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Development and Assessment of E-Learning Teaching Materials for Blended Learning in a Programmable Logic Controller Course*

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This study aimed to develop e-learning materials for a blended learning course focusing on programmable logic controller (PLC) technology and assessed its effectiveness using the technology acceptance model. The course utilized the university's cloud-based learning platform as the teaching platform and incorporated specially designed targeting PLC technology. The objective was to enhance the interactivity and efficiency of the instructional activities while fostering the students' interest in programmable control technology. This study placed emphasis on helping students establish a solid foundation in programmable control technology and improving learning outcomes, thereby achieving the goals of blended instructional design. The results of questionnaire survey were analyzed using statistical methods. Structural equation modeling using SmartPLS software was used to measure the structural model. A number of conclusions were drawn based on the analysis results. First, the developed e-learning material effectively enhanced the learners' interest and learning outcomes. Second, the students generally exhibited high levels of satisfaction with the blended learning course in PLC technology, indicating widespread recognition and affirmation of the course. Third, the blended course for PLC technology demonstrated applicability in the fields of engineering and technology education.

Keywords: programmable logic controller (PLC); blended learning; technology acceptance model; e-learning teaching materials

1. Introduction

Due to the development of the Internet, many teaching activities and teaching materials have achieved their learning objectives through online learning environments or other multimedia forms [1]. Digital teaching materials use informational media to integrate different elements and deliver them through computers or the Internet. Therefore, they have multiple characteristics such as repeatability and long-term storage, which can increase learners' learning interest and motivation. Therefore, when developing digital teaching materials, appropriate digital media tools should be considered and combined with corresponding teaching strategies to ensure learning effects are achieved.

With the advancement of computer technology and improvements in programming technology, the functions of programmable logic controllers (PLC) have been continuously expanded and improved. Today, PLCs have become the core of factory automation and electromechanical integration equipment. Colleges and universities now list courses related to programmable controllers as key internship courses in the fields of motor control and electromechanical integration, which shows the importance of cultivating automation control talents.

In order to allow students to have a more complete understanding of the field of electromechanical control, with the use of information technology teaching methods, and in response to each student's different awareness of digital teaching materials, teachers play the role of a stimulus in synchronous and asynchronous course activities. The role of guidance and assistance allows students to become curious about learning and then learn independently, interact with peers, and generate feedback. At the same time, teaching strategies are adjusted to measure students' learning process to achieve the goals of blended teaching. Wu et al. [2] developed an iBeacon-based ubiquitous learning environment in smart green building courses. Rosales-Asensio et al. [3] investigated electromechanical engineering lecturers' perceptions using the MOOCs course.

This study used an online media platform, which allows learners to use internal learning resources to view PLC-related introductions, receive guidance on the use of various editing software, and complete the main project assigned by this study. The platform also provided basic instructions for use of GX Works3, and written pictures and texts with examples. Operating instructions and videos of operating sequences, including writing instructions, functional explanations, and analog output devices, were combined with synchronous teaching strategies to familiarize the learners with PLC writing software and topic ideas for various extended

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functions, thereby achieving the goals of blended teaching.

The technology acceptance model (TAM) is a theoretical framework used to study and explain individuals' adoption behavior of new technologies or systems. It was proposed by Davis [4] to explain the decision-making process of individuals on whether to accept and use technological products or services. The application of the TAM helps to understand an individual's acceptance and willingness to use new technologies or systems.

The integration of information technology into education is an inevitable trend. The PLC blended course in this study allowed students to edit command actions through external analog switches and indicator lights for synchronous teaching; these resource-assisted learning cultivated the students' basic abilities in the electromechanical and control fields. In today's workplace, digital teaching materials are regarded as tools for the extension of relevant knowledge in the field of cognition, or the field of practical operation and software editing skills, as well as improving learning motivation or even higher-level learning goals. PLC technology has been applied in various automation industries, such as transportation, lifting equipment, and even vending machines. The programming language for PLC is flexible and offers high-level control features, thus achieving high reliability and powerful editing functions.

In order to enable learners to adapt to various editing methods including the most commonly used MITSUBISHI editing software in the practical learning of programmable controllers, practical simulation questions in relevant teaching materials were included in the teaching materials and teaching methods. By combining teaching design and professional theories that were consistent with the students'starting behaviors and individual differences, the teachers could effectively achieve diverse learning goals and select appropriate teaching materials. The digital teaching materials of GX Works3 have been developed to teach design and operation courses, thus cultivating students' ability to use GX Works3 editing software knowledge and design circuits.

To sum up, in addition to using asynchronous teaching materials to provide more learning opportunities and shortening the learning space and time, blended learning courses also need to adjust the teaching mode according to the learners' information processing strategies in order to provide more assistance. Specifically, the research objectives of this study were as follows: (1) to develop digital teaching materials for a PLC blended course, and (2) to evaluate learners' learning satisfaction with the PLC blended course using the TAM.

2. Literature Review

This study discussed the TAM, teaching strategies, and systematic teaching design of blended learning. The TAM was used to explore learners' acceptance of technology and its influencing factors, such as perceived usefulness, perceived ease of use, etc. This helped to understand the learners' acceptance and attitude towards programmable control technology. This study investigated the impact of different teaching strategies under the blended learning mode, such as online teaching, face-to-face teaching, and cooperative learning, on learners' learning effectiveness and participation. This helped identify instructional strategies that were most suitable for blended learning with programmable control technology. The teaching system design: to discuss the design of digital textbook courses with programmable control technology in a systematic way, including the organization of textbook content, the design of the teaching activities, and the formulation of evaluation strategies.

2.1 Technology Acceptance Model

The theory of planned behavior (TPB) divides the influence of human behavior into three factors: behavioral attitudes, subjective cognitive norms, and perceived behavioral control [5]. Behavioral attitudes are used to represent an individual's attitude and evaluation of the behavior, subjective cognitive norms represent the individual's perceptions of others' expectations and social pressure for the behavior, and perceived behavioral control represents the individual's ability and resources to implement the behavior. Paimin et al. [6] investigated the motivational factors necessary to succeed in engineering. The TRA model was used to guide the suggested paths from learning strategy, interest, and intention to academic performance.

2.1.1 Technology Acceptance Model Domains

Technology acceptance model defines each domain of the technology acceptance model as follows:

(1) External variables are factors that affect users' cognitive ease of use and cognitive usefulness when adopting information technology. These external variables have no clear norms or positioning [7].
(2) Perceived usefulness is the degree to which users believe that using an internet technology (IT) system can improve job performance. It represents the user's perception of the value and effectiveness of the system. If a system is considered to have good perceived usefulness, users will have a more positive attitude towards the system. Perceived usefulness is affected by

external variables and the perceived ease of use. Together, these factors affect users' willingness to accept and adopt IT systems [8].

(3) Perceived ease of use refers to the degree to which users think that an information system is easy to operate. When users perceive that the system is easy to operate and does not require a high cognitive load, their attitude towards the system will be more positive. Perceived ease of use is one of the important factors that affect users' acceptance of information systems.
(4) Attitude toward using refers to measuring the user's positive or negative feelings towards the execution of a specific system target behavior. When users find a system useful and easy to use, their attitude toward the system will be positive, indicating they tend to accept and are willing to use the system. Therefore, perceived usefulness and perceived ease of use have an important impact on users' attitudes towards the system.
(5) Behavioral intention to use refers to the user's willingness to perform a specific behavior. In the TAM, behavioral intention refers to the user's intention and desire to use a specific information technology system. Behavioral intention can be regarded as a precursor to predict the occurrence of actual behavior; that is, before users take a specific action, their intention to perform the behavior will affect their final behavior decision [9].

2.1.2 Domain Interaction in the Technology Acceptance Mode

The interrelationships among the domains of the TAM can be divided five types. First, external variables may affect the user's perceived ease of use and perceived usefulness. Second, perceived ease of use will directly affect the user's perceived usefulness of the system – that is, the easier the user thinks the information media system is to operate, the more useful the system will be. Third, perceived ease of use and perceived usefulness affect usage attitude at the same time. When users believe that the information media is not only easy to operate but also increases their learning benefits, their attitudes toward use will become more positive. Fourth, behavioral image is affected by both cognitive usefulness and attitude. The more users believe that an information media system can improve their learning effectiveness, or the more positive their attitude toward use is, the more their intention to use the system will be strengthened. Fifth, actual behavior is affected by behavioral intentions.

2.2 Teaching Strategies for Blended Learning

Blended learning is a combination of computer-mediated and traditional face-to-face environments [10, 11]; suggested that blended learning combines traditional learning and distance learning with a variety of learning technologies. Singh [12] mentioned that blended learning includes learning activities such as face-to-face classrooms, real-time online learning, and asynchronous self-directed learning. Based on the above points of view, blended learning can be summarized as the combination of traditional classroom learning (synchronous teaching) and digital learning (asynchronous teaching).

Syed et al. [13] suggested that the use of virtual learning technology in teaching can improve the mechanical engineering curriculum for students by supplementing the traditional learning experience with outside-the-classroom materials.

2.2.1 Features of Blended Learning

Blended learning leverages the human interaction of traditional instruction and the diversity of digital media systems. In blended learning, teachers play the role of guiding, stimulating, and assisting students upon understanding their learning situation. Students can use teaching materials in digital learning courses according to their own time and place, which changes their learning mentality from passive to active and results in creative and active learners. Blended digital learning provides greater learning motivation and promotes active learning and the active participation of students [14].

2.2.2 Considerations for using Asynchronous Teaching

When using asynchronous digital teaching materials for learning, the adjustment of the interface design or the integrity of the teaching materials may not necessarily improve the students' learning effect. Students' perceptions of textbooks are complex, and the degree to which they encode material found on the web varies from individual to individual. Therefore, teachers need to have a clear picture of the learning status of each student. When using asynchronous textbooks for teaching, teachers should not only focus on the arrangement and design of the textbooks but also pay attention to whether there are any parts the students cannot understand, so as to provide timely and appropriate teaching assistance. At the same time, in asynchronous learning, building common knowledge is necessary. Students should make good use of environmental resources, manage their time, and coordinate their own learning habits and abilities to effectively improve the learning effectiveness and achieve the learning goals. Mosyjowski et al. [15] used asynchronous model for incorporating social

aspects of engineering work into engineering design courses.

2.3 Instructional System Design

Instructional system design (ISD) is a common scientific approach used to address learning dilemmas in education. ISD provides a structured approach to help teachers effectively design and develop instructional activities to achieve learning objectives. In systematic teaching, the components contained in the system include the teachers, students, environment, and teaching materials. These components coordinate with each other, depend on each other, and are continuously improved and revised to achieve the teaching goals [16]. Systematic instructional design has a number of different instructional design models, each of which has its own unique advantages and insights. Understanding different instructional design models can help teachers choose the appropriate model for different teaching situations, thereby inspiring and expanding the level of instructional design.

The ADDIE (Analysis, Design, Development, Implementation, and Evaluation) teaching model [17] provides a standardized instructional design process that can help instructional designers design and implement teaching activities more effectively and evaluate their effectiveness. Therefore, the ADDIE model is an effective and simple tool for implementing systematic teaching. The ADDIE model is a commonly used systematic instructional design model that includes the five steps of analysis, design, development, implementation, and evaluation. These five steps form a circular process that can be adjusted and improved repeatedly according to the actual situation: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation. By adopting the five steps of the ADDIE model, this study systematically analyzed, designed, developed, implemented, and evaluated digital teaching materials to ensure their quality and teaching effectiveness. This organized instructional design process could provide a reliable template model for digital learning using programmable control technology, thus helping to improve learners' learning outcomes.

Liang et al. [18] proposed the design and implementation of an intelligent education prototype for an electronic systems course. Chu et al. [19] proposed a development and assessment for 3D printing course in technical high school.

3. E-Learning Material Development

This study took a programmable control technology course as an example to develop digital teaching materials. Based on the research purpose, it proposed the teaching design, teaching content, teaching strategies, and teaching evaluation in sequence. Hmelo and Lin [20] indicated that in self-directed learning, learners must be responsible for their own learning process and will seek their own interests and goals in the process. In this type of learning, learners set goals, identify resources, and evaluate their progress. Metacognition, which plays an important role in self-directed learning, refers to the ability of reflecting on one's own thinking and learning processes. Learners with metacognitive abilities can monitor their learning, set goals, and adjust strategies when necessary.

3.1 Course Objectives

This study proposed an integrated theoretical framework of students' blended learning course acceptance and behavioral intention to use based mainly on the TAM. Observing the relationship between behavioral intentions, perceived usefulness, attitude toward using and perceived ease of use of learning course will help us to develop a general linear structural model of system acceptance in students. Such a model would provide school administrators or teachers with information that could help them better develop another learning course.

3.2 Instructional Design

Instructional design is an ever-evolving field. The digital learning course of this study utilized the five stages of ADDIE. This study adopted strategies based on the functions represented by each stage. Regarding Analysis, the needs of learners and the goals and content of the course were analyzed. The teaching materials uploaded to the school's online learning platform contained a menu function, which allowed the learners to directly understand the course content and re-watch unfamiliar parts. Regarding design, in order to make it easier for learners to absorb knowledge, this study used multimedia elements such as text, pictures, sounds, and videos, to construct an interactive learning system in the digital learning courses. Regarding Development, carefully designed teaching materials and systematic teaching resources were provided so that learners could learn and master the content systematically. In terms of writing and operating the software, intuitive and easy-to-understand quick-display graphics and related video teaching were used to enable the learners to quickly understand and apply their knowledge. Regarding Implementation, through the video operation teaching method, clear step by step instructions were provided to guide learners in operating the system. Each step was presented in the form of a video that explained the problem

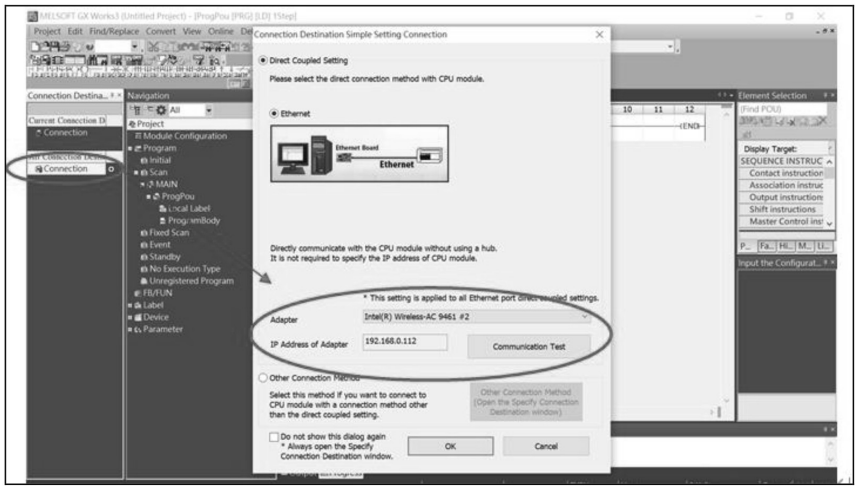

Fig. 1. The step-by-step for GX Works3 software.

description and the writing process in detail, allowing learners to intuitively understand and imitate. Regarding Evaluation, computer statistics and background data calculation methods were used to track the learners' learning progress and test scores. These data provided valuable indicators to help the teachers evaluate the learners' learning outcomes, understanding, and learning effectiveness. Fig. 1 shows the step-by-step software teaching material.

3.3 Teaching Content

The purpose of the teaching content analysis was to determine the depth and content of teaching to achieve the best teaching results. This teaching course aimed to cultivate students' abilities in operating programmable controllers and editing software through digital audio-visual teaching. The students operated the software according to the learning activities and teaching resources designed for the course. Finally, the students evaluated their own learning outcomes through quizzes to achieve the best learning results.

GX Works3 is a PLC editing program with several advantages [21]. It supports many of the common PLC types, including Mitsubishi Electric's latest iQ-R series and iQ-F series PLCs. GX Works3 also provides more editing functions, such as logic searches and variable type conversions, which can help users write and debug programs faster. In addition, GX Works3 also provides more data types, such as double-precision floating-point numbers and time data, as well as better adjustment tools, such as variable monitors and adjustment logs. These features can improve programming efficiency and reduce errors. GX Works 3 provides a better programming environment that can quickly switch between multiple projects and that allows users to drag and drop or copy data between multiple windows. The user interface of GX Works3 is modern and easy to use, which helps users' complete tasks more easily. For example, users can customize toolbars and shortcut keys according to their habits and can also customize window colors and fonts. In addition, GX Works3 provides more shortcuts and text narratives, which can better help users solve problems.

For the teaching analysis on programmable control technology using editing software, the assessment of the learners' prior knowledge was very important. In the teaching environment, learners needed to have basic computer operation skills and be familiar with the use of GX Works3 editing software. Therefore, during the presentation of the digital textbooks, the GX Works3 editing software was introduced in detail, so that the learners could quickly understand, get started, and build up their learning confidence.

3.4 Teaching Strategies

Teaching strategies, including teaching methods, techniques, teaching media, learning activities, and so on, play an important role in teaching. Important factors affecting teaching effectiveness include the design and application of teaching strategies. In order to improve students' learning effectiveness, teachers need to choose appropriate teaching strategies based on factors such as the students' needs, learning characteristics, and teaching objectives.

Ormrod [22] pointed out that teachers can use different strategies, such as multiple intelligence theory, cognitive load theory, differentiated teaching, and other methods, to respond to students' individual needs and thereby improve learning outcomes. The selection of teaching strategies should

take into account many factors, such as teaching objectives, student background, teaching content, etc., in order to effectively improve learning effectiveness. Moreno and Flowerday [23] explored the relationship between multimedia learning and attention, and suggested that in multimedia teaching, the use of multiple media such as images and sounds can improve students' attention and memory. They also argued that multimedia learning is better than single-media learning, as it can attract students' attention and promote the improvement of the learning effect.

Morrison et al. [24] proposed that to effectively guide students' learning, unit teaching method should be adopted to divide the teaching process into five steps: (1) Introduction, (2) Presentation, (3) Practice, (4) Application, and (5) Evaluation.

According to Eggen and Kauchak [25], teaching strategies are methods by which teachers integrate different teaching situations and develop different teaching models to achieve the teaching goals. Through appropriate teaching strategies, teachers can effectively combine these characteristics to promote students' learning effectiveness and motivation. Their teaching model is not only a framework of teaching strategies but also a well-thought-out teaching design to guide students to achieve the set learning goals. When teachers select and apply teaching models, they should consider the subject characteristics, student needs, and teaching objectives to achieve the best teaching results.

In the process of developing digital teaching materials and applying them to blended teaching, the choice of teaching strategies is crucial to teaching effectiveness. According to previous literature, this study referred to the following teaching strategies to support the goals and learning outcomes of blended teaching.

3.4.1 Problem-based Learning

Problem-based learning (PBL) is a problem-solving-based learning method that encourages students to actively participate in exploring and solving real-world problems. Research has pointed out that PBL can promote students' critical thinking, problem-solving skills, and cooperation skills [26].

3.4.2 Self-directed Learning

Self-directed learning emphasizes students' active participation and learning autonomy by setting learning goals and cultivating learning abilities in an atmosphere of self-demand. Research has shown that self-directed learning can improve students' learning effectiveness, self-adjustment abilities, and long-term learning motivation [27].

3.4.3 Blended Learning

Blended learning combines elements of face-to-face teaching and online learning to provide students with a flexible learning environment. This teaching approach integrates different learning activities and resources, improves student learning achievement, learning satisfaction, and learning motivation, encourages students to be actively involved in learning, and provides students with individualized guidance and immediate feedback.

This study aimed to use effective and active teaching strategies, including teacher-based direct teaching and student-based indirect teaching, to stimulate learners' learning motivation and interest and increase their engagement in learning. In addition, this study aimed to cultivate the learners'self-confidence and expressive ability, so that they could actively participate in learning activities and demonstrate their learning results. Finally, enhancing the learners' independent problem-solving abilities enabled them to face challenges and find solutions.

In addition, this digital course incorporated multimedia in the instructional design to provide a rich learning experience. The design of the multimedia teaching screen aimed to improve the students' learning motivation and learning efficiency. Through the use of multimedia elements such as pictures, videos, sounds, etc., learning resources were presented to the students in a vivid and interesting way, thereby stimulating their curiosity and enhancing the attraction of learning.

Teaching strategies should be based on the principle of arousing students' interest in learning, and achieving goals based on student motivation, teaching design, teaching organization, and teaching evaluation [28].

This study followed the principles of instructional design and production, was committed to producing multimedia teaching content, made full use of various media forms, and aimed to create an innovative and high-quality instructional design system. Through the application of digital media, the students were provided with a rich learning experience that stimulated their learning motivation and interest, and promoted their learning effectiveness.

3.5 Teaching Assessment

Teaching assessment plays an important role in secondary education and is considered an integral part of effective learning [29]. Teaching evaluation should be a systematic process designed to collect and analyze information about course design to make judgments about the value and effectiveness of the activity. Its importance lies in providing an

objective and reliable basis for educational decision-making, while promoting the improvement of teaching effectiveness and student learning effects.

Assessment by the participating students were used [30] to help determine the acceptability of the proposed learning course. The assessment form was distributed to all students who had taken the course at the Department of Industrial Education and Technology at the National Changhua University of Education, Taiwan. Most students successfully undertook the experiment with GX Works3, and responded positively to the system. They reported that they enjoyed performing the task and found it interesting. Because of the interviews, which were conducted with the students in an unstructured manner, it was determined that students could use the system covered by augmented reality technology learning presented in this study.

Summative assessment is used to assess instructional programs and student achievement. Dick [31] proposed a multi-step framework for planning and conducting summative assessments. Their teaching system has excellent computer statistics ability and can effectively carry out summative evaluation. This enables teachers to fully understand the teaching effect and learning outcomes, and then takes corresponding improvement measures based on the evaluation results to improve the teaching quality and learning outcomes. This study focused on the development of digital learning teaching materials based on programmable control technology. Through discussions with relevant experts and senior teachers in the field, the teaching materials were repeatedly evaluated to review the affinity and suitability of the teaching materials for students. Based on the evaluation results, revisions of the teaching materials were suggested as a basis for improving the teaching materials.

4. Methodology

This study used the ADDIE teaching design model to develop digital teaching materials for programmable controllers and the GX Works3 software. Based on the existing TAM, we set the teaching goals, arranged the teaching material content, and designed the teaching strategies according to the steps of the ADDIE model. We then evaluated and reviewed the programmable control practice teaching materials to explore the benefits of digital blended teaching.

4.1 Research Framework

This study used Davis's TAM [32] as the basis to construct the research structure. The structure included perceived usefulness, perceived ease of use, usage attitude, behavioral intention, and external variables (such as perceived fun), as well as a set of TAM scales suitable for programmable control technology courses.

4.2 Participants

This study took 39 elective students taking programmable control technology courses in the Department of Industrial Education and Technology of National Changhua University of Education as the research subjects to understand the students' learning situation in the course. An easy-to-understand and practical statistical method was used for a quantitative evaluation of the blended courses [33].

4.3 Research Implementation

Research implementation considered how to set up the teaching activities and teaching environment. This learning course gave priority to physical demonstrations, which are supplemented by briefs, in order that students can easily learn and operate. The teaching outcomes of the blended learning course was explored by using TAM, and the teaching duration of was 12 weeks, with 3 hours per week and 36 hours in total. A quantitative questionnaire based on TAM was used in this study.

Before class, the students were required to have basic computer operation skills. The teaching content was explained in detail using digital teaching materials and videos, which allowed students to easily learn the use of GX Works3. Different topics were handled in a step-by-step operation.

4.4 Research Tools

4.4.1 Survey Design

The questionnaire used in this study was based on the literature proposed by Chen et al. [34]. The Cronbach's α coefficient of the research questionnaire was 0.82, indicating that the scale had good reliability. The evaluation form used a scoring method based on a Likert-type five-point scale, in which strongly agree was rated as five points, agree was rated as four points, no opinion was rated as three points, disagree was rated as two points, and strongly disagree was rated as one point [35]. This scoring method allowed the respondents to make choices based on their opinions on each statement and provided a relative quantitative measure for assessing the degree of each indicator.

4.4.2 Establishing Expert Content Validity

After completing the first draft of the questionnaire, scholars with relevant professional knowledge in the field of education were invited to fill in the questionnaire and provide revision opinions to

ensure the expert validity of the survey. Through this process, valuable opinions from multiple professional perspectives were obtained and incorporated into the improvement and revision of the questionnaire.

4.4.3 Questionnaire Survey

A questionnaire survey is a research method that involves substantial contact and communication with the research subjects to collect their information. By distributing questionnaires and collecting the returned responses, this study attempted to understand the opinions, views, and experiences of the research subjects. This study implemented a questionnaire survey on the current situation of using programmable blended learning courses. The TAM scale was divided into the five domains of perceived enjoyment, perceived usefulness, perceived ease of use, usage attitude, and behavioral intention, with a total of 20 questions.

4.4.4 Scale Reliability and Item Analysis

This study used the TAM pretest scale to measure the subjects'satisfaction and opinions on the TAM. Reliability refers to the reliability and consistency of the measurement results and reflects the stability and consistency of the questionnaire results. This study used the alpha coefficient of internal consistency to evaluate the reliability of the pretest scale. The alpha coefficient of the internal consistency for the pre-test scale of the science and technology acceptance mode was 0.922, indicating the scale had good internal consistency. In addition, item analysis is to evaluate the appropriateness of the items. After the item analysis is performed, bad items can be eliminated to improve the quality of the scale. The KMO (Kaiser-Meyer-Olkin) value is an indicator that measures the commonality between variables, with a larger value indicating the existence of more common factors between variables. After performing the item analysis, the KMO value for the item analysis was calculated to be 0.765.

According to the criteria of Kaiser and Rice [36], when the KMO value is greater than 0.5, factor analysis can be performed to construct the scale validity.

(1) According to the TAM pretest scale of this study, the subjects were divided into high and low groups according to their total scores, with the top 27% being the high group and the last 27% being the low group. Then, a mean difference test (t-test) was performed to obtain the decision value (CR) of each question. If the judgment value did not reach a significance level of $p < 0.05$, it would be recommended to delete the corresponding question. However, all items on this scale reached a significance level of $p < 0.001$, so all items were retained.
(2) The correlation between this scale and the total score was analyzed using Pearson's product-difference correlation coefficient. The results showed that the correlation coefficients between all items and the total score exceeded 0.40 and reached a significance level of $p < 0.05$.
(3) The nature of the factor loading is similar to the regression coefficient, and its value reflects the potential variable influence of a question on a questionnaire. When the loading of a certain factor is greater than 0.71, it means that the factor can explain about 50% of the variation of the observed variable, which is considered an ideal situation. On the contrary, if the loading of a factor is lower than 0.32, it means that the factor can only explain less than 10% of the variation of the observed variable. This is considered an unsatisfactory situation. In this case, it is recommended to delete the corresponding factor. In addition, Bagozzi and Yi [37] pointed out that latent variables and factor loadings should be between 0.5 and 0.95. In this scale, as the factor loadings of all items were greater than 0.5, all items were retained.

5. Data Analysis and Results

This study explored the extent to which blended teaching affected students' perceptions of using blended teaching methods in a programmable control technology course. After completing the teaching course, the researchers conducted a questionnaire survey and used SPSS and Smart PLS 4.0 statistical analysis software to analyze and process the data. In addition, semi-structured interviews were used to collect and analyze the students' suggestions and feedback.

5.1 Sample Data Analysis

This study conducted a survey and successfully recovered 39 valid responses. All valid questionnaires were statistically analyzed using quantitative analysis as well as semi-structured interviews.

5.1.1 Descriptive Statistics of the Technology Acceptance Model Questionnaire

Table 1 shows the collected data of the TAM scale used in this questionnaire.

In the perceived enjoyment, the overall average of the TAM scale was 4.23 and the highest average was 4.30, meaning the students often forgot the passage of time during the learning process of the

Table 1. Descriptive statistics of the TAM questionnaire

Domain	Item	Mean	SD
Perceived enjoyment	1. When learning the PLC blended course, I forget the passing of time.	4.30	0.694
	2. When learning the PLC blended course, I take no particular notice whether my surroundings are noisy.	4.13	0.800
	3. The PLC blended learning course is fun to use.	4.21	0.656
	4. PLC blended learning can trigger my interest in learning.	4.28	0.686
Perceived usefulness	5. I think PLC blended learning can improve my learning outcomes.	4.41	0.677
	6. I think PLC blended learning can improve my learning ability.	4.26	0.715
	7. I think it is useful to learn the PLC blended course.	4.38	0.711
	8. I think the PLC blended course can increase my learning efficiency.	4.23	0.742
Perceived ease of use	9. The interfaces of the PLC blended course are clear and understandable.	4.15	0.812
	10. The software of the PLC blended course is easy to use.	3.92	0.870
	11. The hardware of the PLC blended course is easy to use.	3.94	0.825
	12. The links between software and hardware of the PLC blended course are easy to learn.	4.17	0.720
Attitude toward using	13. I think the PLC blended course is a great system to use.	4.49	0.601
	14. The PLC blended course is satisfactory.	4.36	0.706
	15. The PLC blended course is a good way to learn.	3.36	0.706
	16. I love using the PLC blended learning course.	4.23	0.742
Behavioral intention to use	17. I am willing to use the PLC blended course for learning.	4.44	0.641
	18. I feel happy when using the PLC blended course for learning.	4.25	0.677
	19. I would like to increase the frequency of using the PLC blended course for learning.	3.13	0.922
	20. I hope I still can use the PLC blended course for learning in the future.	4.13	0.863

N = 39.

programmable control technology blended course. The lowest average value was 4.13, indicating the students did not pay special attention to whether the surrounding environment was noisy when studying the programmable control technology blended course. These results showed that the students felt happy about the programmable control technology blended course and could achieve the learning goals in a pleasant learning environment.

In the dimension of perceived usefulness, the overall average of the scale of TAM was 4.32 and the highest average was 4.38. This meant that most students believed that learning a blended course on programmable control technology was beneficial, and that this course was of great significance in improving their learning results. On the other hand, the average minimum score for this domain was 4.23, which showed the students believed that using programmable control technology to blend courses could improve their learning efficiency. These results indicated that the students had a positive attitude towards the performance and future benefits of studying this course.

In the domain of perceived ease of use, the overall average of the TAM scale was 4.04. The highest average was 4.17 for "The links between the software and hardware of the PLC blended course are easy to learn". On the other hand, the lowest average score was 3.92 for "The software of the PLC blended course is easy to use". The results showed that the students found it easy to control the programmable controllers and use the editing software.

In terms of attitude towards using, the TAM scale showed an overall mean of 4.36, with the highest mean score of 4.49. This indicated that most of the students had a positive attitude towards the programmable control technology blended course and believed that it was a good learning system. On the other hand, the average lowest score for this domain was 3.36, which showed that the students had different views on whether blended courses using digital learning platform's programmable control technology represented an effective learning method. Overall, most students gave positive evaluations to the blended course on programmable control technology.

In the domain of behavioral intention to use, the overall average was 3.98, with the highest average being 4.44 for "I am willing to use the PLC blended course for learning". The lowest average was 3.13 for "I would like to increase the frequency of using the PLC blended course for learning".

5.1.2 Students' Suggestions and Feedback on the Programmable Control Technology Blended Course

The students' suggestions and opinions on the programmable control internship course were analyzed and sorted. The students were assigned codes to preserve their anonymity, with S representing the student's code name, and the following two digits

representing the serial number. The results are as follows:

(1) Please give me your suggestions for this digital course or areas for improvement in the future.

For those who have no foundation, it is easy to understand and does not need to be improved. (S01)

I hope to introduce more buttons and software. (S02)

I have more time to operate and practice the software. (S05, S36)

I can update computer hardware, install anti-virus software, and more PLC5U can be used. (S07, S23)

I hope that the number of physical courses can be increased to improve the proficiency of practical operations. (S12)

I hope that the instructions and usage of the PLC can be explained in more detail. (S18, S37)

The picture can be clearer. It is very difficult to understand the ladder diagram. I hope there are more detailed explanations and teachings. (S22)

I hope it can be implemented with an actual motor or machine. (S28, S30, S34)

From the feedback information, it could be seen that the participants wanted the course to provide more relevant resources, including updates to the computer and PLC equipment; in terms of the digital teaching material experience, the participants hoped that the overall recording quality and operating instructions could be improved in the future.

(2) Participants' thoughts on this course

It is novel and great to be exposed to GX Works3, which I have never learned before. (S03, S11, S13)

I am more proficient in PLC control and programming and can also design interesting small topics on my own, which gives me a great sense of accomplishment. (S06)

Because I have never been exposed to PLC in higher vocational colleges, I thought it would be difficult at first. Fortunately, the teaching method is simple and easy to understand. Being able to learn one more skill gives me a sense of accomplishment. (S12)

The practice combined with the digital audio-visual teaching method allowed me to quickly get started with homework and special exercises, but the only pity is that I don' t have a clear understanding of the commands; I only know the general function usage, and even some commands can' t be used freely, or what is the actual function. (S18)

It turns out that PLC is used in the operation of many machines in life, which is very cool! (S15, S22)

The teaching methods of this course are diverse, and the willingness to learn increases. (S7, S19, S23)

The teacher teaches in great detail and the videos can be played repeatedly, so you can listen to it several times for those who are not familiar with it, and then you will not go wrong when you practice it. (S30)

It is basically no problem to operate it after watching the videos of Cloud Academy. (S32)

The senior's guidance is very attentive, and he will clearly explain the sequence of operations if he doesn' t understand. (S08, S31)

The effect of going to the practice classroom is better than at home. Although I can arrange my own time at home, it is more effective to come to the classroom for machine operation courses. (S37)

I only learned writing instruments in high school, but here I can learn software that I have never used such as GPP Win, GX Works2, and GX Works3, and I have benefited a lot. (S38)

The course content of Cloud Academy allows people to get started quickly, which I think is great. (S14, S39)

The feedback information shows that digital courses are effective and practical for students' learning. However, in digital course learning, students may become passive learners due to inertia, which highlights the necessity of traditional classroom teaching. The production of teaching materials should be aimed at increasing students' learning motivation and interest, which will help improve students' initiative in digital learning.

As results of the students' suggestions and feedback, which were conducted with the students in an unstructured manner, it was determined that students could use the learning course presented in this study.

5.2 Reliability Analysis of the TAM Questionnaire

The reliability and consistency of the questionnaire were tested. Reliability refers to whether a measurement instrument (such as a questionnaire) produces consistent results when used multiple times. Overall, high reliability proves that a questionnaire can measure the target variable stably, which improves the credibility and reliability of the research results.

The internal consistency α coefficient of the TAM scale of the programmable control technology blended learning course usage survey questionnaire in this study was 0.922, indicating that the internal consistency of the scale is good. The correlation

coefficient (item-to-total value) for the total score of a scale determines the internal consistency and should be greater than 0.5 to confirm that the factor is accepted.

5.3 Regression Analysis of the TAM Scale

5.3.1 Regression Analysis of the Effect of Perceived Pleasure on Perceived Usefulness

Through regression analysis, the relationship between the independent variable perceived pleasure and the dependent variable perceived usefulness was explored. The results are shown in Table 2. The significance reached a $p = 0.021$ (< 0.05), indicating a significant difference was reached and that perceived pleasure has a significant effect on perceived usefulness. The hypothesis was therefore accepted.

5.3.2 Regression Analysis Exploring the Impact of Perceived Enjoyment on Perceived Ease of Use

Through regression analysis, the relationship between the independent variable perceived pleasure and the dependent variable perceived ease of use was explored. The results are shown in Table 3. The significance value of $p = 0.062$ (> 0.05) indicated there was no significant difference and that perceived enjoyment has no significant impact on perceived ease of use. Therefore, the hypothesis was rejected.

5.3.3 Regression Analysis to Explore the Impact of Perceived Usefulness on Usage Attitude

Through regression analysis, the relationship between the independent variable perceived usefulness and the dependent variable usage attitude was explored. The results are shown in Table 4. The significance value of $p = 0.000$ (< 0.001) indicated a significant difference and that perceived usefulness has a significant impact on usage attitude. Therefore, the hypothesis was accepted.

5.3.4 Regression Analysis to Explore the Impact of Perceived Ease of Use on Attitude Towards Use

Through regression analysis, the relationship between the independent variable perceived ease of use and the dependent variable usage attitude was explored. The results are shown in Table 5. The significance value of $p = 0.004$ (< 0.01) reached a significant difference, indicating that perceived ease of use has a significant difference in usage attitude. Therefore, the hypothesis was accepted.

Table 2. Regression analysis of the impact of perceived enjoyment on perceived usefulness

	Unstandardized coefficient		Standardized coefficient		
	Estimated value of B	Standard error	Beta distribution	t	Significance
Perceived enjoyment	2.597	0.719		3.610	0.001
	0.407	0.169	0.369	2.416*	0.021

$F = 5.835$; $R^2 = 0.136$; $*p < 0.05$.

Table 3. Regression analysis of the impact of perceived fun on perceived ease of use

	Unstandardized coefficient		Standardized coefficient		
	Estimated value of B	Standard error	Beta distribution	t	Significance
Perceived enjoyment	2.522	0.800		3.151	0.003
	0.361	0.188	0.302	1.926	0.062

$F = 3.709$; $R^2 = 0.091$.

Table 4. Regression analysis of the impact of perceived usefulness on attitude toward use

	Unstandardized coefficient		Standardized coefficient		
	Estimated value of B	Standard error	Beta distribution	t	Significance
Perceived usefulness	1.757	0.538		3.268	0.002
	0.602	0.123	0.626	4.883***	0.000

$F = 23.846$; $R^2 = 0.392$; $***p < 0.001$.

Table 5. Regression analysis of the impact of perceived ease of use on attitude towards use

	Unstandardized coefficient		Standardized coefficient		
	Estimated value of B	Standard error	Beta distribution	t	Significance
Perceived ease of use	2.739	0.534		5.132	0.000
	0.400	0.130	0.451	3.073**	0.004

$F = 9.444$; $R^2 = 0.203$; $**p < 0.01$.

Table 6. Regression analysis of the influence of usage attitude on behavioral intention

	Unstandardized coefficient		Standardized coefficient		
	Estimated value of B	**Standard error**	**Beta distribution**	**t**	**Significance**
Usage attitude	0.499	0.561		0.889	0.380
	0.858	0.128	0.741	6.715***	0.000

F = 45.288; R^2 = 0.549; ***p < 0.001.

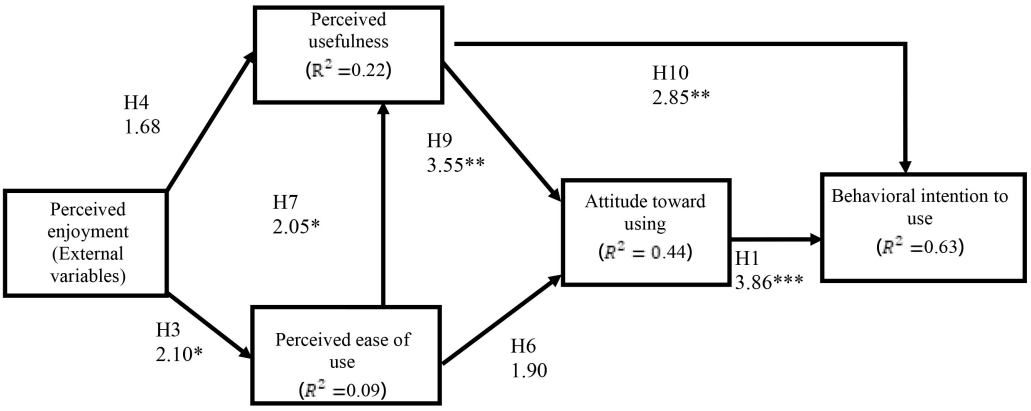

Fig. 2. TAM verification results (*p < 0.05; **p < 0.01; ***p < 0.001).

5.3.5 Regression Analysis to Explore the Impact of Usage Attitude on Behavioral Intention

Through regression analysis, the relationship between the independent variable usage attitude and the dependent variable behavioral intention was explored. The results are shown in Table 6. The significance value of p = 0.000 (< 0.001) indicated a significant difference and that usage attitude has a significant impact on behavioral intention. Therefore, the hypothesis was accepted.

5.4 Model Validation and Hypothesis Testing

This study used SmartPLS 4.0 software to conduct significance testing of the structural model to verify whether the hypotheses could be established. The R^2 value represents the percentage of variation explained by the independent variable for the dependent variable and is used to evaluate the predictive ability of the research model. In PLS analysis, the R^2 value is mainly used to evaluate the predictive ability of the structural paths [38]. This study set up 2000 resampling iterations to test the significance of each structural path. The results of the model verification are shown in Fig. 2.

According to the research results, perceived usefulness and perceived ease of use had relatively low explanatory power on attitude towards use (R^2 = 0.44), while attitude towards use had high explanatory power on behavioral intention (R^2 = 0.63). Based on the results shown in Table 7, the ten hypotheses on the relationship between the variables in the TAM are organized as follows: Overall, except for H4: perceived fun to perceived usefulness and H6: perceived ease of use to usage status, which was not supported by the test results, the other hypotheses all showed positive and significant effects.

In addition, H1: attitude to use to behavioral

Table 7. Test results of the relationships among variables

Hypothesis/relationship between variables	**Path coefficient (β)**	**t**	**Results**
H1:Attitude toward using → Behavioral intention to use	0.51	3.86***	Supported
H2:Perceived enjoyment → Attitude toward using	0.15	2.50*	Supported
H3:Perceived enjoyment → Perceived ease of use	0.30	2.10*	Supported
H4:Perceived enjoyment → Perceived usefulness	0.28	1.68	Unsupported
H5:Perceived enjoyment → Behavioral intention to use	0.10	2.45*	Supported
H6:Perceived ease of use → Attitude toward using	0.24	1.90	Unsupported
H7:Perceived ease of use → Perceived usefulness	0.31	2.05*	Supported
H8:Perceived ease of use → Behavioral intention to use	0.12	2.53*	Supported
H9:Perceived usefulness → Attitude toward using	0.53	3.55***	Supported
H10:Perceived usefulness → Behavioral intention to use	0.36	2.85**	Supported

*p < 0.05; **p < 0.01; ***p < 0.001.

intention ($\beta = 0.51$, t = 3.86, $p < 0.001$) showed a significant positive effect; H2 (H4 + H9): perceived fun to attitude to use ($\beta = 0.15$, t = 2.50, $p < 0.05$) had a significant positive impact; H3: perceived fun to perceived intentionality ($\beta = 0.30$, t = 2.10, $p < 0.05$) had a significant positive impact; H5 (H4 + H10): perceived fun to behavioral intention ($\beta = 0.10$, t = 2.45, $p < 0.05$) had a significant positive impact; H7: perceived ease of use to perceived usefulness ($\beta = 0.31$, t = 2.05, $p < 0.05$) had a significant positive impact; H8 (H6 + H1): perceived ease of use to behavioral intention ($\beta = 0.12$, t = 2.53, $p < 0.05$) had a significant positive impact; H9: perceived usefulness to usage attitude ($\beta = 0.53$, t = 3.55, $p < 0.001$) had a significant positive effect; H10: perceived usefulness to behavioral intention ($\beta = 0.36$, t = 2.85, $p < 0.01$) also showed a positive and significant effect.

6. Discussions

This study used TAM by incorporating PLC blended learning course as well as integrating technology acceptance and learner satisfaction. The overall results did support the influence of learning course to contribute to the critique of this psychological education theory.

In the programmable control technology TAM questionnaire constructed in this study, the domains were divided into perceived enjoyment (external variables), perceived usefulness, perceived ease of use, usage attitude, and behavioral intention to explore programmable control technology. The analysis results are as follows:

(1) User attitude has a positive and significant effect on behavioral intention.
(2) Perceived pleasure has a positive and significant effect on usage attitude.
(3) Perceived pleasure has a positive and significant effect on perceived ease of use.
(4) Perceived pleasure has no significant effect on perceived usefulness.
(5) Perceived pleasure has a positive and significant effect on behavioral intention.
(6) Perceived ease of use has a significant effect on usage attitude.
(7) Perceived ease of use has a positive and significant effect on perceived usefulness.
(8) Perceived ease of use has a positive and significant effect on behavioral intention.
(9) Perceived usefulness has a positive and significant effect on usage attitude.
(10) Perceived usefulness has a positive and significant effect on behavioral intention.

The findings of this study that TAM can be used to predict *Behavioral intention to use* are in alignment with the findings of previous studies [39, 40]. *Perceived usefulness* had indirect as well as direct effects on learner's acceptance of the proposed learning course and *Attitude toward use* had direct effects. Some researchers have obtained similar findings [41, 42].

The results of our statistical analysis demonstrate that the students in this study were willing to use the blended learning course. This study focused on the relationships among the ''perceived usefulness'', ''perceived ease of use'', ''attitude toward use'' and ''behavioral intention to use'' of students.

Moreover, it was not possible to observe long-term usage behavior by these students. Therefore, future studies should utilize a longitudinal research design to predict the beliefs and behaviors of users after a period and thereby provide an understanding of the causal relationships between variables.

7. Conclusions

The purpose of this study was to develop an online teaching courses to facilitate traditional teaching approaches, and constructed a complete blended learning system that could enhance students' interest and learning effects. This study used instructional design theory and developed a programmable control technology blended learning course as an actual teaching aid to design a digital learning course that integrated media information into the teaching process to utilize the characteristics of media information. Through the design of the teaching activities, this study hoped to attract students' interest in learning, build their learning confidence, and improve their learning effect.

This study presented an integrated theoretical framework of students' PLC blended learning course acceptance and behavioral intention to use based on the technology acceptance model (TAM). Three variables, the perceived usefulness (PU), perceived ease of use (PEOU), and attitude toward use (ATU), were shown to have an influence on the intention of learners to use the proposed learning course.

In this study, it was observed from the interaction between the researcher and the course participants that most learners had a positive response to the PLC blended teaching course. They believed that such a learning environment could provide an interesting learning experience and increase the learners' interest in the course content. They felt that the course was practical, easy to use, and helpful. The learners demonstrated positive attitudes and intentions in the learning process and were willing to actively participate in course activities and apply what they had learned to practical situations.

References

1. S. W. Chou and C. H. Liu, Learning effectiveness in a web-based virtual learning environment: a learner control perspective, *Journal of Computer Assisted Learning*, **21**, pp.65–76, 2005.
2. Y. W. Wu, L. M. Young and M. H. Wen, Developing an iBeacon-based ubiquitous learning environment in smart green building courses, *International Journal of Engineering Education*, **32**(2A), pp. 782–789, 2016.
3. E. Rosales-Asensio, E. Gonzá lez, D. Baragañ o and C. Sierra, Investigating electromechanical engineering lecturers' perceptions of MOOCs, *International Journal of Engineering Education*, **39**(5), pp. 1059–1073, 2023.
4. F. D. Davis, Perceived Usefulness, Perceived Ease of Use and User Acceptance of Information Technology, *MIS Quarterly*, **13**(3), pp. 319–340, 1989.
5. J. Cheon, S. Lee, M. C. Steven and J. Song, An investigation of mobile learning readiness in higher education based on the theory of planned behavior, *Computers & Education*, **59**(3), pp. 1054–1064, 2012.
6. A. N. Paimin, R. G. Hadgraft, J. K. Prpic and M. Alias, An application of the theory of reasoned action: Assessing success factors of engineering students, *International Journal of Engineering Education*, **32**(6), pp. 2426–2433, 2016.
7. V. Venkatesh and F. D. Davis, A theoretical extension of the technology acceptance model: Four longitudinal field studies, *Management Science*, **46**, pp. 186–204, 2000.
8. J. Pfeffer, Organizations and organization theory, Marshfield, MA, Pitman, 1982.
9. M. Fishbein and I. Ajzen, Belief, attitude, intention, and behavior: An introduction to theory and research. MA: Addison-Wesley, 1975.
10. B. Güzer and H. Caner, The past, present and future of blended learning: An in depth analysis of literature, *Procedia – Social and Behavioral Sciences*, **116**, pp. 4596–4603, 2014.
11. A. M. Nortvig, A. K. Petersen and S. H. Balle, A literature review of the factors influencing e-learning and blended learning in relation to learning outcome, student satisfaction and engagement, *The Electronic Journal of e-Learning*, **16**, pp. 46–55, 2018.
12. H. Singh, Blended learning, *Issue of Educational Technology*, **43**(6), pp. 51–54, 2003.
13. Z. A. Syed, Z. Trabookis, J. W. Bertrand, K. C. Madathil, R. S. Hartley, K. K. Frady, J. R. Wagner and A. K. Gramopadhye, Evaluation of virtual reality based learning materials as a supplement to the undergraduate mechanical engineering laboratory experience, *International Journal of Engineering Education*, **35**(3), pp. 842–852, 2019.
14. A. P. Rovai and M. Jordan, Blended learning and sense of community: A comparative analysis with traditional and fully online graduate courses, *The International Review of Research in Open and Distance Learning*, **5**, 2004.
15. A. Mosyjowski, R. Daly and J. Skerlos, Investigating an asynchronous model for incorporating social aspects of engineering work into engineering design courses, *International Journal of Engineering Education*, **39**(4), pp. 798–810, 2023.
16. W. Dick, L. Carey and O. C. James, The systematic design of instruction (7th ed.), New York: Harper Collins, 2011.
17. R. M. Gagne, W. W. Wager, K. G. Golas and J. M. Keller, Principles of instructional design, Toronto, ON: Thomson Wadsworth, 2005.
18. D. Liang, W. Li, N. Wang, J. Gao and H. Jin, The design and implementation of an intelligent education prototype for an electronic systems course, *International Journal of Engineering Education*, **38**(1), pp. 117–129, 2022.
19. Y. H. Chu, C. C. Chung, R. C. Shih and S. J. Lou, Development and assessment of a 3D printing course for technical high school students, *International Journal of Engineering Education*, **38**(2), pp. 549–563, 2022.
20. C. Hmelo and X. Lin, Becoming self-directed learners: Strategy development in problem-based learning, In D. Evensen & C. Hmelo (Eds.), Problem-based learning: A research perspective on learning interaction. Mahwah, NJ: Erlbaum, 1998.
21. Mitsubishi Electric, MITSUBISHI ELECTRIC Global website, https://www.mitsubishielectric.com/en/index.html (accessed on 16 November 2023)
22. J. E. Ormrod, *Educational psychology: Developing learners* (7th ed.), NJ: Pearson Education, 2010.
23. R. Moreno, and T. Flowerday, Students' choice of animated pedagogical agents in science learning: A test of the similarity-attraction hypothesis on gender and ethnicity, *Contemporary Educational Psychology*, **31**(2), pp. 186–207, 2006.
24. G. R. Morrison, S. M. Ross, J. E. Kemp and H. Kalman, Designing effective instruction (6th ed.), USA: John Wiley & sons, 2011.
25. P. Eggen and D. Kauchak, Strategies and models for teachers(5th ed.), Boston: Pearson Allyn and Bacon, 2006.
26. C. E. Hmelo-Silver, R. G. Duncan and C. A. Chinn, Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark, *Educational Psychologist*, **42**, pp. 99–107, 2007.
27. B. J. Zimmerman, Investigating self-regulation and motivation: Historical background, methodological developments and future prospects, *American Educational Research Journal*, **45**, pp. 166–183, 2008.
28. P. R. Pintrich and D. Schunk, Motivation in education: Theory, research, and applications (2nd ed.). Upper Saddle River, NJ: Prentice Hall, 2002.
29. A. R. P. Maria, Informal formative assessment: The role of instructional dialogues in assessing students' learning, *Studies in Educational Evaluation*, **37**(1), pp. 15–24, 2011.
30. T. C. Chen, Y. C. Wang and M. C. Chiu, Assessing the robustness of a factory amid the COVID-19 pandemic: A fuzzy collaborative intelligence approach, *Healthcare*, **8**(4), p. 481, 2020.
31. W. Dick, The dick and carey model: Will it survive the decade? *Educational Technology Research and Development*, **44**(3), pp. 55–63, 2011.
32. F. D. Davis, R. Bagozzi and P. R. Warshaw, User acceptance of computer technology: A comparison of two theoretical models, *Management Science*, **35**, pp. 982–1003, 1989.
33. E. Freund and M. Perles, Modern elementary statistics(12th ed.), NJ: Pearson education, 2007.
34. H. C. Chen, R. G. Tsai, Y. C. Lin, C. C. Hsu and Y. M. Huang, Applying the technology acceptance model to evaluate an interactive glove learning system on the electrical and electronics engineering course, *The 5th Asia-Pacific Conference on Engineering and Technology Education*, pp. 247–255, 2012.
35. W. J. Shyr, C. C. Huang, C. H. Chen and J. S. Wei, Students' acceptance of applying internet of things in a smart agriculture course, *International Journal of Engineering Education*, **36**(6), pp. 1956–1966, 2020.
36. H. F. Kaiser and J. Rice, Little Jiffy Mark IV, *Educational and Psychological Measurement*, **34**, pp. 111–117, 1974.

37. R. P. Bagozzi and Y. Yi, On the evaluation of structural equation models, *Journal of the Academy of Marketing Science*, **16**, pp. 74–94, 1980.
38. H. H. Teo, K. K. Wei and I. Benbasat, Predicting intention to adopt interorganizational linkages: An institutional perspective, *MIS Quarterly*, **27**(1), pp. 19–49, 2003.
39. Y. M. Cheng, S. J. Lou, S. H. Kuo and R. C. Shih, Investigating elementary school students' technology acceptance by applying digital game-based learning to environmental education, *Australasian Journal of Educational Technology*, **29**(1), pp. 96–110, 2013.
40. Y. Park, H. Son and C. Kim, Investigating the determinants of construction professionals' acceptance of web-based training: An extension of the technology acceptance model, *Automation in Construction*, **22**, pp. 377–386, 2012.
41. J. C. Hong, M. Y. Hwang, H. F. Hsu, W. T. Wong and M. Y. Chen, Applying the technology acceptance model in a study of the factors affecting usage of the Taiwan digital archives system, *Computers & Education*, **57**(3), pp. 2086–2094, 2011.
42. A. Al-Azawei, P. Parslow and K. Lundqvist, Investigating the effect of learning styles in a blended e-learning system: An extension of the technology acceptance model (TAM), *Australasian Journal of Educational Technology*, **33**(2), pp. 1–23, 2017.

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