equally critical role. A correlation coefficient of .790 between TEL and teaching presence, along with .804 between engagement and teaching presence, demonstrates that the instructor's role extends beyond content delivery. In the context of digital environments, instructional design, feedback, clarity of objectives, and emotional support form the backbone of what Anderson et al. (2001) describe as "teaching presence." Effective teaching presence bridges the gap between technology and pedagogy, ensuring that learners do not feel isolated and remain motivated. Richardson et al. (2017) highlighted that pre-recorded lectures, personalized comments, and instructor visibility can improve learner satisfaction and persistence—points that are echoed by the present study.

In addition, this study systematically examines the differential expression of gender and age on the four core variables of technology-enhanced learning, self-regulated learning (SRL), pedagogical presence, and student engagement. The analysis results show that these two variables have a significant impact on all dimensions, indicating that individual gender and age factors still play a significant role in the digital learning environment. This finding is in dialogue with earlier research such as Kay (2006), which proposed that "gender may affect technology adoption," but also shows a new trend. In the context of the widespread use of educational technology and the highly normalized use of learning platforms, the technology gap between the genders is gradually narrowing, although there may still be

some differences in performance in terms of learning motivation, strategy use, and interaction perception.

Similarly, the age variable also shows statistically significant differences in the four dimensions, indicating that generational background and stage of development may affect individual learning cognition and behavior to some extent. This result suggests that when understanding digital learning behavior, it should not be simply attributed to the "universal homogenization" of technological literacy, but rather attention should be paid to the differences between genders and ages in terms of self-regulatory ability, cognitive maturity, and social participation tendencies, so as to provide a more targeted basis for subsequent personalized teaching interventions and technology adaptation strategies.

The mediation analysis confirmed that self-regulated learning significantly mediates the relationship between TEL and student engagement. The indirect effect (B = 0.2813) accounted for roughly one-third of the total effect, suggesting that students benefit most from technology when they are capable of managing their own learning. This supports Zimmerman's (2002) theory that students who regulate their cognition, behavior, and emotions are better equipped to engage with flexible, asynchronous digital learning environments. Instructors and platform designers should, therefore, embed SRL-supportive tools such as goal-setting features, learning analytics dashboards, and reflection prompts into their course designs.

Additionally, the moderation analysis established that teaching presence significantly moderates the relationship between TEL and student engagement (interaction term B = 0.0312, $p < .001$). This means that students' engagement is amplified when they perceive their instructors as present, supportive, and responsive. This aligns with the CoI model, which emphasizes that social and cognitive presence are reinforced through active teaching presence (Anderson et al., 2001). Teachers must be more than facilitators of content; they must be emotionally and cognitively present through timely responses, personalized guidance, and active involvement in online forums and discussions.

In conclusion, the discussion of results underscores the multifaceted nature of student engagement in digital environments. While technology offers tools for personalization, flexibility, and efficiency, its impact is not deterministic. Engagement is best achieved through the dynamic interaction between technology, self-regulation, and instructional support. These findings contribute to a growing body of literature that calls for a balanced and integrated approach to digital education—one that recognizes both technological affordances and pedagogical imperatives.

Conclusion

First, this study verified that technology-enhanced learning has a significant positive predictive effect on student engagement. This result supports Hypothesis 1 (H1) and is consistent with previous literature, which emphasizes that technology, when combined with good instructional design, can effectively enhance students' cognitive, behavioral, and affective engagement (Broadbent & Poon, 2015;

Martin & Bolliger, 2018). When students believe that digital platforms are well-functioning, the content is clear, and feedback is timely, they are more willing to actively participate in learning.

Second, the study confirmed that self-regulated learning plays a significant mediating role between technology-enhanced learning and student engagement. Students who have the ability to set learning goals, monitor progress, and reflect can make fuller use of platform resources to achieve in-depth learning. This result supports the theories of Zimmerman (2002) and Winne and Hadwin (2008), which emphasize that self-regulation is a key learning ability that can be cultivated. Therefore, it is not enough to rely on technology to promote learning; it is also necessary to support students' self-management by designing teaching strategies that promote metacognitive behaviors.

Third, the empirical results verify the moderating role of pedagogical presence in the impact of TEL on engagement. The impact of technology on learning behavior was significantly enhanced when students felt that the teacher remained active, provided feedback, and guided discussions in the digital environment. This finding supports Hypothesis 3 (H3) and echoes the key role of teachers in cognitive and affective engagement in the Communities of Inquiry model (Anderson et al., 2001; Richardson et al., 2017). In virtual learning spaces, teaching should not be limited to content delivery, but should also focus on interaction, feedback, and empathy.

In addition, the results of this study further indicate that academic performance (GPA) and Internet accessibility have a significant impact in predicting student learning behavior, and their role is stronger than demographic variables such as gender and age. Specifically, students with higher GPA scores demonstrated significant advantages in the four dimensions of technology-enhanced learning, self-regulated learning, student engagement, and sense of presence in teaching (all $p < .001$). These students showed stronger learning motivation and self-discipline, and were able to integrate technology tools into the learning process more effectively, indicating a high positive correlation between academic ability and learning strategies.

This study contributes to the theoretical development in the field of educational technology in the following ways:

1. A comprehensive research model that combines self-determination theory and the community of inquiry model was validated, providing theoretical support for understanding student learning behavior in a technology-rich environment.

2. The bridging role of self-regulated learning as a mechanism variable between technology and participation was emphasized, expanding the theoretical boundaries of the relationship between learning motivation and behavior.

3. The sense of presence in teaching was established as a conditional variable, demonstrating the boundary moderating effect of teachers' guiding and supporting role in a digital environment.

4. A “technology-psychology-pedagogy” ternary interaction model is proposed, which explains the relationship between technology and educational effectiveness in digital learning from a structural

mechanism.

The empirical results of this study provide the following practical insights for college teachers, curriculum designers, and education policymakers:

Teachers should enhance the sense of digital teaching presence: improve students' perceived sense of teaching presence through curriculum structure optimization, timely feedback, online interaction, and emotional support. It is recommended that teachers take the initiative to design student-teacher communication sessions when using platforms such as Moodle, Rain Classroom or Tencent Classroom. Designers should embed SRL support functions: It is recommended that course platforms add modules such as goal setting, learning diaries, progress reminders, and visualization of learning trajectories to promote students' self-regulation abilities, especially for beginners or low self-discipline students. Educational institutions need to pay attention to technological equality: It is recommended that the impact of the technological divide on learning equity be reduced through school-supported network access plans, data subsidies, optimizing low-bandwidth learning resources, etc., to reduce the impact of the technology divide on learning equity. Course management should support the ecological design of blended learning: courses should no longer just be the digitization of content, but should consider the integration of digital resources with cognitive tasks and social interactions to create a complete learning environment that includes interaction, reflection, and feedback. Monitoring and evaluation mechanisms need to be institutionalized: through learning data analysis, participation monitoring, and questionnaire feedback, teaching practices can be continuously optimized and strategies adjusted to form a “data-driven, continuous improvement” education quality improvement mechanism.

Based on the empirical findings of this study, the following five recommendations are proposed to improve the effectiveness and fairness of technology-enhanced learning in higher education. First, teacher training mechanisms should be strengthened. It is recommended that universities regularly organize online teaching literacy training, focusing on improving teachers' interaction skills, feedback methods, and student support strategies in virtual teaching environments, and enhancing teachers' sense of presence in teaching on digital platforms. Second, a Self-Regulated Learning (SRL) support module should be embedded in the teaching design, such as setting goal-guidance prompts, task lists, self-assessment tools, and reflection diaries, to promote the development of students' metacognitive abilities and enhance their learning autonomy and persistence in the digital environment. Third, in view of the current digital divide, universities should work with operators to actively explore the provision of educational data packages or Wi-Fi subsidies for students, especially those from economically disadvantaged or geographically remote areas, to achieve equitable access to digital learning resources. Fourth, for students with relatively weak academic performance, a personalized intervention system should be established, including the implementation of a peer tutoring mechanism, the development of academic counseling services, and the provision of learning strategy training workshops to help students

enhance their sense of self-efficacy and academic adaptability. Finally, it is recommended that educational management departments establish a data-based decision support system that dynamically assesses the effectiveness of teaching quality and technology integration through the continuous collection and analysis of data on student engagement, platform usage, and satisfaction, in order to optimize and upgrade teaching content and resource allocation. The above five recommendations complement each other and together they can build a future-oriented high-quality, inclusive, and learner-centered technology-enhanced learning ecosystem. In summary, this study shows that student engagement is not an automatic product of technology itself, but rather the result of the interaction between technology, learners' self-regulation abilities, and teachers' pedagogical support. As higher education continues to transition towards digitalization, future curriculum design and educational reform should pay more attention to the collaborative advancement of platform functions, instructional design, and student learning strategies. Only by building a learning ecosystem with "people-oriented, interactive, and data-driven" as its core can educational innovation with true deep engagement and fairness be achieved.

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