Article

Perceived Effectiveness of Developing a Mobile System of Formative Test with Handwriting Revision to Devise an Instruction Design Based on Cognitive Apprenticeship Theory

Shih-Che Lo [1] and Hung-Hsu Tsai [2,*]

1   Department of Industrial Management, National Taiwan University of Science and Technology, Taipei City 106335, Taiwan; sclo@mail.ntust.edu.tw
2   Institute of Data Science and Information Computing, National Chung Hsing University, Taichung City 402204, Taiwan
*   Correspondence: afhmthh@nchu.edu.tw; Tel.: +886-4-2284-0421 (ext. 621)

Abstract: Education helps increase socioeconomic mobility and is an important way of leaving poverty according to the United Nations, especially since COVID-19 hit the world hard in early 2020. A Mobile System of Formative Tests with Handwriting Revision is proposed in the paper, called the MSFT system. The MSFT is developed from the cognitive apprenticeship theory (CAT) in instructional design. The instruction model can be utilized for higher education mathematics teaching/studying for quiz-oriented instruction inside traditional classrooms as well as for distance-learning modes. The MSFT platform provides college undergraduates and graduates an app for a handheld device, which is used to upload their answer sheets with captured photos to the cloud database server. Moreover, instructors can use the platform to revise or assess answer sheets with instructors' handwriting through web interfaces or apps. Important features of the integrated platform for teachers are (1) grading answer sheets by handwriting, (2) correcting mistakes in the answer sheets by handwriting, (3) writing down instructors' comments on students' answer sheets directly, and (4) choosing examples to demonstrate during class presentation, in a single window through web applications. To evaluate MSFT performance and service level for students, a questionnaire survey was conducted for 51 students and separated into an experimental group and a control group. Results from the experiment show that learning attitudes and learning satisfaction were significantly increased with the MSFT system in the experimental group compared to the control group.

Keywords: instructional design; sustainable education; mathematics learning; higher education; cognitive apprenticeship theory

1. Introduction

Education helps increase socioeconomic mobility and is an important way of leaving poverty according to the United Nations (UN), especially after COVID-19 hit the world hard in 2020. The UN defines Education for Sustainable Development (ESD) as sustainable education that promotes teaching changes in attitudes, technology, locations, values, and information to target a more sustainable way for all levels of education [1,2]. ESD empowers and equips current and future generations to meet their needs by providing a sustainable path to environmental, social, and economic dimensions in order to achieve the sustainable development goals (SDGs) [3].

With rapid developments in computer technology and wireless networks, mobile devices such as tablet PCs and smartphones are ubiquitous in our life currently. People use them easily, and they have diverse functions, such as apps. Mobile devices have caused a great reduction in the need for personal computers [4–6]. Moreover, teachers utilize apps in class to display teaching multimedia, including comprehensive text, voice, and images

in the application. This way teachers can easily create teaching guidelines for instruction. Academic fields use e-Learning to improve teaching quality, improve learning outcomes, and provide students with opportunities to achieve promising results. Additionally, an extended development of e-Learning, which is called mobile learning (m-Learning), can be appropriately applied in traditional classrooms without computers but with wireless network facilities [7]. Hence, one of the main advantages of using m-Learning is that learning can happen anytime and anywhere.

In order to cope with ESD, a new teaching framework based on the CAT is proposed in this paper. It emphasizes the real learning situation, especially the authenticity of cognition. Teachers teach materials by cognitive–apprenticeship methods, such as modeling, coaching, and scaffolding, so that students can realize the cognitive thinking process and gain knowledge of situation changes. This helps students to enhance their understanding of the overall learning contents and methods. A teaching method based on the CAT can be specified as learning that is integrated and activated with deliberate utilization of physical and social materials [8].

Nowadays, the CAT has been used in devising new instruction models in various research fields for studying at all levels of education. The instructional model of the CAT utilizes the principles of cognitive apprenticeship for clinical skills teaching [9,10]. The authors of [9] proposed a model to overcome the problem that many learners tend to have a degraded emphasis on apprenticeship instruction. The authors of [10] used the CAT in pharmacy education based on a flipped classroom and blended learning to foster the critical-thinking skills required of pharmacists in practice. The authors of [11] followed the principles of the cognitive apprenticeship model (CAM) in the design of instructor–participant interaction teaching in the classroom. These interactions support studying while delivering modern technological thinking as well as problem-solving skills to seventh-graders. The authors of [12] implemented the CAM based on a web-based manner for a course to construct a methodological framework that is used to foster students to be teachers. The CAM is also used to construct a learning environment for a class teaching computer programming [13]. The design of the educational environment takes apprenticeship cognition and coping with programming teaching methods as the primary instructional formats. An objective was to apply the CAM to the design of instruction in the classroom and to discover which clues were encountered while realizing the proposed classroom instruction of cultivating teachers in vocational institutions [14]. The authors of [15] developed a learning mechanism that combines the CAMs and collaborative studying models, and then the learning mechanism was applied to foster students' problem-solving abilities. They investigated learning mechanisms for human factors on the problem-solving effectiveness of the CAM.

The CAT was also used in math courses [16–18]. The authors of [17] explored how to apply 3D virtual reality technology to promote teaching mathematics in elementary schools. A novel framework with the CAT was first developed by a 3D virtual reality technology, and then was used in mathematics learning. The authors of [18] proposed a cognitive apprenticeship studying space that was applied to studying for math modeling and problem-solving. By monitoring students in the learning space, instructors can show various techniques to be used in fostering students' way of thinking with a specialist's way of thinking.

Many studies have proposed integrating information technology in teaching mathematics and have obtained outstanding results. Many schemes of teaching mathematics in conventional classrooms require additional equipment—for instance, a laptop PC, projector, TVs, etc. In addition, the learning management system (LMS) helps students study math. Currently, it is ubiquitous to observe that the younger generation use their own handheld devices in the classroom for on-campus courses or have participated in distance learning at home through web conference platforms since the beginning of the COVID-19 outbreak. Therefore, how to integrate CAT-based instruction with m-Learning for teaching

mathematics in a traditional classroom or using long-distance web meetings is a popular and emerging research topic for ESD [19].

Many articles have been presented to reflect that employing handwriting to assist students in learning mathematics has shown promising results [20,21]. An approach was proposed in [20] to show the deployment, adaptation, and examination of handwriting-based interfaces in developing intelligent tutoring platforms for learning while solving algebra equations. Results show that the proposed platform helped students by using handwriting while learning mathematics in higher education. A digital pen learning platform was presented in [21] and was applied in collaborative learning with problem solving to explore the effectiveness of learning motivation and learning achievement in traditional mathematics courses. Moreover, most popular LMSs do not offer instructors user-friendly operations for revising answer sheets with an image version with the instructors' handwriting. In the learning process of proceeding with a quiz, once the students have finished the handwriting quiz by writing down their answers on answer sheets, they utilize mobile devices to get photo versions of the students' answer sheets and then transfer the images to the LMS. For instance, one LMS, e3 campus (http://e3.nfu.edu.tw/EasyE3P/LMS2/, accessed on 5 January 2022), is utilized at National Formosa University in Taiwan. First, instructors revise the students' handwritten answers in the LMS. Second, they submit their handwritten answer sheets to the LMS and view their teacher-revised answer sheets in the LMS. The following limits and drawbacks can be found.

- Instructors cannot quickly download students' answer sheets to proceed with revisions. Figure 1a illustrates instructors get learners' answer sheets during revision using a batch process. Figure 1b shows instructors getting learners' answer sheets during revision using a step-by-step method.
- Instructors require other tools—for instance, paint (mspaint.exe in MS Windows operation system)—while revising participants' papers by handwriting. Figure 2a displays instructors grading papers by hand using handwriting software, which is often required to be installed on instructors' PCs or handheld devices. Figure 2b exhibits instructors being required to switch between two separate windows. One is used to view students' answer sheets. The other is used to revise them with handwriting.
- Instructors have difficulties uploading students' revised answer sheets to the LMS. That is, revising current answer sheets and uploading the revised answer sheets are shown in two individual windows. Figure 3a,b show that instructors save revised answer sheets on their computers and that these sheets are uploaded to the LMS, respectively.
- The e3 campus does not provide management operations for recording, answering mistakes, and then analyzing them.
- Instructors have difficulties marking or assigning graded papers for two teaching methods of the CAM, modeling and reflection.
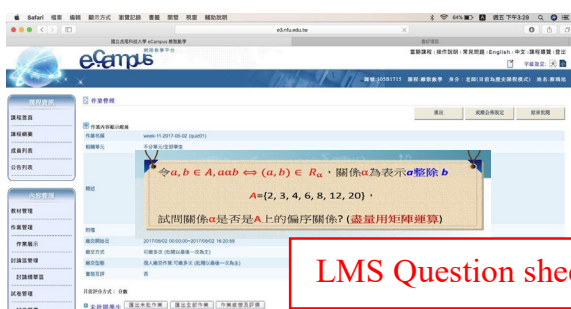
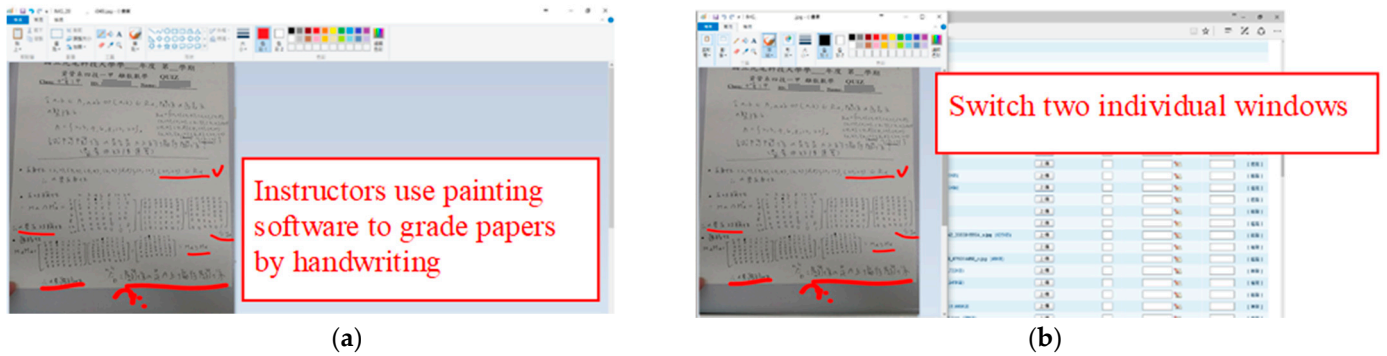
(**a**)　　　　　　　　　　　　　　　　(**b**)

Figure 1. (**a**) Shows how instructors receive participants' answer sheets for grading by batch processing. (**b**) Shows how instructors receive participants' answer sheets for grading using one-by-one steps.

Figure 2. (**a**) Instructors grade papers by handwriting using handwriting-supported software. (**b**) Instructors have to switch between two individual windows on screen while receiving participants' papers and grading them by handwriting.
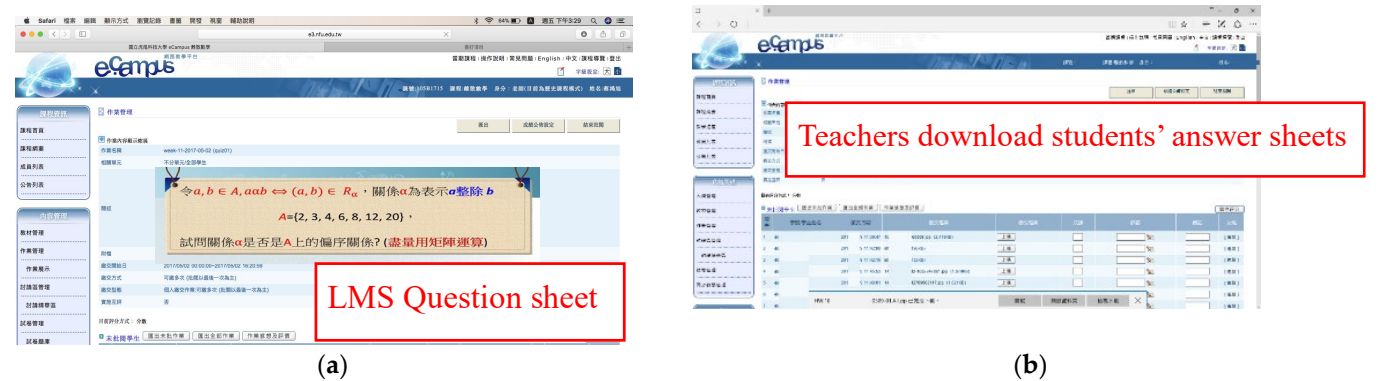
Figure 3. (**a**,**b**) show instructors saving revised papers on their computers first and then uploading them to the LMS.

This motivates us to propose an instructional design that is based on the CAT and using handwriting to answer quizzes in mathematics. Moreover, the MSFT platform is devised in the paper to support instructional design in mathematics, which offers cross-platform operations for teachers to revise answer sheets by handwriting, to assign kinds of mistakes to students' answers by handwriting, and to collect the results of learners' answers according to Bloom's cognitive domains. In the proposed instructional design model, the learning process for mathematics teaching/studying in the traditional classroom concentrates on handwritten quizzes. Teacher revises students' answer sheets by handwriting to show learning results for students' answers. Therefore, the instructional design involves taking teachers' handwritten revisions. This way implements two methods, modelling and reflection, of the CAM in the traditional classroom for quizzes that are used while learning mathematics. One of the important characteristics of the MSFT platform is that teachers can work on these tasks with web-based apps as we enter the metaverse. These functions can be operated in the same window without switching windows. The platform also offers students several operations that are implemented by apps, such as uploading participants' papers by camera-captured photos, inquiring about the results of answer sheets, obtaining graded papers via instructors' handwriting, and studying learning materials. The operations mentioned above are detailed in the proposed instructional design model of the CAM for learning mathematics.

A questionnaire was utilized to assess the perceived effectiveness of the instructional design involving the MSFT platform while lecturing in conventional classrooms. The authors of [22] developed a mobile learning environment to investigate the learning effects in terms of learning interest and learning attributes using a formative assessment-based approach for a local culture course. The authors of [23] developed a video annotation

learning system to make students easily annotate and highlight key content. The learning effects of learning satisfaction and cognitive style in terms of both mental load and mental effect were investigated for the system while watching a video in a CPR course. In the paper, the research questions for the questionnaire were designed based on the above research literature, and are as follows.

- Do the participants who receive the instructional design supported by the MSFT platform outperform those learning without the MSFT platform in terms of interests of learning?
- Do the participants who receive the instructional design supported by the MSFT platform outperform those learning without the MSFT platform in terms of attitudes of learning?
- Do the participants who receive the instructional design supported by the MSFT platform outperform those learning without the MSFT platform in terms of satisfaction of learning?

This research paper is organized as follows. Section 2 reviews related articles. Section 3 briefly describes the MSFT system. The instructional design model according to the CAT is proposed for teaching mathematics classes, with the results and discussion provided in Section 4. Conclusions are given in the last section.

2. Literature Review

2.1. Mobile Learning

Recently, much literature has obtained significant outcomes in using m-Learning in higher education. Utilizing innovations in mobile technology, m-Learning has become more popular and varied for education. Because of the highly mobile characteristic of m-Learning, it is capable of performing data access easily through various formats through a wireless network for reading or studying. How to get available data using mobile devices while learning and then exploring correlations or relationships among data is emerging as a challenging problem [24]. In an m-Learning model, the authors of [25] found out that learners often acquire diverse learning content through mobile devices over a network. Learners feel free and more flexible than in traditional learning without mobile devices. Furthermore, m-Learning can assist learners to promote their learning performance. Generally speaking, an m-Learning model roughly contains five basic components: participant, instructor, environment, materials, and evaluation. Critical characteristics of m-Learning include it being pervasive, interactive, private, spontaneous, blended, instant, and collaborative, as well as involving portable mobile devices. The authors of [26] analyzed 49 empirical studies (60 papers) that were published from 2003 to 2016. The topics of these studies related to mathematics or science learning where teachers lectured with mobile apps and technologies in secondary school education. The authors of [27] showed that learning with mobile technologies has shown improvements in learning outcomes. The authors of [28] showed that teachers realize collaborative learning by combining mobile and conventional learning for elementary students. The learning scheme led to a positive effect on school children's thinking skills.

2.2. CAT

The cognitive apprenticeship theory (CAT) was presented in [8] as a sort of instructional model based on mimicking apprentices working under master craftspeople in conventional communities. In this master–apprentice model, the master craftspeople usually realize a psycho-motor skill observed by the apprentices, who continue learning this skill under guidance and also receive the masters' aid. A major dissimilarity between the conventional model and the CAM is from the viewpoint of task visibility. In a conventional apprenticeship, the procedure of doing to learn a task or skill is always facilely observable. In the CAM, implementing the task or skill is probably observable. At the same time, an emphasis between these two models focuses on thinking that has to precede and be a part of the task, and accompany any required observations made after its completion. The six

main learning schemes of the CAM during learning activities are (1) modeling, (2) coaching, (3) scaffolding, (4) articulation, (5) reflection, and (6) exploration. Readers can find the definitions and functions of these activities in our previous publication [29].

Recently, CAM was widely treated as an instructional model in the development of higher-order cognitive skills by the authors of [30]. The authors of [31] presented a mentorship approach for facilitator development models based on the CAM. Facilitators effectively utilize simulation-based education for clinicians and clinical educators. The authors of [32] presented the results of implementing cognitive apprenticeship in STEM graduate education. The authors of [33] developed a model of instruction based on the coaching method of cognitive apprenticeship theory, which was applied to K-8 writing instruction. The authors of [34] presented the result that students' performance can be improved by utilizing higher-order thinking skills based on cognitive apprenticeship theory. The authors of [35] presented the integration of a cognitive apprenticeship model with a coaching method to construct an instructional model on devising higher-order cognitive skills, which can be applied in management education. The article also investigated using robot teaching based on cognitive apprenticeship theory in collaborative learning to solve problems. The results showed that the learning effects of junior high school and university students could be improved. The authors of [36] investigated students' perspectives concerning a curricular unit that was reconstructed according to cognitivist and constructivist learning theories, the cognitive apprenticeship instructional model, and a T-shaped design. The authors of [37] proposed an artificial agent created by virtual reality, which can be used to foster a situated learning experience in an oral presentation. The agent was developed based on the coaching method of the cognitive apprenticeship model. Receiving embodied feedback makes the agent stronger in coaching competence.

2.3. Bloom's Cognitive Theory

The authors of [38] developed a classifying platform for the cognitive, affective, and psychomotor domains. The cognitive domain is commonly referred to as Bloom's taxonomy of the cognitive domain (category). The main concept of the taxonomy is to arrange statements of educational objectives in a hierarchical form from less to more complex. These six levels, from low to high, are knowledge, comprehension, application, analysis, synthesis, and assessment. Many papers present the use of Bloom's taxonomy to develop instructional models. The authors of [39] utilized a revised version of Bloom's taxonomy for cognitive processes and knowledge types to develop a method that can be employed in reviewing the learning of mathematics in integral calculus. The authors of [40] developed learning contents of audit simulation according to the third and fourth levels of Bloom's taxonomy, and applied and analyzed them to promote audit education. The authors of [41] applied Bloom's cognitive learning taxonomy to clinical lecturing by offering practical clinical examples to promote medical education.

In this paper, knowledge, comprehension, application, and analysis are four categories of Bloom's taxonomy that are used to specify the educational objectives of the questions of each quiz and implemented in the design of the MSFT platform. After teachers have revised the students' question sheets, teachers can assign one or more of the four categories to the revised question sheet to form a record. The record indicates that the student who answered the revised question sheet needs to enhance their abilities in these four categories.

3. The MSFT Platform

3.1. Platform Introduction

The MSFT platform is designed to aid instructors who fulfill the proposed instructional design in traditional classrooms. Figure 4 shows an illustration for fulfilling the instruction in a classroom according to the CAM modeling method. Students employ mobile devices to study learning units or the answer sheets their instructor revised or commented on.
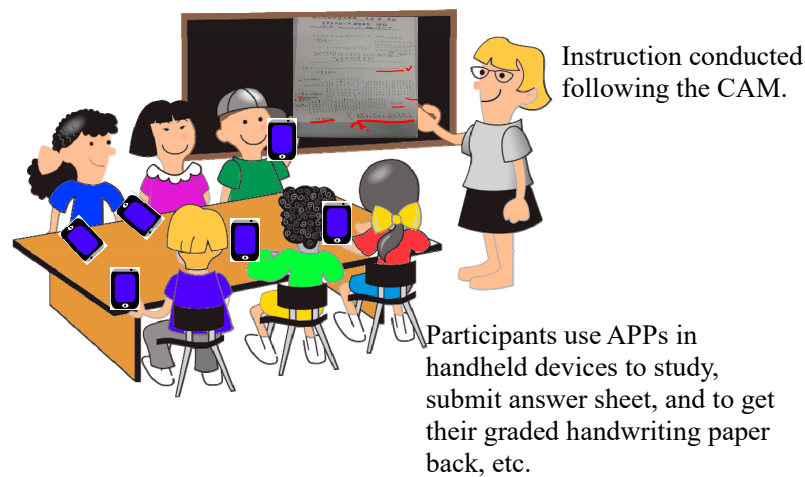
Figure 4. This example demonstrates the concept of teaching by using the CAM modeling method in the classroom. Participants use smartphones or tablet PCs to watch course materials and read graded papers.

3.2. Platform Architecture

Figure 5 shows the platform architecture of the MSFT platform. For teachers, it offers cross-platform services using large-screen mobile devices or PCs that contain digital pen or touch screen functions. First, the MSFT platform lets the administrator maintain users/roles, classes, courses, and authentications. Instructors can use the MSFT platform to manage learning units with a multimedia version, manage question sheets for quizzes, schedule quizzes to be displayed, revise answer sheets, assign kinds of mistakes or errors to revised answer sheets, query analysis results of students' answer sheets, and manage announcements in class activities. Learners employ apps that the platform offers to study learning units, take photos of learners' answer sheets, ask questions for tests, and query revised answer sheets.
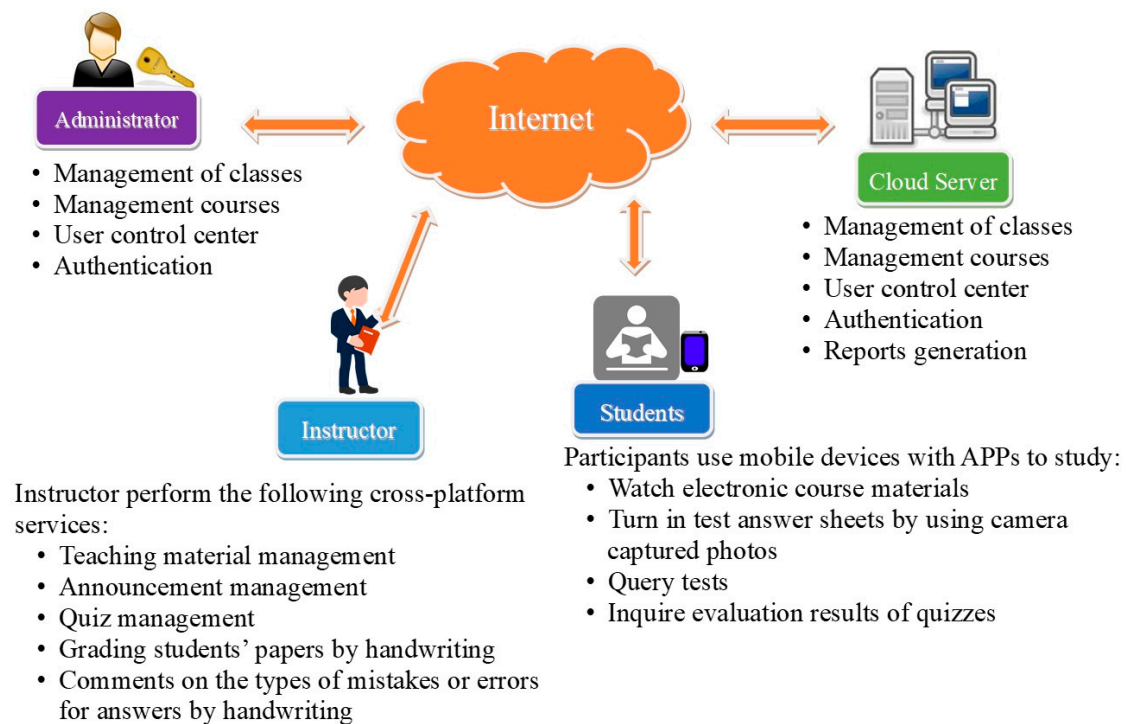
Figure 5. The information flow of the MSFT procedure and functions each party has.

3.3. Platform Operations

The MSFT platform provides three categories of operations for three roles, including administrator, instructor, and student. Figure 5 also exhibits these three categories of operations the platform provides, which are briefly described as follows.

1. The administrator has cross-platform services such as managing classes, courses, users/roles, and authentications.

2. Instructors can use cross-platform services as follows.

    - Teaching material management: The instructor employs the operation to maintain learning units or quizzes—for example, the instructor's answers for quizzes.
    - Announcement management: The instructor utilizes this operation to deliver announcements or notifications to learners.
    - Quiz management: The instructor uses the operation to maintain a quiz schedule, question sheets, which cognitive level a quiz belongs to, etc.
    - Revision of learners' handwritten version of answer sheets: The instructor employs the operation to revise learners' handwritten version of papers by handwriting through the Internet, and also transfers the learners' graded papers to the proposed MSFT system.
    - Assignment of several kinds of mistakes for solutions: The instructor adopts the operation to assign the kinds of errors found in learners' answer sheets. These soft copies of mistakes or errors can be further analyzed to make sense of students' learning status.

3. Learners employ apps while learning via the following services:

    - Studying learning units: Learners use the operation to view learning units related to quizzes—for example, the instructor's answers for quizzes.
    - Submitting an image version of the quiz answer sheet via apps: Learners use apps to take photos of handwritten version of their answer sheets and then submit the photos to a database on the MSFT platform.
    - Query quizzes: Learners utilize apps to inquire about quizzes that were done or will be displayed soon.
    - Query evaluation outcomes of quizzes: Learners use apps to query assessment outcomes of their answer sheets.

4. The administrator fulfills the following operations carried out using web apps before class:

    - Management of classes: The administrator employs the operation to manage class information. For instance, several courses are arranged in the same class.
    - Management of courses: The administrator uses the operation to manage course information, such as recording learners taking certain courses.
    - Management of users/roles: The administrator uses the operation to maintain user or role information.
    - Management of authentications: The administrator adopts the operation to maintain authentications to prohibit illegal users.

4. Research Methodology

4.1. Participants

Students at a vocational university in Taiwan contributed to the experiment. Fifty-one freshman and senior learners (37 boys and 14 girls) participated in our experiment with written permission. Participants were arranged randomly into a control group and an experimental group. The control group (47%) received lecturing without the MSFT system and the experimental group (53%) received lecturing with the support of the MSFT system. Participants in the experimental group had smart mobile devices with Android.

4.2. Learning Procedure

The instructional design model with the CAT is shown in the following figure. The proposed MSFT system can support this instruction model. The participants in these two groups were lectured by a teacher on discrete mathematics content. Figure 6 illustrates an instructional process while applying the modeling method and reflection method of the CAM in the experiment. The instructional procedure is briefly summarized as follows.

- Step 1: The administrator first produces a class and then imports a list of courses a class has.
- Step 2: The administrator imports a list of participants who take the course and creates accounts of teachers who lecture in their courses.
- Step 3: The instructors import their learning units before class by web apps. They maintain course information and import learning units and quizzes for each course. The instructors also maintain schedules for showing quizzes.
- Step 4: The participants use apps during lectures. Participants may watch teaching units outside the classroom before class. First, a quiz is issued by the teachers. The participants then inquire about quizzes inside the classroom. Subsequently, the participants write down their answers to the quizzes on answer sheets in the classroom. Once the participants finish writing their answers on answer sheets, they use apps to make an image version of their answer sheets and upload the image version of their answer sheets to the cloud server of the platform.
- Step 5: The instructors use PCs with web interfaces or mobile devices with web apps during the process of revising answer sheets by handwriting. Note that PCs possess touch screen or digital pen features for convenience during the phase of grading answer sheets. The instructor uses either mobile devices or computers to grade answer sheets by handwriting. They upload the participants' graded papers to the Internet database. The instructors select the best results among the answer sheets to show on the platform so as to realize the modeling method of the CAM.
- Step 6: The participants employ apps to query the evaluation outcomes of quizzes such as scores for the quiz, the image version of the revised answer sheets with the teacher's handwritten revision, and the mistakes or errors that (most) participants often make.
- Step 7: The instructors employ teaching schemes from the CAM to develop new instruction in the classroom. They implement the modeling method of the CAM. The instructors select candidates from the answer sheets and then show them in class, explaining errors that participants often encounter. The instructors carry out the reflection method of CAM by displaying representative answer sheets in class, and then ask participants to inspect these representative graded answer sheets to see the findings that can be obtained.

Here the MSFT platform is involved to support learning activities to learn discrete mathematics using the proposed instructional design according to the CAT. Figures 7–9 express the results of using web apps or mobile apps during learning activities. The instruction can be carried out inside the traditional classroom. Figure 7 shows an instance of accomplishing Step 3. Figure 8 depicts the procedure for fulfilling Step 4. Figure 9 displays the case of performing the process of revising answer sheets, carrying out Step 5. A considerable feature of the MFST system is integrating the following four tasks: (1) grading handwritten versions of answer sheets, (2) correcting mistakes in the answer sheets by handwriting, (3) writing down instructors' comments directly on learners' answer sheets, and (4) choosing examples to demonstrate during class presentations. Moreover, these four tasks can work together in a single window to be operated through web apps. Consequently, the instructors can quickly revise answer sheets by handwriting, in contrast to other existing platforms where instructors need to switch between several separate windows to revise answer sheets by handwriting. Finally, another important characteristic of the platform is that it provides cross-platform capacities for both instructors and students.
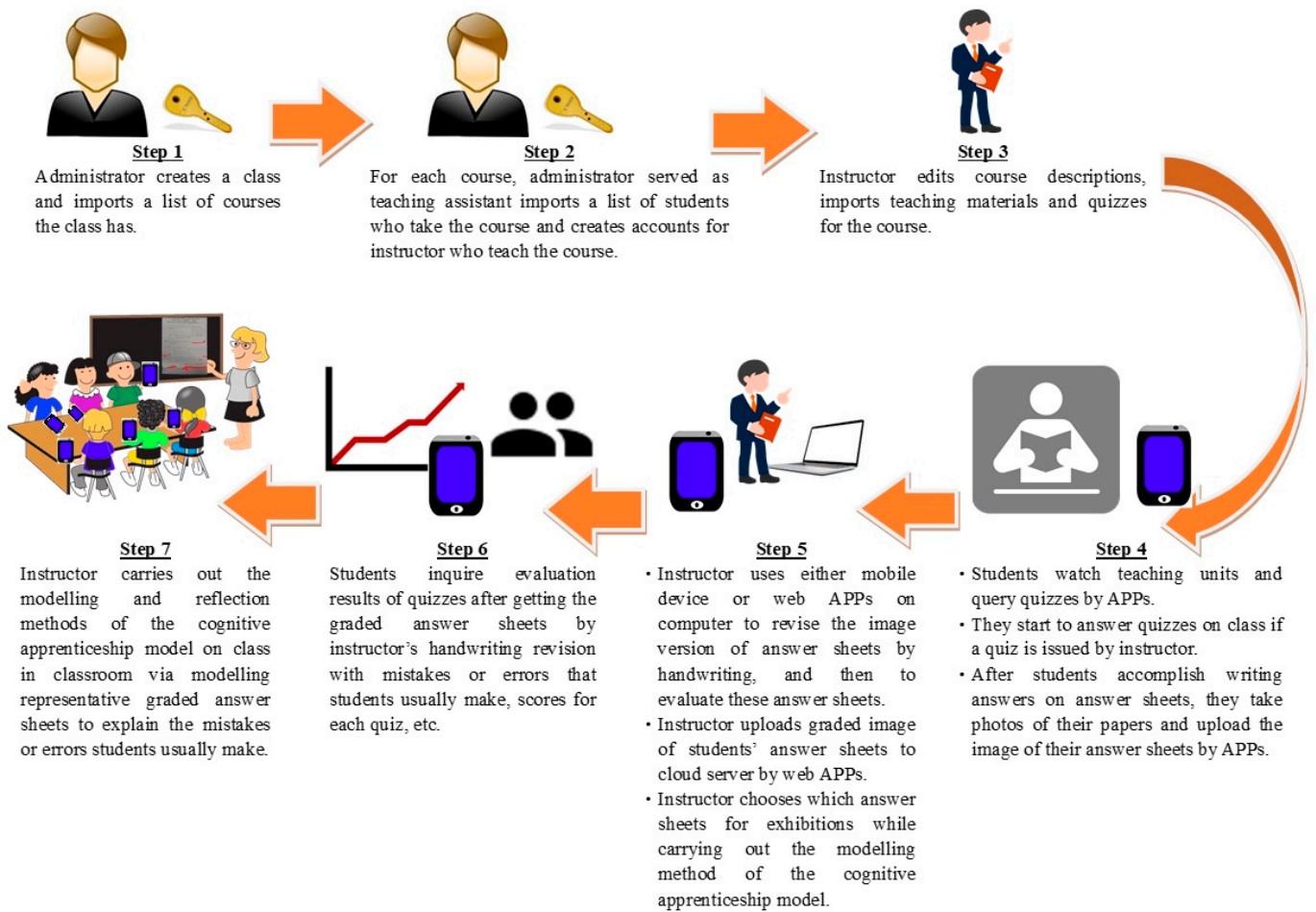
Figure 6. The modeling methods and reflection methods of the CAT in the model of the instructional design procedure design.
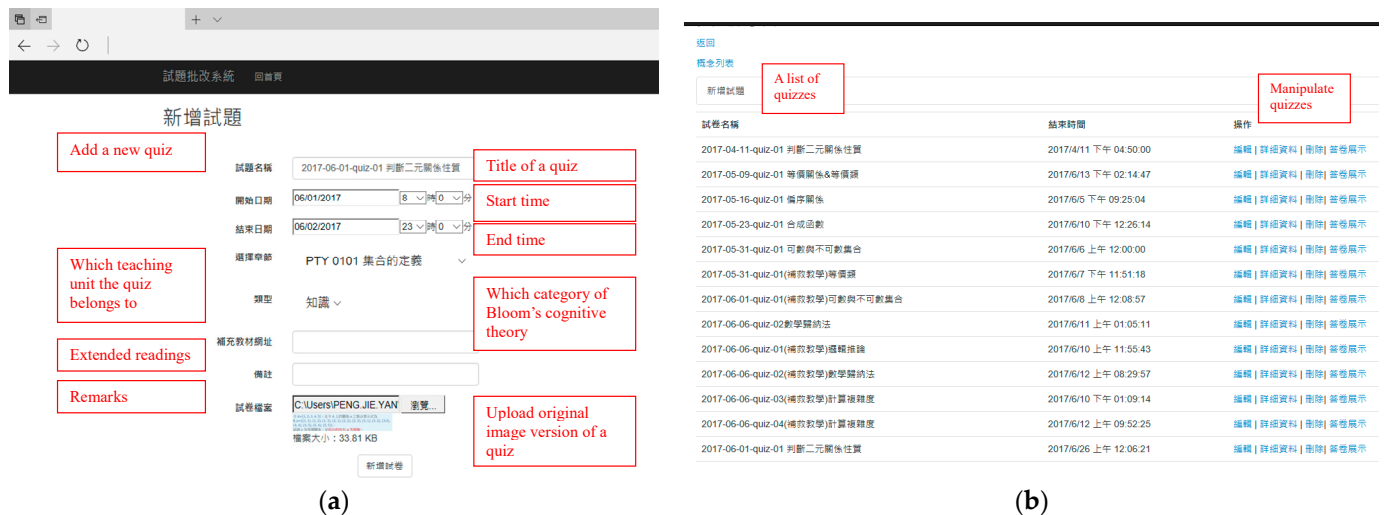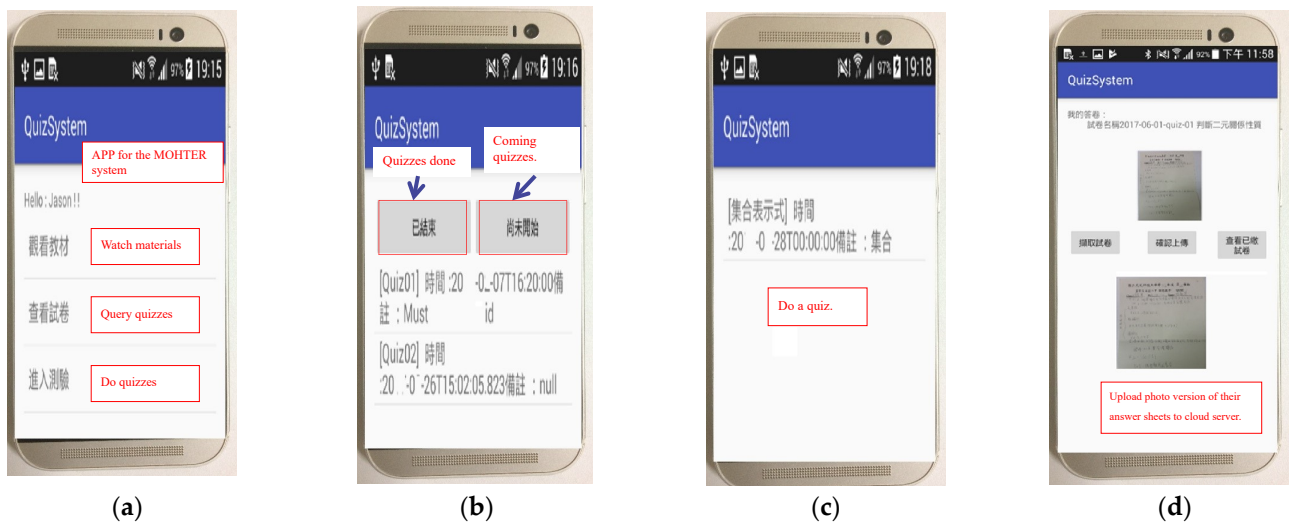

(**a**)

(**b**)

Figure 7. (**a**) The instructor creates a test. (**b**) A list of schedules for showing tests.

(**a**) (**b**) (**c**) (**d**)

Figure 8. (**a**) Participants use apps to login into the MSFT platform. (**b**) Participants query on-going tests to get started on the tests. (**c**) The test starts. (**d**) Participants use a camera to take photos of their answers and upload them to the cloud server.

(**a**)

(**b**)

(**c**)

(**d**)

Figure 9. *Cont.*

(**e**)

(**f**)
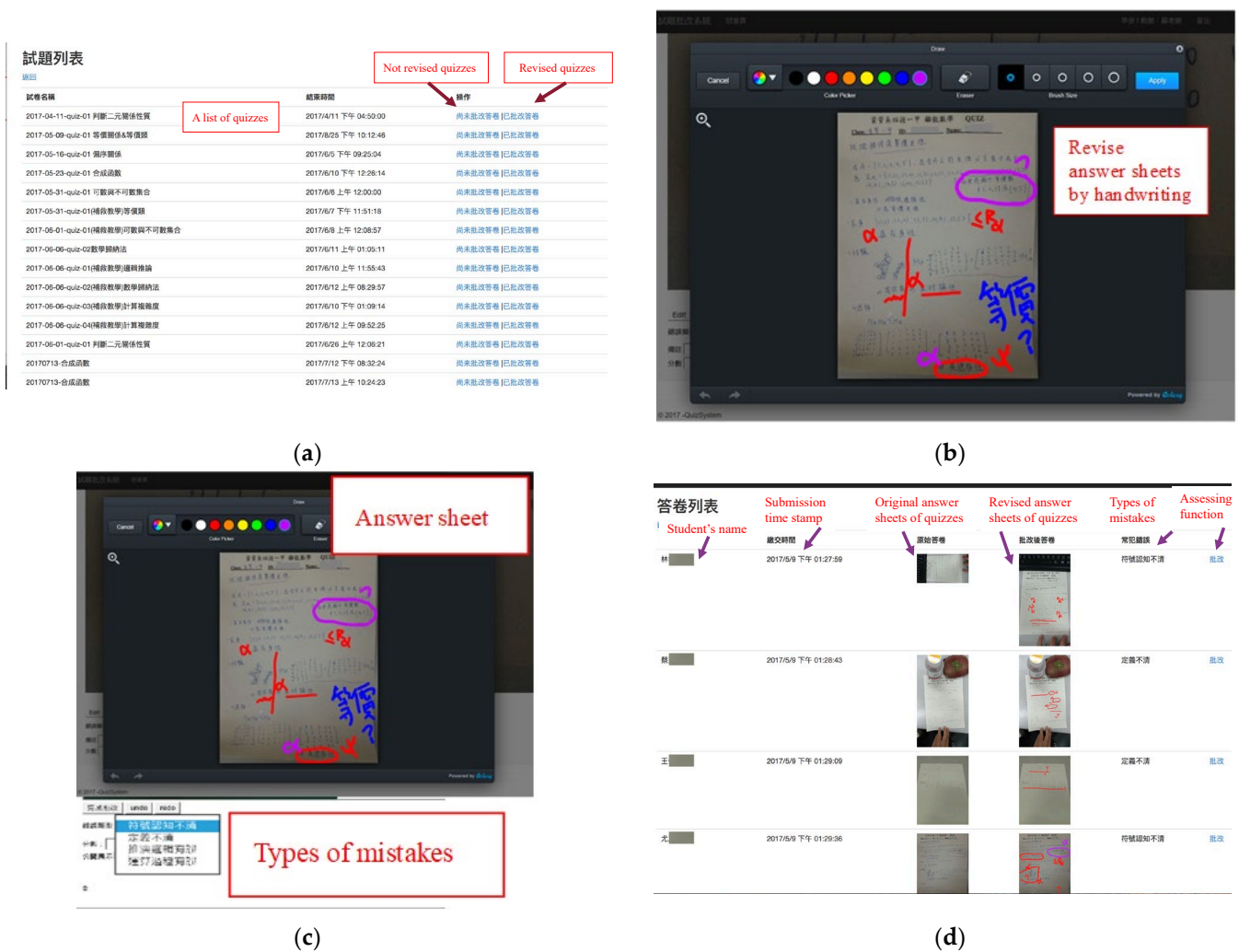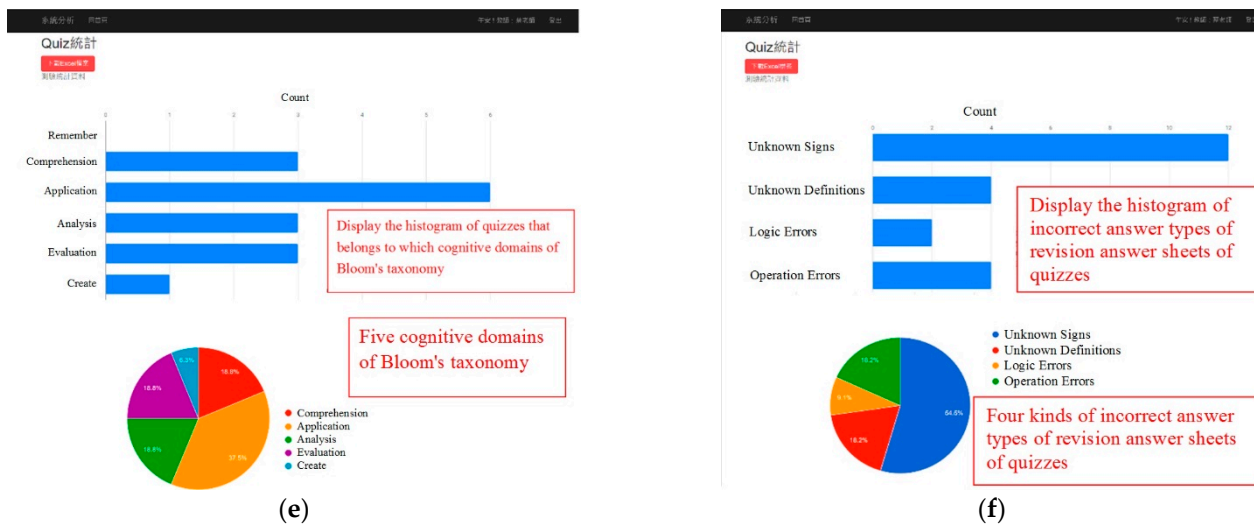
Figure 9. (**a**) The teacher queries quizzes that are not yet assessed and were already revised. (**b**) The instructor utilizes web apps to revise answer sheets by handwriting, which may have the touchscreen function. The instructor revises answer sheets through web operations. (**c**) A list of statuses for participants' quiz answer sheets. (**d**) The instructor assesses the answer sheet, provides the kinds of mistakes or errors that occur in the answer sheets, and chooses which sheet is a candidate to be utilized in the modeling phase of the class. (**e**) The instructor can acquire histograms of outcomes of quizzes that belong to a certain cognitive domain of Bloom's taxonomy. (**f**) The instructor can inquire about results of analyzing the sorts of mistakes or errors participants make.

4.3. Instruments

The experiment utilized a questionnaire to assess the perceived effectiveness of involving the MSFT platform while lecturing in a conventional classroom. The items on the questionnaire were written in Chinese. The participants first received the lectures supported by the MSFT platform, and then answered the questionnaire voluntarily. The questionnaire had 22 questions, including three sub-categories: interests of learning, attitudes of learning, and satisfaction with learning. Questions for "interests of learning" were restated according to [21], such as "In the discrete mathematics class, using the apps that the MSFT system offers is fun". Questions for "attitudes of learning" were restated according to [21] as well, such as "Learning discrete mathematics with the apps that the MSFT system offers is valuable". The items of "learning satisfaction" were restated based on [22], such as "The apps in the MSFT system help me learn discrete mathematics".

The questionnaire used a five-point Likert scale. Each question had five selections, from "strongly disagree" (1) to "strongly agree" (5). The validity of these data was evaluated by two specialists who majored in information management and mathematics. A higher score indicates a higher perception of effectiveness for the case of employing the MSFT platform. Figure 10 displays an instruction experiment on discrete mathematics classes in a classroom. Figure 11 exhibits the procedure of the questionnaire survey, which indicates the learning process of the four-week experiment. During the learning activity in the experiment, all of the participants received the lecture with the same learning materials. Then, participants received the traditional instruction for answering questions for quizzes in the classroom by handwriting. The traditional instruction did not involve the MSFT platform. The participants completed the pre-questionnaires on interaction, learning interest, learning attitude, and learning satisfaction. Subsequently, the participants were randomly divided into a control group and an experimental group. Next, the control group (24 participants) received the instruction in the same traditional way mentioned above. In contrast, the experimental group (27 participants) was treated with the proposed instructional design based on the CAT and supported by the MSFT system. After the

learning activity, all of the participants completed the post-questionnaires on interaction, learning interest, learning attitude, and learning satisfaction.

(**a**)

(**b**)

(**c**)

(**d**)

(**e**)

(**f**)

Figure 10. (**a**–**f**) Lecturing situations while performing the proposed instruction model in the classroom.
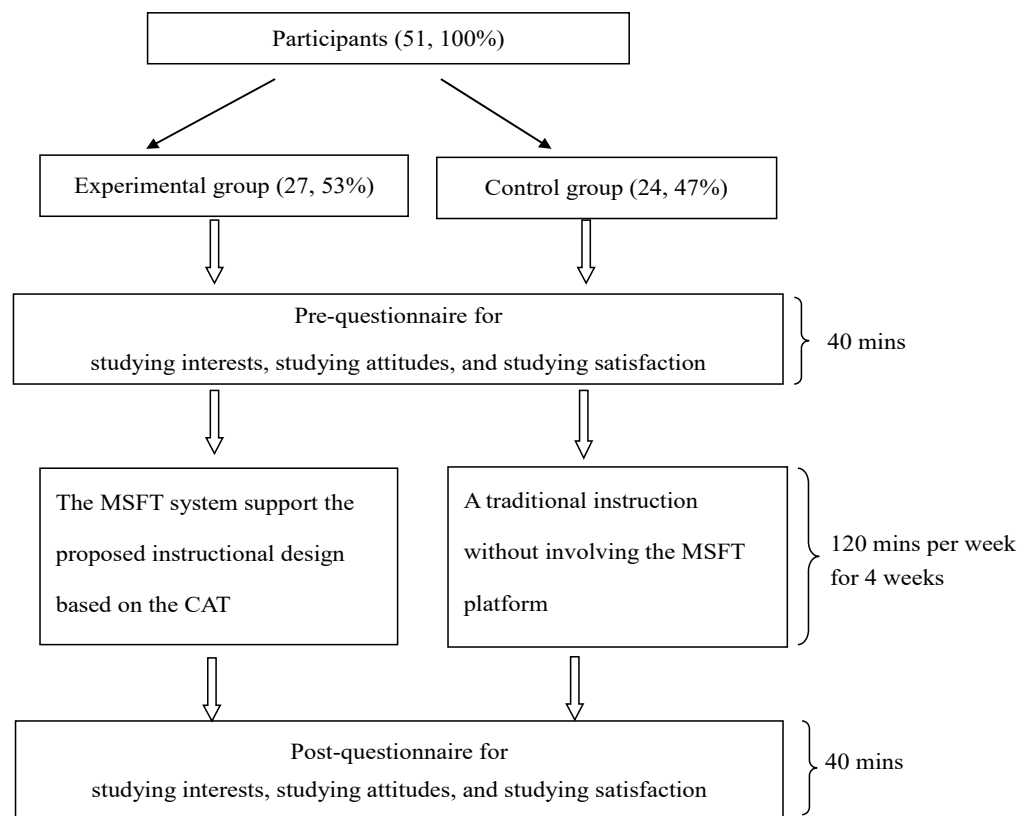
Figure 11. The procedure of the experimental design.

5. Results and Discussions

5.1. Experimental Results

Two sample *t*-tests were carried out to examine the effectiveness of the experimental group using the instructional design model with the CAT with the support of the MSFT platform. The control group received traditional instruction without using the MSFT platform. The questionnaire contained 22 survey items.

Table 1 presents Cronbach's α for testing internal consistency and reliability. The total scale α coefficients for both pretest and post-test cases were larger than 0.95. This indicates that it was acceptable for the reliability of the scale for the questionnaire. Table 2 illustrates two sample *t*-test hypotheses for the pre-questionnaires from participants in our two groups. Results show that without participating in learning activities and not using the MSFT platform, the learning interest, learning attitude, and learning satisfaction of the pupils in the two groups showed insignificant differences. Table 3 reflects two sample *t*-test hypotheses for the post-questionnaires from participants in our two groups. It was found that after participating in learning activities, the participants had significant differences in both their learning attitudes ($t = 2.806$, $p < 0.01$) and their learning satisfaction ($t = 2.986$, $p < 0.01$). That is, the support the MSFT platform for the proposed instruction model improved not only the participants' attitudes, but also their satisfaction toward learning the discrete mathematics course content. Another finding shows that most participants who were in a vocational university in Taiwan seemed to not be very interested in mathematics, so there was no significance in interest in learning.

Table 1. Cronbach's alpha for the questionnaire in the experiment.

	Learning Interests Scale	Learning Attitudes Scale	Learning Satisfaction Scale	Total
Pre-test	0.922	0.850	0.878	0.957
Post-test	0.928	0.738	0.884	0.955

Table 2. Independent two-samples hypothesis test for the pre-test.

	F Value	Sig.	*t*	d.f.	*p*	$\mu_1 - \mu_2$	Standard Error Difference
Learning interests	1.390	0.244	1.363	49	0.179	0.23906	0.17545
Learning attitudes	1.366	0.248	0.301	49	0.764	0.05278	0.17518
Learning Satisfaction	0.321	0.574	0.947	49	0.348	0.16435	0.17349

Table 3. Independent two-samples hypothesis test for post-test.

	F Value	Sig.	*t*	d.f.	*p*	$\mu_1 - \mu_2$	Standard Error Difference
Learning interests	0.831	0.367	1.581	49	0.120	0.27189	0.17196
Learning attitudes	0.167	0.685	2.806	49	0.007	0.40278	0.14353
Learning satisfaction	0.010	0.919	2.986	49	0.004	0.51852	0.17367

5.2. Discussions

Observing the experimental results shown in Tables 1–3, participants who utilized the MSFT platform for study benefitted. The findings show that involving the proposed instructional design with the support of exploiting the MSFT platform tool can obviously benefit instructors and participants based on the experiment results. First, participants recalled the learning content of quizzes easily in the traditional classroom for on-campus teaching classes while taking quizzes as test-oriented learning activities in class. The learning units consist of instructors' revisions or comments with handwriting on participants' answer sheets, the types of mistakes participants often made, etc. Moreover, the MSFT platform offers instructors a flexible way to give their comments or correct answers (for examples, the use of mathematics symbols and the derivation of solving problems) so as to promote participants' capabilities in thinking, clarification, and memorization. Furthermore, participants can repeatedly use the MSFT platform to study the learning content on the cloud server outside the classroom. They can effectively recall teachers' explanations (comments with handwriting on question sheets) for their misunderstanding of mathematical concepts.

Finally, utilizing the MSFT platform in a traditional classroom during the proposed instruction to carry out CAT learning methods can definitely lead to high learning effects for participants. Modeling and reflection, in particular, were applied in the experiment of the paper. In the modeling phase, teachers first use the query function of the MSFT platform to find the revised answer sheets that are selected by teachers after evaluating the answer sheets. Teachers then display those revised answer sheets and discuss them with participants to explain which mistakes or errors exist in those answer sheets. Subsequently, instruction proceeds to the reflection phase. Once participants get the teachers' explanations for the answer sheets, the teachers ask the participants to compare their answer sheets to those answer sheets.

6. Conclusions

The main contribution of this paper is the development of an MSFT platform that offers cross-platform operations for teachers in the revision of answer sheets by handwriting, in assigning types of mistakes for students' answers by handwriting, and in collecting results of learners' answers according to Bloom's cognitive domain. Another chief contribution of the paper is the development of an instructional design according to the CAT for

learning mathematics. Here, the MSFT system for learning can support an instructional design for sustainable education by the CAT. It provides participants with mobile apps to submit camera-captured photos of their answers to the online database information system during on-campus courses or remote distance learning after they complete their answer sheets by handwriting. When the instructor finishes grading the papers, example answer sheets can be selected to give more explanations to present in the classroom or by broadcasting through online learning platform to offer participants a comparison between the participants' answer sheets and the examples, referred to as modeling methods and reflection methods of the CAT, respectively. An important function of the MSFT system is to integrate four operations: (1) using handwriting to grade papers, (2) correcting students' mistakes by handwriting, (3) writing down instructors' comments on participants' papers directly, and (4) choosing examples to demonstrate during class presentation, in a single window through web applications. Therefore, instructors grade papers by handwriting quickly instead of other existing methods that require instructors to switch between several separate windows while grading papers by handwriting through the Internet. Another special property of the MSFT system is to offer cross-platform capacities for instructors. Hence, the MSFT system provides huge support for activities in the classroom or distance teaching with the CAT for teaching mathematics. Moreover, the experimental results show significant statistical differences between the control and experiment groups in "learning attitudes" and "learning satisfaction".

Using information technology in sustainable education has become more important than before the start of the global COVID-19 paramedic in early 2020. Both instructors and students were forced to stay at home and on-campus teaching was unavailable during the outbreak. The MSFT platform is easy to adjust to a remote teaching mode because of the built-in digital-learning/mobile-learning functions. Therefore, we believe that the MSFT platform could help all levels of education during crisis now and in the future, especially in the metaverse.

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