International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
Article Received: *25 July 2023* ***Revised:*** *12 September 2023* ***Accepted:*** *30 September 2023*

Research on Influencing Factors of College Students' Online Learning Effectiveness and Satisfaction Based on the Structural Equation Model

Yanping Dai[1], Tiamyod Pasawano[2*], Thosporn Sangsawang[3]
[1]Vocational Education Division, Faculty of Technical Education, Rajamangala University of Technology Thanyaburi, Pathum Thani, 12110, Thailand.
[2*](Corresponding author)
Educational Technology and Learning Innovation Division, Faculty of Technical Education, Rajamangala University of Technology Thanyaburi, Pathum Thani 12110, Thailand.
[3]Educational Technology and Communications Division, Faculty of Technical Education, Rajamangala University of Technology, Thanyaburi, Pathum Thani, 12110, Thailand.

Abstract — This study aims to develop a model elucidating the factors influencing the effectiveness and satisfaction of online learning for college students. Employing structural equation model analysis and empirical research, the paper explores the interaction paths, degrees of association, and influence mechanisms between various elements and the effectiveness and satisfaction of e-learning. Three significant prospective variables were identified, including knowledge construction, teacher-student interaction, and information processing, along with 32 observed variables. A questionnaire was formulated based on these observed variables, and professionals were requested to review and finalize the formal questionnaire. The study population comprises 389 online college students from diverse schools and majors utilizing Chinese institutions' MOOC online learning platforms. Selected through deliberate random sampling, these students have engaged in online study for over a year. Statistical analysis using SPSS 24.0 and model testing, refinement, and production using AMOS 24.0 revealed key findings: 1. Knowledge construction, teacher-student interaction, and information processing significantly and positively impact online learning for college students. 2. Clear positive associations exist with direct positive correlations. 3. Variances in learning effects and student satisfaction are noted between geographies and school types. 4. Specific learning differences are observed between male and female students. Based on these findings, educators are advised to define teachers' roles in online learning, nurture students' information processing and knowledge construction abilities, design diverse course resources and interaction modes, optimize information software and hardware facilities, and create a supportive external environment to offer substantive guidance and support.

Index Terms— Online Learning, Learning Effectiveness, Learning Satisfaction, Structural Equation Model.

I. INTRODUCTION

Many colleges have implemented online learning techniques during the COVID-19 pandemic. According to a study report from the University's Teacher Development Center involving 118,191 college students from 334 universities, 97.1% actively participate in online learning [1]. Baolai et al. in 2020 [2] extensively discussed the obstacles of online learning, covering areas such as learning techniques, efficiency, experience, teaching interaction, style, and teacher-student relationships. Their research and evaluation also delved into the future of online teaching [2]. Wenjun et al. in 2021 [3] identified factors influencing college student's online learning, including teachers' teaching level, students' autonomous learning ability, learning platform, and technical hardware facilities. Weiping and Wen [4] focused on the online learning experience of college students in different regions, revealing that students in the eastern region had a better online learning experience. Interaction, platform, and environment impact the online learning experience. Mumford and Dikilitas [5] concentrated on online teaching in pre-service teacher education, exploring connections between learning reflection, instructional technology, information technology, and the significance of online engagement in teaching. These studies offer valuable insights into the challenges faced by college students and directions for improvement in the context of online learning.

II. LITERATURE REVIEW

A. Research on online learning

(1) Study on learning behavior of online learners

Yiling et al. in 2014 [6], proposed a multi-level online learner behavior model encompassing three levels of data, mechanism, and outcome for a comprehensive investigation into the learning behaviors of diverse online learners. Concurrently, She et al. in 2012 [7] employed a fine-grained behavior capture method, recording learners' operational behaviors in online learning with a time unit of 5 seconds, to explore the relationship between metacognitive strategies and problem-solving ability.

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(2) Investigation into the development of online learning tools

Research has been conducted on constructing online learning resources, including improvement strategies like simplifying course content and enhancing practicability [8], [9]. The construction of content quality evaluation indicators, from learners' perspectives, focusing on knowledge needs and learning experience, is a key aspect of this research [10], [11].

(3) Online learning activity design

Zhihe et al. in 2019 [12] considered the network learning space as the supporting background, emphasizing students' collaborative and independent learning, and established the activity mechanism of the blended learning community. Foreign scholar, Ko and Rossen in 2017 [13] categorized online learning activities into various types, such as group collaboration, online debate, case study, role-playing, and reflective summaries.

(4) Online and systems learning platforms include Fluent English, Squirrel AI, and Chinese university MOOC, while foreign platforms encompass Edx, Future Learn, and more.

(5) Online learning support technology

The surge in 5G technology is bringing about significant changes in education. Wenhui [14] outlined the framework of an intelligent adaptive learning platform with the assistance of artificial intelligence and 5G technology. She discussed the crucial role of the platform in promoting intelligent teaching.

B. Research the status of online learning satisfaction

Learning motivation, learner self-management, course and platform design, teacher support, and learner interaction influence online learning satisfaction.

TABLE 1
Factors and Variables Influencing Online Learning Satisfaction in China

Domestic Scholars	Year	Factors Influencing Online Learning Satisfaction Variables
Zeng Jialing, Lu Xinger, Yang, Wu Xiuhan, Zheng Qinhua	2016	Learning ability, learning process, learning motivation, learning difficulties
Xu Xiaoqing, Zhao Wei, Liu Hongxia	2017	Interaction (between teachers and students, between students and other learners, and between learning content), self-efficacy on the internet, as well as self-regulated learning
Zhao Wenjun, Zhao Chengling, Yang Hailu, Jiang Zhihui	2018	Objective quality, perceived quality, motivation, subjective norms, perceived value
Shen Zhonghua,Wu Daguang	2020	Knowledge construction, teacher-student interaction, information processing

TABLE 2
Factors Influencing Satisfaction in Foreign Online Learning

Foreign Scholars	Influencing Variables of Online Learning Satisfaction
Sun P C,Tsai R J, Finger G, et al.	Learners' online learning anxiety, the attitude and behavior of the course teacher, course flexibility, course quality, perceived utility, perceived simplicity of use, a variety of evaluation techniques, and so on
Wu Tennyson & Hsia	Cognitive level, technical environment, social environment
Cole Shelley & Swartz	Mentor, learner, course structure, technical level

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C. Model of structural equations

SEM is a statistical analytic method that combines factor analysis and path analysis and is commonly utilized in social science domains such as psychology and management. The measurement and structure models are used to explain and test the causal link and influence path among variables in SEM. The model setting, identification, estimation, evaluation, and revision are all procedures involved in constructing an SEM model to ensure a good match between the model and the actual data and accurately explain the complex interaction between variables.

III. METHODS

Through a literature review, this paper identifies three potential variables affecting college students' online learning effectiveness and satisfaction. It establishes hypotheses among these variables and constructs an initial model depicting the influence path of college students' online learning effectiveness and satisfaction. The empirical analysis involves 32 observed variables derived from the MOOC learning platform of Chinese institutions. Questionnaires were formulated based on these observed variables, validated by specialists, and then used for data collection. Statistical analysis, utilizing SPSS24.0, and model modification through AMOS24.0 tests were carried out to develop the final influencing factor model.

In Step 1, the theoretical framework of the research model was constructed, drawing upon the constructivism learning theory as a foundation for evaluating college students learning effectiveness and satisfaction. This theoretical framework was then aligned with the current practices of online education in Chinese institutions. The research model proposed by Eom et al. was considered in this context to refine and adapt the theoretical framework to the specifics of online learning in Chinese institutions.

TABLE 3
Theoretical Framework of the Research Model

Related Theories	Target Expectations	Influencing Factors
Constructivism	Construct knowledge and form abstract concepts through self-directed learning, thus increasing the effectiveness and satisfaction of online learning.	Knowledge construction
Collaborationism	Promote learning capacity through sharing and collaboration, thus increasing the effectiveness and satisfaction of online learning.	Teacher-student interaction
Cognitive Information Processing	Promoting personalized development through cognitive information processing increases the effectiveness and satisfaction of online learning.	Information Processing

Step 2: Build the Initial Model. As depicted in Figure 1, the initial model illustrating the influence path of online learning effectiveness and satisfaction is constructed, incorporating three crucial variables—knowledge construction, teacher-student interaction, and information processing—along with the two observed variables of online learning effectiveness and satisfaction.

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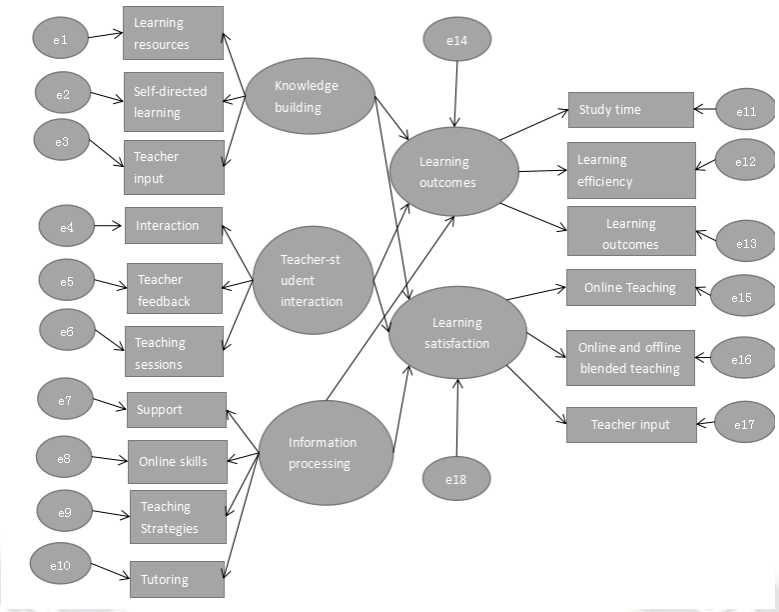

FIGURE 1
Initial Model of the Influence Path of E-learning Effectiveness and Satisfaction

Step 3: Sample selection. The population of this paper comprises 389 online college students from various schools and majors who have been engaged in online learning for over a year. The students were randomly selected from Chinese universities' MOOC online learning platforms to collect research data.

Step 4: Data collection. A questionnaire on online learning effectiveness and satisfaction for college students was utilized. The questionnaire was distributed to nine experts in content, educational technology, measurement, and assessment disciplines for feedback and suggestions. An open questionnaire was created for experts to comment on the IOC (Project et al.). The questionnaire covered learning resources, independent learning, teacher input, communication and interaction, platform quality, online skills, learning effectiveness, and learning satisfaction.

Step 5: Data analysis: (1) Frequency and percentage were employed, and the Likert five-level rating scale was used for the questionnaire. Mean (M), standard deviation (SD), and correlation were applied to analyze the five scales, with agreement ranging from an average of 1.00 to 1.49 and strong disagreement from 4.50 to 5.00. (2) The independent sample T-test in SPSS24.0 was utilized for item analysis, and reliability analysis in SPSS24.0 assessed the reliability level through Cronbach's α coefficient. The AMOS24.0 test was conducted for reliability and validity tests, exploratory factor analyses, and questionnaire revisions to ensure the survey tool's reliability and credibility.

Step 6: The AMOS24.0 program was used to develop a structural equation model, employing the maximum likelihood approach for estimating, testing, validating, and adjusting the initial model. This resulted in a modified model of the influence path of online learning efficacy and satisfaction.

Step 7: The report scrutinizes the action path, degree of connection, and influence mechanism between each influencing element and online learning efficacy and satisfaction through structural equation model analysis and empirical research.

IV. FINDINGS

We investigated the links between knowledge construction, teacher-student interaction, information processing, learning outcomes, and learning satisfaction using hierarchical linear regression, single-component analysis, and structural equation models. The following are the significant conclusions of our sicro video resources. Encouraging collaborative research involving multiple institutions and stakeholders will contribute to a nuanced understanding of library entry education's evolving landscape, technology integration, and its impact on student learning outcomes.

A. Analysis of hierarchical linear regression

Before conducting structural equation model analysis, hierarchical linear regression analysis was performed to explore the effects of different components on learning effectiveness and satisfaction. The dimensions of the basic scenario, knowledge construction, teacher-student interaction, and information processing were used as independent variables, with dummy variables for categorical variables. A test level of 0.05 was chosen to establish statistical significance.

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(1) Hierarchical regression analysis with learning effectiveness as the dependent variable:

In intra-group comparisons of the independent variables of the final model (layer 4), it was found that females had higher learning outcomes than males (β= .036, p= .001). Students in the central region had lower learning efficiency than those in other regions (β= -.035, p= .003). Additionally, students in research-type colleges had lower learning efficiency based on the quality of other subjects (β=-.051, p= .037). In the knowledge construction part, learning effectiveness increased with the mean scores of independent learning and teacher involvement (β= .264, p< .001; β= .293, p< .001). In the teacher-student interaction part, learning effectiveness increased with the increase in teaching feedback and the mean score of teaching links (β= .370, p<m.001). In the information processing part, learning effectiveness decreased with the increase of the mean score of the tutoring dimension (β=- .083, p< .001).

(2) Learning satisfaction as the dependent variable in hierarchical regression analysis:

Comparing △R2 values of each layer without investigating the influence path, it was found that knowledge creation had a more significant impact on learning satisfaction than the basic scenario and teacher-student interaction. Information processing increased the ability to explain the variation in learning satisfaction by 35.0%. Students who had not used online learning before the epidemic showed higher satisfaction (β= .086, p< .001). For knowledge construction, learning satisfaction increased with the average score of learning resources and independent learning (β=.091, p< .001) but decreased with the increase of the average score of teacher involvement (β= -.050, p=.008). In student-teacher interaction, learning satisfaction increased with the average score of communication interaction, teacher feedback, and teaching process (β=.142, p<.001; β=.074, p<.001). In information processing, learning satisfaction increased with the increase of the average score of online skills and teaching strategies (β=.120, p<.001; β=.058, p=.001) but decreased with the increase of average scores of technical support and student counseling (β= -.040, p= .014; β= -.127, p< .001).

B. Single factor analysis

(1) Single-factor analysis of learning effectiveness:

Univariate results revealed statistically significant differences in learning effectiveness among students of different genders, school regions, whether they had used online teaching before the epidemic, different grades, and school types (p< .05). However, there were no statistically significant differences in learning effectiveness among students of different school types (p> .05).

(2) Single-factor analysis of learning satisfaction:

A single-component analysis showed statistically significant disparities in learning satisfaction among students from different school districts, whether they had used online teaching before the epidemic and different grades (p< .05). Students with different genders, school natures, and school categories had no statistical significance in learning satisfaction (p> .05).

(3) Correlation analysis:

Learning resources, independent learning, and instructor engagement in knowledge generation were positively related to learning effectiveness and satisfaction. The most significant link was between instructor involvement and learning outcomes, while self-directed learning was substantially linked to learner satisfaction. Instructor-student interaction, feedback, and the teaching process were positively connected to learning effectiveness and satisfaction. Teacher feedback is most closely associated with learning effects, and communication interaction is highly related to learning satisfaction. Learning outcomes and satisfaction were also favorably connected with information processing technology support, online capabilities, teaching styles, and tutoring. Teaching tactics have the most significant influence on learning effects, while online skills influence learning satisfaction. For more information, see Table 4.

TABLE 4

Correlation Analysis of Knowledge Construction, Cooperative Learning, Information Processing, Learning Effectiveness, and Learning Satisfaction

Category	Dimensional	Learning Effectiveness	Learning Satisfaction
Knowledge construction	Learning resources	.328	.467
	Self-directed learning	.441	.586
	Teacher input	.541	.187

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Teacher-student interaction	Interaction	.199	.487
	Teacher feedback	.575	.249
	Teaching sessions	.139	.365
Information processing	Technical Support	.341	.137
	Online skills	.204	.435
	Teaching Strategies	.352	.345
	Financial assistance	.349	.140

C. Structural equation model analysis results

(1) Model Fitting

The maximum likelihood method was used to estimate the initial model, and the results revealed that the MI value of the three potential variables of knowledge construction, teacher-student interaction, and information processing was high, necessitating the addition of correlation paths and residual paths like [e6-e9] and [e15-e16]. The modified p-value for each path was less than .05, showing statistical significance. The CMIN/DF index was large due to the study's colossal sample size, but the fitting results, when coupled with other fit indices, were superior, and the final model is displayed in Figure 2.

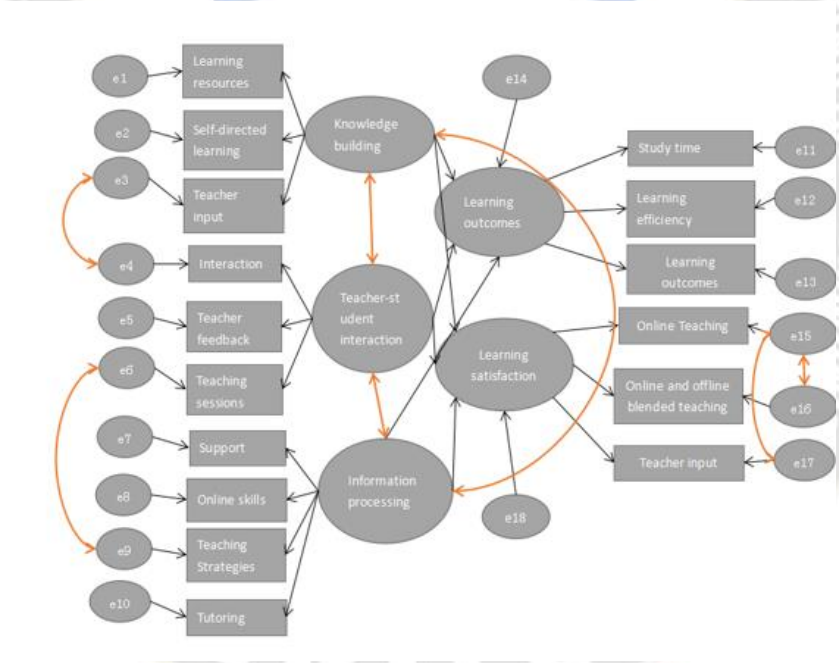

FIGURE 2
Modified Model of the Influence Path of E-learning Effectiveness and Satisfaction

TABLE 5
Fit Results of the Structural Equation Model

Fit Index	Fit Value	Whether The Fit Criteria Are Met
Indicators of absolute fit:		
AGFI	.910	Confirm
GFI	.948	Conform
RMSEA	.044	Confirm
Value-added fitness indicators:		

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CFI	.950	Confirm
NFI	.946	Confirm
Pared fit indicators:		
PNFI	.515	Confirm
PGFI	.544	Confirm
CMIN/DF	7.97	On the large side

(2) The Path Analysis Results of the Fitted Model

The model indicates that knowledge construction positively influences learning effectiveness and satisfaction, with standardized path coefficients of .319 and .174 (p<.01). Additionally, teacher-student interaction positively affects learning effectiveness and satisfaction, with standardized path coefficients of .351 and .281, respectively (p<.05). For more details, refer to Table 6.

TABLE 6
Fit of the Effect Relationship Between the Factors in the Model

Variables			**Standard Path Estimated Value**	**C.R.**	**p**
Learning satisfaction	<---	Knowledge construction	.174	5.149	.002
Learning satisfaction	<---	Information processing	.249	6.956	.050
Learning satisfaction	<---	Teacher-student interaction	.281	8.208	< .001
Learning effectiveness	<---	Knowledge construction	.319	9.317	< .001
Learning effectiveness	<---	Student-teacher interaction	.351	10.903	< .001
Learning effectiveness	<---	Information processing	.193	5.612	< .001
Teacher input	<---	Knowledge construction	.762		
Self-directed learning	<---	Knowledge construction	.530	24.886	< .001
Learning resources	<---	Knowledge construction	.685	28.536	< .001
Teacher feedback	<---	Teacher-student interaction	.795	43.118	< .001
Teaching Strategies	<---	Information processing	.724	39.291	< .001
Online skills	<---	Information processing	.695	35.675	< .001
Technical Support	<---	Information processing	.785		
Online Teaching	<---	Learning satisfaction	.389		
Financial assistance	<---	Information processing	.790	40.225	< .001
Interaction	<---	Student-teacher interaction	.832		
Teaching sessions	<---	Student-teacher interaction	.529	26.9	< .001
Offline teaching	<---	Learning satisfaction	.813	19.733	< .001

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Variables			Standard Path Estimated Value	C.R.	p
Online and offline blended teaching	<---	Learning satisfaction	.403	18.317	< .001
Study time	<---	Learning effectiveness	.816		
Learning outcomes	<---	Learning effectiveness	.608	28.304	< .001
Learning efficiency	<---	Learning effectiveness	.786	35.202	< .001

(3) Effect Relationship and Hypothesis Testing Results

Upon analyzing the interaction between the latent variables of the modified structural equation model, it is observed that knowledge creation has only a direct positive impact on learning effectiveness, with a path coefficient of 0.319 (p<.01). The teacher-student interaction directly influences the learning effect, with a path coefficient of 0.351 (p< .01). The path coefficient for knowledge construction is 0.174 (p<.01). Information processing directly affects learning satisfaction, with a path coefficient of .249 (p< .05). In terms of standardized influence effect analysis, the total effect on learning effectiveness is as follows: teacher-student interaction (.351) > knowledge construction (.319) > information processing (.193). Similarly, the total effect on learning satisfaction is as follows: teacher-student interaction (.281) > information processing (.249) > knowledge construction. (.174).

V. CONCLUSION AND EVALUATION

Using data from their online learning satisfaction questionnaire, we investigated the influence of knowledge construction, teacher-student interaction, and information processing on the effectiveness and satisfaction of college students' online learning. We obtained its path through structural equation modeling, and the following conclusions were drawn:

(1) The relationship between knowledge construction, teacher-student interaction, information processing, and online learning outcomes.

Knowledge production, teacher-student contact, and information processing directly benefit learning outcomes, implying that intermediate variables have no function in the transmission channel. This demonstrates that knowledge production, teacher-student interaction, and information processing directly and positively impact students' online learning success. Furthermore, from the analysis of the effect of standardization, the total effect of altering students' online learning effect is as follows: teacher-student interaction > knowledge construction > information processing.

(2) The relationship between knowledge acquisition, teacher-student interaction, information processing, and online learning pleasure.

Knowledge production, teacher-student contact, and information processing positively affect learning satisfaction, implying that intermediate variables in the transmission channel are insignificant. It also shows that knowledge production, teacher-student interaction, and information processing directly and positively affect students' happiness with online learning. Furthermore, using standardized impact analysis, we discovered that the overall effect on students' online learning pleasure is teacher-student interaction > information processing > knowledge development.

(3) The correlation between the observed variable corresponding to each potential variable and learning outcomes and satisfaction.

Learning results and satisfaction were positively connected with learning resources, self-directed learning, and instructor participation in knowledge creation. Teacher engagement had the most vital link to learning outcomes, while self-directed learning had the weakest link. Communication interaction, instructor feedback, and teaching connection are all favorably connected with learning effectiveness and satisfaction. The learning impact is directly tied to teacher feedback, while communicative contact is most strongly related to learning satisfaction. Technical support, online skills, teaching strategies, and tutoring are all positively correlated with learning outcomes and learning satisfaction regarding information processing, with teaching strategies having the strongest correlation with learning outcomes, online skills, and learning satisfaction.

(4) The influence of observed variables corresponding to each potential variable on learning effectiveness.

From the perspective of knowledge construction, learning effectiveness increases with the average scores of self-learning and teacher involvement. From the perspective of teacher-student interaction, learning effectiveness increases with the average score of teaching feedback and teaching links. From the point of view of information processing, the learning

effectiveness decreases with the increase of the average score of the observed variable.

(5) The influence of observed variables corresponding to each potential variable on learning satisfaction.

The total effect on students' online learning results is in the following order: teacher-student interaction > knowledge construction > information processing, whereas the total effect on students' online learning satisfaction is in the following order: teacher-student interaction > information processing > knowledge construction.

VI. SUGGESTIONS

In future research within a similar domain, the study could advance by adopting a longitudinal approach to track the prolonged impact of online learning factors, capturing evolving trends and changes in student satisfaction and effectiveness. Additionally, the scope could broaden to encompass a cross-cultural or cross-institutional comparative analysis, shedding light on variations in factors across diverse educational contexts. Intervention studies may be incorporated to assess the effectiveness of specific strategies to enhance key factors influencing online learning satisfaction and effectiveness. New objectives could involve predictive modeling to forecast online learning outcomes, exploration of emerging technologies such as virtual reality or AI-driven personalized learning, and in-depth analyses of underexplored factors like socio-economic status or learner motivation. Methodologically, a mixed-methods approach, big data analytics for large-scale datasets, and experimental designs, including randomized controlled trials, could be implemented for a comprehensive understanding of student experiences and the causal relationships between interventions and online learning outcomes. These endeavors collectively aim to provide nuanced insights and practical strategies further to enrich online learning experiences across diverse educational settings.

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Mrs. Yanping Dai
Vocational Education Division, Faculty of Technical Education, Rajamangala University of Technology Thanyaburi, Pathum Thani, 12110, Thailand

Tiamyod Pasawano, Ed., Asst. Prof. *(Corresponding author)
Chairman of Educational Technology and Learning Innovation Division, Faculty of Technical Education, Rajamangala University of Technology Thanyaburi, Pathum Thani, Thailand. He earned a Doctor of Education Technology and Communications from Kasetsart University, Thailand, Dr. Pasawano specializes in research areas such as Edutainment, Education Technology and Communications

Thosporn Sangsawang, Ph.D., Asst.Prof. is an Assistant Professor and the Head of the Center of Innovation Learning and Technology at the Faculty of Technical Education, Rajamangala University of Technology. She earned a Doctor of Philosophy in Learning Innovation in Technology from King Mongkut's University of Technology Thonburi, Thailand, in 2011. Dr. Sangsawang specializes in research areas such as Innovation and Learning Technology, Education Technology and Communications, Digital Technology, Internet of Things, Web-Based Instruction Design, Educational Media, and New Technology Media. With a strong academic background and expertise in these fields, she contributes to advancing education by integrating innovative technologies and learning methodologies.