

INTRODUCTION

Worldwide, higher education establishments are progressively investing in and implementing digital technologies, propelling all-around changes throughout the education field. This tendency shows an active reaction to digital transformation, as universities make use of creative technologies to boost teaching methods and elevate educational standards. The notion of emergency remote teaching, as deliberated by Hodges et al. (2020), has progressively been replaced by systematically designed digital teaching models. This transformation not only shows the deep cognition of online learning in the academic circle, but also highlights the increasing complexity of the application of technology in the whole field of education. In this context, the digital transformation of the manufacturing industry and the advent of the era of Industry 4.0 have further promoted the development of online engineering education. Especially in China, these global trends are very consistent with the national strategy of Made in China 2025 and the policy of new engineering construction, which adds new vitality and development direction to higher education.

However, this transformation shows an unbalanced development situation in different fields. Mechanical engineering is a typical practical field, which focuses on hands-on practice, intuitive cognition and teamwork to solve problems. This field faces major challenges that traditional online platforms are difficult to deal with (Fatehiboroujeni et al., 2020). For the most important interactive and immersive learning environments in these fields, it is often impossible to get sufficient support from existing technical solutions. Empirical data confirm the finding that the dropout rate of students in STEM-related fields is higher than that of other courses (Seymour & Hunter, 2019), and the completion rate of online courses reflects a more obvious lack (Shaikh & Asif, 2022). In detail, the phenomenon of dropout in online mechanical engineering education can be seen as a process of gradual reduction of cognition, emotion, behavior and social participation, in which psychosocial factors play a major intermediary role. This shows that students may further gradually experience a progressive sense of alienation due to

insufficient cognitive stimulation, lack of emotional support, lack of behavioral guidance or insufficient social participation.

Online learning involvement of mechanical engineering students is affected by a variety of interrelated elements, forming a multi-level barrier structure that includes both external environmental circumstances and internal psychological states. External elements consist of technical assistance, curriculum planning, and resource availability. In contrast, internal elements relate to self-confidence, learning drive, and emotional state. Most of the existing studies analyze these factors individually. Concentrating mainly on variables centered around students or teachers, yet neglecting the synergistic impacts among psychosocial and technological factors—such as online self-efficacy (OLSE), social presence (SP), and teacher emotional support (TES). Online self-efficacy is vital for learners assurance in handling tasks and technologies, influencing their perseverance, stances, and achievements (Maarek, 2021). Teacher Emotional support is crucial in cultivating intrinsic motivation and encouraging profound involvement. (Ong & Quek, 2023) Emotionally supportive instruction corresponds to students psychological requirements for autonomy, competence, and relatedness, thus improving cognitive and affective involvement (Otto et al., 2023; Pan, 2022). Interactive elements in the curriculum, like the dialogue between instructors and students, collaboration among peers, and responsive digital interfaces, further foster social presence, which is a key construct affecting engagement (Petretto et al., 2021; Qi & Yue, 2023).

Although there is a large amount of literature exploring the elements influencing student engagement, some research lacunae still exist. Firstly, there is a dearth of empirically-based studies customized to the particular requirements of online mechanical engineering education. In other words, the current research frequently fails to properly tackle the disciplines strong dependence on practical skill growth, leading to a gap between theoretical deliberations and real-world educational requirements. Secondly, the mechanisms by which psychosocial factors impact engagement need

further elucidation. Although certain studies emphasize the significance of these elements, their causal associations and impact pathways are still inadequately investigated.

The inquiries for the research (RQs) are presented below:

RQ1: What are the immediate impacts of OLSE and TES on SP, and the immediate impacts of OLSE, TES, and SP on OSE?

RQ2: Is there a significant mediating effect of SP on the relationship between TES and OSE?

RQ3: Does SP notably mediate the connection between OLSE and OSE?

Current Research Landscape on Online Student Engagement

Most of the previous studies rely on shallow indicators such as login duration and click frequency to evaluate the degree of learning engagement. This method has inherent limitations. With the continuous advancement of academic research, the paradigm shift towards neuropedagogy methods is more obvious. For example, in the field of mechanical engineering, the lack of specific tactile feedback may hinder the full activation of the somatosensory cortex and further weaken the spatial reasoning ability (Khodadad, 2023). Therefore, it is insufficient to rely solely on traditional surface behavior indicators when evaluating the degree of learning engagement. It is necessary to carry out comprehensive research work, integrating emotional, cognitive and neurophysiological factors. Emotional engagement is related to learners ' emotional feelings in online teaching situations, including curiosity, motivation, anxiety and sense of belonging. Positive emotional effort can significantly improve the durability and depth of learning. From the perspective of cognitive engagement, it mainly lies in learners ' mastery of mechanical engineering knowledge, critical thinking literacy and problem-solving ability, such as the ability to use high-order reasoning or evaluate engineering systems in complex mechanical design assignments. This multi-dimensional evaluation framework brings a more complete and true portrayal of students ' engagement in online mechanical engineering education. The current research breaks through

the limitations of traditional single-aspect behavior measurement and provides theoretical support for deeply exploring the complex mechanism behind students ' engagement. Psychosocial factors are the main aspects of the analysis, which not only show the differences in the degree of long-term investment, but also deeply reveal the internal mechanism behind these differences. Specifically, this aspect includes students ' self-regulation ability, emotional support perceived in the learning environment, and their sense of belonging in the learning group. This study focuses on this basic element, and studies the influence of self-confidence, teachers ' emotional support and social presence on the engagement behavior in online mechanical engineering courses.

Oline self-efficacy(OLSE) and Online Student Engagement(OSE)

In 1977, the well-known psychologist Albert Bandura initially put forward the idea of self-efficacy. This concept pertains to an individuals evaluation of their capacity to arrange and execute the necessary actions to achieve specific goals. Susilowati et al (2022) further elaborated that self-efficacy plays a vital role in affecting decision-making, the distribution of effort, and the tenacity in task completion. The need to view Online Learning Self-Efficacy (OLSE) as a distinct concept comes from the understanding that extra capabilities are needed in online learning settings. In the context of Chinas higher-education field, the available research data offers useful perspectives for the current study. A study carried out on 605 students who participated in an online math class at a university in Guangzhou indicated that learning self-efficacy directly affects three elements of learning involvement, namely, learning passion, concentration, and immersion. (Luo et al., 2024). A domestic research involving 1,032 college students further confirmed the direct connection between academic self-efficacy and learning involvement. However, when psychological resilience and professional commitment were introduced as mediating variables, the relationship was fully mediated. (Wang et al., 2024). The patterns of full and partial mediation observed in various studies imply that the association between OLSE and learning engagement might rely on the particular

mediating variables included in the model, which provides direct implications for the mediation design of this research.

Teacher emotional support(TES) and Online Student Engagement(OSE)

Teacher emotional support (TES) pertains to the aspect by which educators express care, responsiveness, empathy, and encouragement to students through instructional actions. Within the framework of the Classroom Assessment Scoring System (CLASS), Pianta and Hamre (2009) defined emotional support as including aspects like creating a positive classroom environment, addressing students personal requirements, and valuing their viewpoints. This conceptualization views TES as a distinct set of teachable and evaluable instructional actions, instead of as a personality characteristic. In the current research, TES is described as the perception of mechanical engineering students regarding the degree to which instructors show such supportive actions in a digital educational context.

In in-person teaching settings, Ruzek et al. (2016) conducted a long-term investigation by using independent classroom observations (CLASS-S). They found that higher degrees of teacher emotional support at the beginning of the school year were associated with improved behavioral engagement and mastery motivation in teenagers later in that year. By means of structural equation modeling (SEM) involving 411 Chinese university students, Shen and colleagues (2024) demonstrated that teacher support (TES) predicts academic engagement through positive academic emotions and mastery-approach goals, providing empirical support for the social-cognitive perspective that external support influences engagement via internal psychological processes.

Furthermore, proof within the realm of online learning is quickly amassing. A research by Sun and colleagues (2025) encompassing 361 Chinese university students showed that the perceived emotional support from teachers significantly and positively forecasts online learning engagement, where academic burnout acts as a mediator. Guo et al. (2025) additionally verified, also through structural equation modeling with Chinese university students, that TES has a positive prediction on learning engagement,

where academic self-efficacy and academic resilience serve as sequential mediators. The overall indirect effect (0.265) was more prominent than the direct effect, indicating that teacher emotional support impacts learning engagement mainly via psychological mediating mechanisms instead of through direct motivation. However, studies on the emotional support provided by teachers are still relatively limited in the realm of engineering education.

Social Presence as a Mediating Mechanism

The concept of Social Presence (SP) originates from the groundbreaking research conducted by Short et al. (1976), who emphasized the importance of interaction partners in mediated communication. Garrison 等人 (2000) subsequently positioned social presence within the Community of Inquiry (CoI) framework, depicting it as the ability of participants to present themselves as genuine individuals in socio-emotional contexts. Social presence shows a transitive characteristic: through offering social-emotional mediation, it transfers the effect of Teacher Emotional Support (TES) and Online Learning Support Environment (OLSE) to learning engagement results, thus allowing these impacts to be felt and maintained. Kong 等人 (2025) conducted empirical validation with a sample of high-school pupils and found that the emotional support perceived by teachers can positively forecast online learning engagement via a serial mediation route. Garrison et al. (2010) showed that in online courses, teaching presence can forecast social presence—this result was further confirmed by Shea and Bidjerano (2009) when studying community college students. Although these research efforts defined teaching presence in a wide-ranging manner, including instructional design, facilitative teaching, and direct instruction, instead of singling out emotional support, the aspect of facilitative teaching, which lays stress on interpersonal communication and emotional manifestation in teaching actions, is most in line with the definition of TES. Miao and Ma (2022) further discovered that self-regulation, a concept closely linked to self-efficacy in social cognitive theory, forecasts social presence. This social presence then mediates the relationship between self-regulation and learning engagement.

Theoretical framework

The current model consists of three component parts: inherent beliefs, external assistance, and social

connectivity. These dimensions of explanation vary significantly, and no solitary theoretical framework can fully account for all the relevant elements. The Social Cognitive Theory (SCT), presented by Bandura (1986), provides a theoretical foundation for self-efficacy within online learning. Self-Determination Theory (SDT), initially presented by Deci and Ryan in 1985 and comprehensively revised by Ryan and Deci in 2017, provides a theoretical basis for integrating teacher emotional support as a crucial external motivator in the framework. The Community of Inquiry (CoI) framework, put forward by Garrison et al. (2000), constitutes the theoretical foundation for the mediating impact of social presence in the suggested conceptual model.

According to Self-Determination Theory, the satisfaction of three fundamental psychological needs, namely autonomy, competence, and relatedness, drives learners self-guided behaviors. (Ryan & Deci 1985) Autonomy denotes the ability for decision-making and willpower in learning endeavors; competence represents an individual's perceived feeling of efficacy and proficiency, which is closely linked to self-efficacy; and relatedness involves emotional assistance and interpersonal bond, frequently shown in teacher-student communications. Flexible learning assignments and constructive input boost autonomy and proficiency, while emotionally supportive instruction nurtures relatedness and intrinsic drive (Romano et al 2020). Accomplishment of these requirements encourages continuous involvement, as learners encounter a stronger feeling of control, self-assurance, and a more profound connection during their online learning encounters.

Social Cognitive Theory highlights the concept of triadic reciprocal determinism, where individual factors (such as beliefs and self-efficacy), environmental elements (like instructional design and peer interaction), and behavioral aspects (for example, effort and engagement) interact in a dynamic way (Bandura 1997). In this framework, self-efficacy holds a significant position as a crucial personal factor influencing effort, perseverance, and task achievement. The theory suggests that strong self-efficacy results in greater effort and continued involvement.

The CoI framework indicates that effective learning within virtual environments depends on the interplay of three vital elements (Garrison et al. 2000). Within these, social presence pertains to the ability of participants to showcase themselves socially and emotionally as real individuals, thereby promoting self-expression. Social presence acts as an environmental element that represents authenticity and interpersonal connections in virtual learning settings, acting as a mediating variable that boosts learner involvement.

In conclusion, Self-Determination Theory clarifies the mechanisms of inherent motivation that support online learning involvement through the satisfaction of fundamental psychological needs for autonomy, competence, and relatedness. Social Cognitive Theory emphasizes the active interaction between self-efficacy beliefs and environmental elements, explaining how students keep up continuous learning motivation in online settings (Richardson & Swan, 2003). The integration of these two theoretical models provides a solid foundation for analyzing the complex evolution of learning engagement in online mechanical engineering education. In detail, the comprehensive model explains how self-efficacy (as a major personal belief), teachers' emotional support (as an important social psychological factor) and social presence (as a core variable linking technical factors and situational factors) together determine the degree of learning engagement. Among them, social presence not only reflects learners' cognition of the technical environment, but also serves as a major mediating variable: it is the main way for teachers' emotional support to act on students' psychological cognition, and it is also a situational factor that strengthens or regulates the influence of self-efficacy on learning participation. This integrated theoretical basis provides strong support for the construction of the theoretical model of this study, and finally establishes an integrated online learning participation analysis framework that integrates social psychological and technical environmental factors, and provides a clear theoretical guidance for the subsequent exploration of the direct impact and mediating effect between variables.

Hypothesis derivation

H1: Emotional support from teachers (TES) has a notable positive impact on social presence (SP). When educators show empathy, address student problems, and create a safe classroom environment, they meet a basic relational requirement that enhances students social participation in the learning community (Ryan and Deci 2020). In digital settings with limited social signals, this kindness started by instructors could be the crucial factor for students to view others as sincere and approachable, which is the essence of social presence (Kong et al.2025). This influence is expected to be especially significant in mechanical engineering, as technical challenges and performance-associated stress can limit social communication unless the teacher designates a secure relational context.

H2: Online learning self-efficacy (OLSE) exerts a notable positive influence on social presence (SP).

According to Social Cognitive Theory, the perseverance in tasks is decided by self-efficacy and then affects an individuals inclination to participate in challenging social behaviors (Bandura, 1997). Students doubting their capacity to finish online course tasks usually hesitate to disclose uncertainties via social interaction. In contrast, self-assured learners are inclined to start discussions actively, help fellow students, and voice opposing views openly—actions that represent social presence. The study carried out by Hsu et al.(2022) indicates that self-efficacy in online learning environments predicts an individuals inclination towards social engagement, strengthening the concept that confidence leads to social presence rather than social presence emerging from confidence.

H3: Emotional support from teachers (TES) exerts a notably positive influence on students online engagement (OSE).

Instructors emotional support can effectively alleviate the affective obstacles that online learners encounter when there is no face-to-face interaction. A research conducted by Yang and colleagues(2022) showed that this kind of support boosts course involvement among Chinese university students through reducing anxiety and enhancing learning drive. Analogous findings were

reported by Huang and Wang (2023) within the context of blended learning. Research additionally forecasts that in technically challenging online mechanical engineering courses having high failure percentages, a friendly instructor attitude along with prompt feedback can directly combat student burnout.

H4: Online learning self-efficacy (OLSE) exerts a notable positive impact on online student engagement (OSE).

Whether students will undertake difficult tasks, the degree of effort they put in, and the perseverance they show when they encounter obstacles all depend on their self-efficacy (Bandura, 1997). Zimmerman (2000) integrated these determinants into a self-regulated learning cycle, highlighting that efficient learners tend to set more challenging goals and monitor their progress in a more strategic way. In the context of network mechanical engineering education, if there is no direct guidance of physical laboratories and hands-on practice workshops, the demand for autonomous learning is particularly obvious. Therefore, self-efficacy is defined as the most direct cognitive driving factor for continuous engagement in the learning process.

H5: Social presence has a significant positive effect on the participation of online students.

When students regard classmates and teachers as real people in real life, not just text images on the screen, they will show more active input, firmer will to overcome difficulties and deeper emotional effort in the learning process. Garrison et al. (2010) regarded social presence as the core element of the research community framework, which is very important for achieving meaningful cognitive participation. Richardson et al. (2017) conducted a meta-analysis of 42 research work and confirmed that there is a continuous positive correlation between social presence and learning outcomes in various online learning situations. This type of association is also applicable in the field of mechanical engineering. In this field, collaborative design projects and the solution of technical problems require a solid social association.

H6: Sense of social presence plays a significant mediating role in the relationship between

teachers' emotional support and online student engagement.

H7: Social presence plays a significant mediating role between online learning self-efficacy and online student engagement.

Research estimates show that teachers' emotional support and online learning self-efficacy not only directly improve students' participation, but also maintain participation based on cultivating social presence. Although the ways of influence are different, the basic mechanism remains unchanged. Teachers' emotional support is based on relationship building and normative setting, which makes social interaction meaningful, and self-efficacy determines whether students can gain a sense of security by virtue of their self-confidence. The perception of social presence as an important part of transforming pre-existing resources into participatory action (Wu, 2023 ; kong et al., 2025). Doo and Bonk (2020) provide indirect support for the theoretical scheme. They point out that in online teaching, the effect of teaching presence on learning effectiveness is mediated by social presence. This study expands this idea into a model that distinguishes internal and external prerequisites, and studies their indirect influence paths in a unified analysis scheme.

METHODS

Study Design

This study employs a quantitative cross-sectional survey approach and uses structural equation modeling (SEM) to analyze the data. Its objective is to investigate the inter-connections among online learning self-efficacy (OLSE), teacher emotional support (TES), social presence (SP), and online student engagement (OSE) among undergraduate students majoring in Mechanical Engineering in China, as well as the mediating function of social presence (SP) within this framework. This study focuses on structural correlation analysis, not causal derivation, which makes cross-sectional surveys particularly applicable in the exploratory period of model verification. From the perspective of methodology, the main purpose is to verify whether the structural association of the hypothesis exists and to evaluate its strength. On the basis of careful analysis of the

data, cross-sectional data are considered sufficient to achieve the objectives of this study (Creswell & Creswell, 2018).

Target population and sampling

The object of this study is the full-time undergraduate students majoring in mechanical engineering in Guangdong Province, China. In order to comprehensively consider the representativeness and the feasibility of actual operation, this study used a two-stage stratified cluster sampling method.

At the initial stage, a stratified cluster screening method was used. The main criteria for stratification are determined according to geographical factors : the core regional cities of the Pearl River Delta, as the hub of advanced equipment manufacturing industry, gather high-density engineering projects ; most of the surrounding cities in the Pearl River Delta focus on supporting industries or specific manufacturing fields ; the agglomeration degree of machinery manufacturing enterprises in non-Pearl River Delta cities is usually low. The classification system roughly describes the regional distribution pattern of industrial resources and higher education resources. Secondary stratification is carried out in colleges and universities. In the field of geographical classification, according to the overall status of colleges and universities and professional standards, colleges and universities are divided into key colleges and ordinary colleges and universities, ensuring that the sample includes both research universities and practice-oriented vocational colleges, so as to capture the diverse institutional environment for students to participate in online learning.

The final selected samples include 25 schools in 14 cities in the three major geographical categories, including key universities, ordinary undergraduate colleges and vocational colleges. In the subsequent stage, data collection is carried out in the selected cluster. The researchers distributed questionnaires to students from grade 1 to grade 4 of mechanical engineering in participating institutions, including all groups of students who can contact. A total of 595 questionnaires were distributed.

After removing invalid answers, processing missing data and identifying abnormal values, 507

valid samples were retained for subsequent analysis. The selection of the number of samples follows the general principle of multivariate analysis to ensure that the statistical power reaches the appropriate level.

Measuring tools

The questionnaire includes four validated subscales and demographic related parts.

- (1) The degree of students' online engagement. The assessment uses a 16-item scale compiled by Hoi and Le (2021). This scale is based on the 5-point Likert scale (1 = very disagree to 5 = very agree) to assess behavioral, cognitive, and emotional engagement.
- (2) Perception of social existence. The measurement scale is derived from the study of Richardson and Swan (2023), with a total of nine items. The purpose is to evaluate the authenticity and sense of connection perceived by students in online interaction.
- (3) Online learning self-efficacy. The cited data come from the research carried out by Tsai et al. This scale contains 10 items to assess the self-efficacy of individuals in dealing with online tasks, using digital tools, and participating in collaborative work in a virtual environment. All data were collected in 2020.
- (4) Teachers provide emotional support. The measurement scale is from the research results of Romano et al. (2020), which is used to evaluate the level of empathy, motivation and response characteristics displayed by teachers. It includes a total of 12 projects. Each item was scored using a 5-point Likert scale. The higher the score, the higher the recognition of the corresponding psychological construct or the more prominent the performance.

Scale revision process

The scale optimization is based on four stages to carry out systematic verification and improvement work. In the initial expert review process, adjustments were made according to the project content validity index (I-CVI) and qualitative feedback: in order to improve clarity, two projects related to online

learning self-efficacy (OLSE) were reformulated; to adjust a teacher's emotional support (TES) program; the demographic part was recombined to form three revised items (no deletions). The I-CVI of the project level is in the range of 0.87 to 1.00.

After that, a pre-test was conducted on 30 participants to assess the comprehensibility of the project and the length of time required to respond. A sense of social presence (SP) project is adjusted due to translation-related clarity issues; the term expressions of the two OLSE projects are unified (including one modification). Exploratory factor analysis (EFA) and reliability analysis were conducted in the initial test with 212 respondents. According to the criteria of factor loading less than 0.50 or common factor variance less than 0.50, six projects are finally eliminated: three OLSE projects, one SP project and two TES projects.

The final formal questionnaire was composed of 60 items in four main aspects: online learning self-efficacy (OLSE, 22 items), online learning engagement (OLE, 16 items), social presence (SP, 9 items) and teacher emotional support (TES, 13 items).

Data collection process

The data collection phase of the initial survey ended within four weeks. The whole process includes five successive steps: university cooperation, questionnaire delivery, follow-up tracking, answer verification and final data selection. All participants should read and understand the informed consent form to ensure voluntary participation and anonymity. All the answers will be automatically recorded in Microsoft Excel, and then imported into SPSS for analysis.

Ethical considerations

The data collection phase of the basic research was completed within four weeks. The whole process includes five coherent steps: university cooperation, questionnaire delivery, tracking and supervision, step-by-step verification and final data screening. All participants should carefully study and understand the informed consent, so as to ensure the voluntary participation and anonymity of the whole process. All response system data are recorded in Microsoft Excel and then imported into SPSS for in-depth analysis.

Data analysis

Statistical analyses were performed using SPSS 20 and AMOS 29, which consisted of five consecutive stages :

- (1) Conduct preliminary screening : based on descriptive statistics (such as mean, skewness, kurtosis) to assess missing values, extreme values, and normality assumptions.
- (2) Reliability and Validity Evaluation: Internal Consistency Reliability: This was calculated using Cronbachs α (threshold set at 0.70) and Composite Reliability (CR, with a threshold of 0.90) (Zhou et al.,(2025). Convergent Validity: It was assessed through the Average Variance Extracted (AVE, >0.50).
- (3) Pearsons Correlation Test: Before carrying out Structural Equation Modeling (SEM), Bivariate linear relationships among four crucial constructs (OLSE, TES, SP, OSE) were evaluated using Pearsons product-moment correlation coefficient. Based on the classification criterion put forward by Cohen (1988), correlation intensities were defined as follows: r-values ranging from 0.10 to 0.29. Show a weak correlation, values ranging from 0.30 to 0.49 imply a moderate correlation, and values greater than or equal to 0.50 signify a strong correlation. To mitigate the likelihood of spurious statistical Significance stemming from the large sample size led to all bivariate analyses using a more strict significance threshold of $p < 0.001$ to reduce Type I error (Cohen et al., 2003).
- (4) Confirmatory factor analysis : According to the common practice of the academic community, this study selected a variety of fitting indicators to evaluate the fitting degree of the measurement model and the structural model. Specifically, a χ^2 / df value of less than 3.0 means that the model fits well and less than 5.0 is in the acceptable range (Kline, 2016). When comparing the fitting index (CFI) with the Tucker-Lewis index (TLI), the value of more than 0.95 means that the fitting effect is excellent, and more than 0.90 is in the acceptable range (Hu & Bentler, 1999). The root mean square error of approximation (RMSEA) less than 0.06 means that the fitting is in good condition, and less than 0.08 can be considered acceptable (Hu & Bentler, 1999 ; steiger, 1990).

Standardized residual root mean square (SRMR) less than 0.05 means that the fitting is in good condition, and less than 0.08 is in the acceptable range (Hu & Bentler, 1999). The goodness of fit index (GFI) greater than 0.95 indicates that the fitting effect is excellent, and greater than 0.90 means that the fitting condition is satisfactory (Hair et al., 2012). A Standardized Root Mean Square Residual (SRMR) value below 0.05 suggests a good fit, with values below 0.08 considered acceptable (Hu & Bentler, 1999). A Goodness-of-Fit Index (GFI) value exceeding 0.95 signifies an excellent fit, while values above 0.90 denote an acceptable fit (Hair et al., 2012).

- (5) Structural Equation Modeling: Following satisfactory model fit, path modeling employing maximum likelihood estimation was carried out with AMOS 29 software. Structural analysis was executed in two stages: Path Coefficient Evaluation and Mediation Effect Examination.

RESULTS

Descriptive Statistics

Based on a sample consisting of 507 respondents, descriptive statistical analysis at the construct level indicates that the mean values of the constructs range from 3.17 to 3.39. Teacher Emotional Support (TES) had the highest mean ($M = 3.39$, $SD = 1.27$), while Online Learning Self-Efficacy (OLSE) showed the lowest mean ($M = 3.17$, $SD = 1.05$). The standard deviations, with values from 1.04 to 1.27, show a medium-level dispersion in the data. The absolute magnitudes of skewness and kurtosis lie between 0.27 and 0.49, and 0.89 and 1.18 respectively, and both of these values are beneath the critical thresholds. This implies that the data distribution is close to normality, fulfilling the fundamental assumptions for the following parametric tests.

Reliability and Convergent Validity Analysis

All constructs measurement models display strong psychometric characteristics. The Cronbachs alpha coefficients for Teacher Emotional Support (TES), Online Learning Self-Efficacy (OLSE), Social Presence (SP), and Online Learning Engagement (OSE) range

from .958 to .984, and the composite reliability (CR) figures are in the range of .943 to .971, all exceeding the recommended cutoff of .70. These results indicate excellent internal consistency reliability. The average variance extracted (AVE) values of each construct fall within the range from .806 to .919, all surpassing the standard of .50, thereby providing strong evidence for convergent validity.

Table 3.1 Reliability and Convergent Validity Indices (N = 507)

Construct	Items	Cronbach's α	CR	AVE
TES	13	.984	.971	.919
OLSE	22	.979	.954	.806
SP	9	.958	.943	.806
OSE	16	.974	.958	.850

Note. Cronbach's α was calculated based on the initial questionnaire items. CR and AVE were calculated based on the standardised CFA loadings for dimensional indicators. Threshold values: α is greater than .70, CR is greater than .70, AVE is greater than .50 (Hair et al., 2019).

Pearson Correlation Analysis

A notable positive correlation was detected among all the core variables ($p < .001$). Notably, the strongest

correlation coefficient was found between social presence (SP) and online learning self-efficacy (OLSE) ($r = .492$). After that, there was the correlation between SP and online learning engagement (OSE) ($r = .485$). Teacher emotional support (TES) showed comparable correlation magnitudes with OSE ($r = .443$) and SP ($r = .443$), yet presented a relatively less strong association with OLSE ($r = .377$). Since none of the correlation coefficients went beyond the critical threshold, potential multicollinearity problems were initially excluded, thus backing the feasibility of carrying out subsequent hypothesis testing.

Confirmatory Factor Analysis

The results show that the ratio of chi-square and degree of freedom (χ^2 / df) is 2.953, which is lower than the threshold value of 5.0 and meets the acceptable standard. The root mean square residual (RMR) is 0.032, which is better than the standard threshold of 0.05, which shows that the model has a very good fitting effect. The goodness of fit index (GFI) was 0.929, exceeding the acceptable standard of 0.90. The Tucker-Lewis index (TLI) and comparative fit index (CFI) reached 0.976 and 0.980, respectively, both of which exceeded the ideal critical value of 0.95. Overall, these indicators show that the mediation model shows a satisfactory overall fit.

Table 3.2: Pearson Correlation Matrix of Core Variables (N = 507)

Variable	TES	OLSE	SP	OSE
TES	1			
OLSE	.377***	1		
SP	.443***	.492***	1	
OSE	.443***	.466***	.485***	1

Note. *** $p < 0.001$

Table 3.3: Modelling Model Fit Indices (Mediation Model)

Fit Index	Model Result	Threshold	Evaluation
χ^2	289.351	—	—
df	98	—	—
χ^2 / df	2.953	< 5.0	Acceptable
RMR	.032	< .05	Good
GFI	.929	> .90	Acceptable
CFI	.980	> .95	Good
TLI	.976	> .95	Good

Structural Equation Modeling

Path coefficient assessment shows that all the proposed hypotheses obtained statistical backing ($p < 0.001$). In the aspect of predictive relationships, online learning self-efficacy (OLSE) had the most significant impact on social presence (SP) ($B = 0.398$). Next came the direct influence of OLSE on online learning engagement (OSE) ($B = 0.243$) and the direct effect of teacher emotional support (TES) on OSE ($B = 0.231$). As an intervening variable, SP showed a notable positive impact on OSE ($B = 0.285$). Overall, both TES and OLSE not only directly forecasted OSE but also had an indirect impact via SP. Every path coefficient within the model was statistically significant.

Bootstrap mediation assessment: Hypothesis H6 (TES \rightarrow SP \rightarrow OSE) shows that the indirect influence of TES on OSE through SP is 0.088. The 95% bootstrapped confidence interval, following bias adjustment, was [0.048, 0.142]. As this time-span does not contain zero, the indirect impact is statistically notable. After incorporating the mediator, the direct influence of TES on OSE stayed significant ($B = 0.231$, $p < 0.001$). Since both the indirect and direct impacts are notable, the outcomes meet the standards for partial mediation put forward by Zhao et al. (2010). H6 is affirmed: SP plays a partial mediating role in the

relationship between TES and OSE.

Hypothesis H7 (OLSE \rightarrow SP \rightarrow OSE): The indirect influence of OLSE on OSE via SP was 0.113, having a bias-corrected 95% bootstrap confidence interval spanning from [0.066, 0.172]. Since the range does not include zero, the indirect influence is statistically notable. Following the incorporation of the mediator, the direct impact of OLSE on OSE remained significant ($B = 0.243$, $p < 0.001$). Considering the significance of both the indirect and direct impacts, partial mediation is suggested. H7 is verified: SP plays a partial role in mediating the link between OLSE and OSE.

DISCUSSION OF RESULTS

The current research shows that teachers' emotional support and online learning self-efficacy have a significant positive effect on predicting online learning engagement, which is consistent with the existing research conclusions. For example, Fredricks et al. (2004) showed that teacher support was the main external factor affecting learning engagement. The social cognitive theory proposed by Bandura (1997) shows that self-efficacy is the main internal motivation to maintain learning behavior. The direct impact of teachers' emotional support on online learning engagement

Table 3.4: Standardised Path Coefficients (Mediation Model)

H	Path	B	B	S.E.	C.R.	p	Result
H1	TES \square SP	.308	.235	.033	7.213	< 0.001	Supported
H2	OLSE \square SP	.398	.377	.042	9.091	< 0.001	Supported
H3	TES \square OSE	.231	.167	.032	5.302	< 0.001	Supported
H4	OLSE \square OSE	.243	.218	.041	5.309	< 0.001	Supported
H5	SP \square OSE	.285	.270	.046	5.860	< 0.001	Supported

Note. B represents the standard-sized coefficient; B stands for the non-standardised coefficient. The interpretation of effect size adheres to Keith (2015): $B \geq 0.10$ is considered small, $B \geq 0.30$ is regarded as medium, and $B \geq 0.50$ is deemed large.

Table 3.5: Bootstrap Mediation Test Results (5,000 Resamples)

Indirect Path	Indirect Effect	95% CI Lower	95% CI Upper	Direct Effect	Mediation Type
H6: TES \rightarrow SP \rightarrow OSE	.088	.048	.142	.231***	Partial
H7: OLSE \rightarrow SP \rightarrow OSE	.113	.066	.172	.243***	Partial

Note. 95% bias-corrected confidence intervals derived from 5,000 bootstrap resamples. Direct effect = standardised path coefficient from antecedent to OSE in Model 2. *** $p < .001$. Mediation type determined following Zhao et al. (2010): partial mediation when both indirect and direct effects are significant.

($\beta = 0.231$) and the direct impact of online learning self-efficacy on online learning engagement ($\beta = 0.243$) observed in this study further confirmed the applicability of these mechanisms in the field of online mechanical engineering education. These findings suggest that both external relational support and internal confidence remain important even in technically demanding online environments. In the context of mechanical engineering education, this result is particularly meaningful because students are expected to remain engaged in courses that often require problem solving, technical interpretation, and independent task completion without the continuous physical guidance that is more available in face-to-face settings. The slightly stronger direct effect of online learning self-efficacy also suggests that students' belief in their ability to manage online learning demands may be one of the most immediate conditions for sustained engagement in this discipline. This may explain why OLSE showed a marginally stronger effect than TES, since confidence in handling online tasks can directly influence persistence, participation, and willingness to continue learning under technically complex conditions.

More notably, this research pinpoints social presence (SP) as a partial intermediary in the connection between teaching experience (TES) and overall student involvement (OSE), and also between teaching presence (OLSE) and OSE, thus putting forward a more thorough theoretical account. Specifically, the intervening role of SP is in line with the idea of social presence in Garrison et al.'s (2000) Community of Inquiry framework. In this model, the learners perceived feeling of social connection and sense of belonging is considered a crucial factor that promotes effective learning. By incorporating SP into the overall framework, this research shows that TES not only directly improves OSE but also indirectly boosts OSE by reinforcing SP ($\beta = 0.308$), which subsequently further raises OSE ($\beta = 0.285$). This Mediating mechanism shows that teachers emotional support partly boosts learning involvement by cultivating learners feeling of social inclusion—a discovery in line with Richardson et al.'s (2017) observation that the influence of teacher presence is partly conveyed via socio-emotional mediators. This

also means that supportive teacher behavior should not be understood only as emotional encouragement, but also as a condition that makes the online learning environment feel more human, interactive, and socially meaningful. In practical terms, when students perceive empathy, understanding and concern on the part of the instructors, they are more likely to feel the digital classroom as a genuine learning community and not merely a place for the transmission of information through technology. That the mediation is partial, as opposed to full, is also important as it indicates that sense of presence SP is a prominent, but not the only pathway, through which TES Impact engagement. Teacher emotional support may still operate on engagement through other key influences which may include, motivation, reassurance, and academic self-confidence.

Moreover, the notable mediating route from OLSE to OSE via SP (indirect effect = 0.113) shows that learners having higher self-efficacy are more likely to cultivate a positive perception of social presence, which subsequently boosts their engagement. This discovery broadens Pajares (2006) view on the interplay between self-efficacy and learning settings. Studies have shown that self-efficacy beliefs not only directly affect behavior patterns, but also change learners' understanding of the technological environment and further form a virtuous circle. This is consistent with the conclusion of Lees (2020)'s research on online learning environment, that is, students with higher self-efficacy are better at using technical tools to promote social interaction. The present result therefore suggests that self-efficacy is not limited to task execution alone; it may also shape how confidently students communicate, participate, and position themselves within online academic communities. This pathway is most valuable for mechanical engineering students as they often need to pose questions, share technical perspectives, and work group to complete learning activities. Students who feel comfortable in the online environment are likely to be more proactive, more willing to respond to others, and more likely to take an active role in collaborative learning activities. Such students also tend to be more highly engaged.

Like the TES pathway, the partial mediation here shows that OLSE helps people engage socially, as well as directly. There is a confidence factor, which suggests that students who are socially confident also tend to stick to their tasks, even when the online learning becomes challenging.

Different from previous studies, this study clearly places social presence at the intersection of psychosocial factors and technology intermediary environment, and confirms its bridge function based on empirical evidence. Most of the previous studies have studied the direct effect of technical environment stimulation and online learning support environment on career self-efficacy. Based on the Bootstrap mediating effect test, this study reveals the important mediating mechanism of social presence. The confidence intervals of the two indirect paths do not contain zero values, which further verifies the reliability of the mediating effect. In this sense, the study contributes not only by confirming the significance of TES, OLSE, and SP, but also by clarifying how these variables work together within a single explanatory framework. Rather than treating social presence as a secondary online learning characteristic, the present findings support its role as a functional transmission mechanism through which both personal beliefs and instructional support are translated into stronger engagement outcomes. This interpretation adds value to the current literature because it provides a more integrated explanation of engagement in online engineering education, where technological conditions and psychosocial experiences are closely intertwined. At the same time, because the model does not account for all variance in SP and OSE, the findings also suggest that additional contextual and learner-related factors may influence engagement and deserve further investigation.

The above research results not only verify the main role of technical education support (TES) and online learning support environment (OLSE), but also highlight the special value of social partners (SP) as psychosocial and technical intermediaries. This finding brings a new perspective to the design of educational interventions : in order to improve the degree of learning participation, relevant measures should not be limited to strengthening teach-

er support or establishing personal self-confidence, but should be based on technical design and social interaction, focusing on improving learners ' social presence. From an applied perspective, this means that course designers and instructors in mechanical engineering should pay attention not only to content delivery, but also to the social architecture of online courses, including interaction opportunities, visible teacher responsiveness, collaborative tasks, and interface features that reduce isolation. Future studies should focus on the potential of social presence as a mediator of engagement and disengagement on various technology platforms, in various cultural settings, and engineering disciplines. Further research may also test this model in applicable, blended, and hybrid versions of this model. However, the findings from this study should be embraced in caution due to the limitations of self-reported data and the restrictive conditions to the overall breadth of the study's causal claims

CONCLUSIONS

This study builds a theoretical model that uses self-determination theory (SP) as a mediator variable, and its purpose is to reveal the mechanism that affects online learning engagement. This model integrates self-determination theory (SDT), social cognitive theory (SCT) and research community (Col) framework, and carries out empirical test in the online mechanical engineering education scene. Through the data analysis of 507 valid samples, the main conclusions are as follows :

Online student involvement (OSE) is notably and positively forecasted by teacher emotional backing (TES) and online learning self-efficacy (OLSE). This validates the dual driving impacts of external assistance and internal beliefs on learning involvement, and shows the suitability of SDT and SCT in online education. Social presence (SP) has a significant partial mediating function between TES and OSE, and also between OLSE and OSE. Specifically, emotional support from teachers promotes learning engagement in an indirect way by strengthening learners sense of social presence. Meanwhile, self-efficacy in online learning impacts engagement levels indirectly through enhancing learners perception of

social connectedness. These discoveries clarify the crucial mediating mechanism of SP and enhance the explanatory ability of the theoretical framework. The measurement and structural models display satisfactory or acceptable fit indicators, which shows that the integrated model presents good stability and explanatory ability. Reliability and validity assessments additionally back the scientific strictness and trustworthiness of the measurement tools utilized.

Theoretical and Methodological Contributions

From a theoretical viewpoint, this research clearly integrates social presence into an integrated structure that consists of SDT, SCT, and Col, and empirically verifies its mediating function in the connections between external assistance (TES), intrinsic convictions (OLSE), and learning involvement. This research provides an innovative theoretical perspective for understanding the complex mechanisms underlying student engagement in online learning. From a practical standpoint, the findings indicate that online education practitioners should not only enhance supportive teaching behaviors and foster students' self-efficacy beliefs, but also actively cultivate learners' sense of social presence through technological design (e.g., interactive platforms and collaborative tools) and pedagogical strategies (e.g., peer interaction and emotional feedback). This method promotes a positive cycle where teacher assistance, personal beliefs, and social connection work together to boost learning involvement.

Practical Implications

These discoveries present several educational implications for boosting student involvement in online mechanical engineering instruction. First, studies show that the emotional support provided by teachers can boost students learning engagement, either directly or indirectly by improving their sense of social presence. To set up an emotional presence in online teaching, educators should concentrate on three aspects: putting into practice regular emotional interaction methods (e.g., sharing motivational videos), devising interpersonal visibility activities that

promote real-time interaction and genuine instructor participation in asynchronous conversations, and actively recognizing and interacting with marginalized students via personalized communication. Secondly, self-efficacy serves as a crucial factor driving learning involvement and social perception. This methodology can be implemented through the following approaches: providing scaffolded opportunities for success by breaking down complex tasks; utilizing peer modeling and video-based technical guides to demonstrate exemplary practices; and guiding students to engage in positive attribution to sustain their sense of self-efficacy. Thirdly, the mediating effect of social presence underscores the significance of optimizing socio-emotional design in technological platforms. Online learning platforms should integrate lightweight social tools, expand diversified interaction formats, construct collaborative virtual environments using VR/AR technologies, and visually represent social presence metrics. The final comprehensive research model shows that online learning participation is derived from the synergistic effect of multiple factors, which highlights the importance of systematic intervention. The emotional support strategy into the teacher training curriculum ; establish learning analysis and early warning system ; it is also possible to cultivate a peer-assisted learning atmosphere based on online communities or supportive groups.

Future Research Directions

The current research has certain limitations. Sample collection is limited to specific academic fields (mechanical engineering) and educational scenarios, which may limit the versatility of research results in different situations. Subsequent research needs to validate this comprehensive model in a wider range of disciplines (such as humanities, social sciences, medical education) and educational levels (such as graduate education, vocational training) to assess its cross-situational stability. In addition, cross-cultural comparative research can study the differences and similarities between teachers ' emotional support, social presence and students ' participation in different cultural situations, and further explain the adjustment function of cultural elements. This study

uses a cross-sectional survey method ; subsequent studies can use longitudinal research methods to study the changes in these relationships over time.

It should be noted that social presence only plays a partial mediating role in the observed relationship, which means that there may be other mediating ways. Subsequent studies can take other potential moderating factors and mediating variables into account, so as to deepen the understanding of its internal mechanism.

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