Research Article

Applying Activity System-Based Process Model in Augmented Reality-Based Learning for Natural Science Course in Elementary School

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Since learning environments have the support of innovational technology, blended learning environments could integrate the physical learning methods with multimedia learning materials, which combines the use of technology with the traditional teaching methods and offers a potential for teachers and students to meet the requirements of learning flexibility and innovation. This study aims to redesign a user-centered Activity System-Based Process Model (ASPM) and integrate the Augmented Reality (AR) into blended learning to implement the Augmented Reality-Based Blended Learning (ARBL) system. There were 57 participants who learned with the ARBL while the control group was made up of 52 students who learned with the Traditional Blended Learning (TBL) approach. Analytical results indicate that the learning outcomes and learning attitude of the ARBL group were better than those of the TBL group. The activity system-based process model could provide a helpful structure in the ARBL to guide course designers, teachers, and researchers for designing the AR learning activity.

1. Introduction

As innovational technology supports learning environments, blended learning environments could integrate physical learning methods with multimedia learning materials. Graham [1] has proposed that blended learning combines face-to-face learning approaches and computer-mediated learning to assist interactive and reflective learning. Bliuc et al. [2] also have a defined blended learning as, "blended learning describes learning activities that involve a systematic combination of co-present (face-to-face) interactions and technologically-mediated interactions between students, teachers and learning resources" (p. 234). At the same time, because of the advances in computer hardware and software, blended learning has developed in various ways of integrating different learning environments, learning multimedia, and learning method, which has

become a popular learning strategy. Blended learning allows teachers to adapt to the needs of instructions, using the technology-assisted way to mix learning environments and learning materials to achieve more meaningful learning [3]. Moreover, blended learning provides a more student-orientated learning environment, promotes learning practices, and allows students to have self-paced learning [4–6]. Research by Keengwe and Kang [7] have indicated that blended learning needs a conceptual framework to design and implement an effective learning strategy. This statement has led us to conceptualize an instructional learning model as a guide for designing and implementing the blended learning activities and systems.

It is required to have an instructional learning model that enables the systematic study of innovation in technology-assisted learning environments, which could take the Activity Theory (AT) into consideration [8]; the design of the

instructional learning model would be a potential contribution to the study of blended learning. AT is an analytical framework used to design and develop technology-assisted curriculums, human-computer interactions, and blended learning programs [7]. Studies have also pointed out that the activity systems could help researchers analyze and understand the phenomena of teaching activities, such as analyzing and discussing the relationship between the use of new technologies and situations, as well as providing new ideas for improving existing designs [9, 10]. However, some research has revealed that the activity systems utilize static images with manifest arrowed lines among each component that would not clearly illustrate the activity system processin details [11, 12].

In addition, the core idea of blended learning is to solve problems in diverse approaches as different problems and requirements would apply different ways of media and messages to learn. This research focuses on observing the activity needs of natural sciences learning in elementary schools. We found some critical problems in the current learning, which the learning contentspresented by using 2D materials such as textbooks, videos, and pictures to demonstrate the concepts involving abstract, 3D geometric, and phenomenal topics are not clear. According to Piaget's theory of cognitive development, the cognitive development of elementary students is at the concrete operational stage, in which children gain the mental aptitude that enables them to think logically about concrete events. Children in the concrete operation stage experience the spatial knowledge between the projected space and the Euclidean geometric phase [13]. At this stage, children mainly recognize the surrounding environments by their specific operations and cannot escape from the visual impact. Many studies have indicated that spatial visualization is a trainable ability [14–16]. These studies also showed that the types of instructional materials used in increasing the visualization of students' spatial cognitive influence the learning outcomes of spatial and 3D geometric. Children's mental growth depends not only on their level of cognitive development but also on the interaction between them and the learning environments. Teachers could provide a stimulating learning environment and combine the learning contents and learning environments with appropriate technologies to stimulate students' learning outcomes [17]. Therefore, using computer technologies to assist the presentation of abstract and express the concepts of geometric learning contents is necessary. Augmented Reality (AR) has been proven as an effective and potential learning visualization supported tool [18], and it has a potential benefit to present learning knowledge in 3D space because it provides learners to enhance their spatial ability and abstract conceptions of science courses [19]. AR learning activities not only provide innovative and flexible learning materials but also improve students' learning achievements and learning motivations positively [20, 21]. Moreover, the potential for applying AR learning activities in mobile learning has increased and encouraged students to engage in learning processes through the interactive and immersive learning experience [22, 23], and provide the capability to make novel learning space [24].

AR also has potential in self-directed and collaborative learning when facing complex and abstract subjects; objects and books could be augmented to demonstrate facts, processes, and relationships that are crucial in understanding the learning topics [3]. However, some studies have pointed out that the user's emotional engagement will be an important factor when they experience AR learning [25]. The degree of participation in the application of new technology depends on various personal background factors, such as age, gender, learning background, growth environment, etc. [25–27]. However, some studies suggest that there are differences in gender perceptions of technology use [28–30]; on the contrary, some studies suggest that there is no significant gender difference in the use of augmented reality learning [31–33]. Accordingly, gender was included as one of the research variables to explore whether it has an impact on teaching effectiveness and attitudes.

Therefore, the purpose of this study aims to propose a new perspective to use the ASPM to design and plan a systematic combination that integrates AR technology into blended learning. We implement an Augmented Reality-based Blended Learning (ARBL) system to enhance the teaching objectives of teachers and improve the learning outcomes of students. This study compares ARBL's effectiveness with that of Traditional Blended Learning (TBL). In short, two research purposes of this paper are to examine the following:

(1) Whether ARBL improves more students' learning achievement and learning attitude than TBL

(2) Whether males' use of ARBL can improve learning achievement and learning attitude more than females

2. Review of the Literature

2.1. Activity Theory (AT). Activity Theory originates between the early-1920 and 1930, and it was developed by psychologists from Soviet Union, namely, Vygotsky, Rubinshtein, Leont'ev, etc. Vygotsky believes that human knowledge is formulated from the interactions through meaningful and complete activities, and speech can restructure the concepts and contrive relevant mentality. The term "internalization" is applied by Vygotsky [34] to explain the phenomenon that under social interactions and the mediation of external activities, an individual develops the process of specific consciousness. The initial activity system is based on the instruments (tools), subjects, and objects (elements), and the outcomes are the interactions of the three elements.

Later on, Engeström [35] found that the three components of the former AT are too simple and failed to meet the requirements of people when carrying out activities. Hence, they developed one set of Activity System in 1999, in which humankind activity emphasizes the relationship between subjects and objects. Figure 1 proves the existence of influence upon each component of the Activity Theory. Subject refers to the objects that carry out the activity. Object refers to the goal and motive of the activity being carried out.
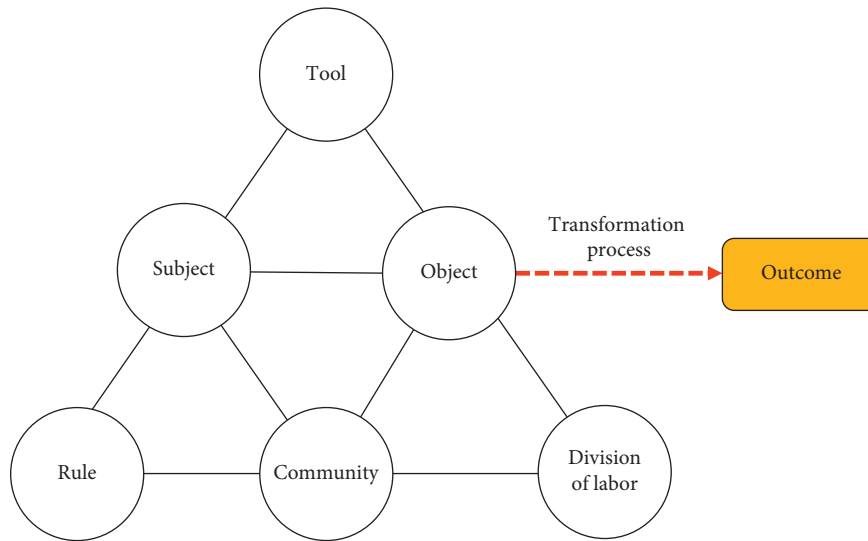
FIGURE 1: A model of an activity system of Engeström [35].

Instruments/tools refer to the tools used in the activity to help to reach the goal of the activity carried out by the subject. Community is the environment within which the subject is involved in the activity of implementation. Rule is the resection of laws upon the activity of implementation in a community. Division of labor is the role played by the subject during the activity of implementation in a community. Finally, Outcome is whether the implementation activity meets the desired effects.

In exploring the human-computer Interface, the AT offers a broad conceptual structure, which describes how the human-computer Interface activity develops, as well as the scenario and structure it contains. AT is gradually applied in constructivist learning environments, instructional design, and instructional activity analyses [9, 10, 36]. This study would propose an improved ASPM as a guide tool to help us design and plan the technology-mediated blended learning system. Based on the AT, this study will systematically analyze the current learning activities of blended learning to clarify the entry point of AR technology for blended learning by using the AR technology to solve the problem of blended learning, which is a lack of presence in 3D conceptual issue with visualized materials.

2.2. Augmented Reality (AR) in Education. Azuma [37] has defined AR as "a variation of Virtual Environments (VE), or Virtual Reality (VR), as it is more commonly called." AR systems are characterized by three properties: Combining real and virtual objects in an actual environment, running interactively in real-time, and presenting in 3D space. Because of the advances in hardware and software, AR widely uses in our life that includes the fields of entertainment, engineering, design, and education [18, 38–40]. AR also plays an important role in the field of education in these years. AR is a novel tool that could let users immerse themselves in the contents, and it improves the learning environments and makes learning more interesting and attractive [41]. Furthermore, AR has a potential benefit that could present learning knowledge in 3D space, and it provides learners to enhance spatial abilities and abstract conceptions for science courses [19, 42, 43].

In education, many researchers use AR technology to assist learning activities in various fields, such as design, geometry, natural sciences, mathematics, and mental rotation [29, 44–46]. Radu [47] has stated that the benefits of AR include increasing long-term memory retention, raising content understanding, promoting task performance, encouraging motivation, and improving collaboration. Some researchers present an AR-based inquiry learning system that could guide learners to share their knowledge in activities. The study concluded that the AR-based learning activities could engage learners in interactions for knowledge construction [44]. Yilmaz [48] has used an AR educational magic toys to obtain teachers' and children's opinions, and determine children's behavior models and their cognitive achievements. This study showed that teachers and children had positive attitudes toward the educational magic toy activity. Amir et al. [49] pointed out that elementary school children need visualized learning aids or tools to train their abstract spatial concepts and thinking skills. The 3D metric augmented reality learning system developed in the study is used to train students' spatial thinking ability. The experimental results show that the 3D metric augmented reality learning system can help students improve their spatial ability. Turan and Atila [50] used AR technology for learning of science concepts by students with a specific learning difficulty. Their study showed that AR technology was helpful in supporting the learning of students with a specific learning difficulty and these students have positive feedback for AR learning. As shown in Table 1, related AR education research is summarized.

Some researchers have also proposed that AR has the characteristics of having a tangible user interface and is highly interactive, it improves seamless integration between learning contents and virtual objects, and AR is inexpensive

Table 1: A summary of AR in education.

Authors	Year	Research topic	Participants/ subjects	Findings in research
Amir et al.	2108	Spatial ability	36 students	The 3D metric augmented reality learning system can help students improve their spatial ability.
Atmojo, Ardiansyah, Saputri, and Adi	2021	Natural science	120 sixth graders	Using STEAM-based augmented reality interactive multimedia effectively improved the quality of natural science learning.
Chiang et al.	2014	Natural science	57 students aged 9–10	The AR-based learning activities could engage learners in interactions for knowledge construction.
Radu	2014	Review analysis	26 publications	Identified several positive and negative effects of AR on learning, such as interaction, collaboration, 3D simulation, physically enacting the educational concepts et al.
Turan and Atila	2021	Science	4 sixth graders	AR technology was helpful in supporting the learning of students with a specific learning difficulty.
Yilmaz	2016	Early childhood education	33 children aged 5–6	Educational magic toys were developed with augmented reality technology effectively used in early childhood education.
Kerr and Lawson	2020	Landscape architecture	50 first-year students	This study shows the learning potential and advantages of AR technology on creating new practices in digital storytelling across situated experiences.
Kao and Ruan	2022	Programming learning	98 fifth graders	AR system was helpful for improving students' logic performance.

for providing learners with attractive and interesting experience [26, 51]. Moreover, augmented reality is as such an immersive technology that could provide the capability to build innovation of learning spaces [24, 40]. For this reason, AR learning contents provide appropriate teaching materials to let learners have immersion-learning activities. Some studies propose that the AR learning modes could increase learners' motivation and attitude [22, 27, 28, 52, 53].

In addition, researchers have used AR-based learning systems to improve the learning performance of students; some of them have noticed that there are no differences between genders [31–33], while the others have found that AR training is more effective for males on 3D assemble than females [28–30]. Moreover, researchers have suggested that the differences between genders could be treated as a consideration factor while developing the AR system in assisting learning [29, 31, 33]. Therefore, this study explores the effectiveness of AR in blended learning and investigates whether gender differences have a significant impact on AR learning activities. The learning activities would use the environments in the classroom and on campus as a natural science learning scenario to design different AR learning activities for evaluation.

3. Learning Approach and System Design

3.1. Constructing the Activity System-Based Process Model (ASPM) of Blended Learning. In order to construct the systematic process model for blended learning that supports designing learning activities completely, we must understand the structure of blended learning in advance. According to the AT, the fundamental element of analyzing human behavior is the completed activity interactions between the subject and object in mutual transformation [10]. We could understand the aspects of blended learning activity through the activity system, which provides a common perspective for this study; we use the activity system to clarify the learning activity of blended learning of natural sciences courses in elementary schools. The activity system takes six components as the conceptual tools to help researchers organize the contexts of learning activities: Subject, Object, Instruments/Tools, Community, Rule, and Division of Labor. Figure 2 shows the activity system of the blended learning of natural sciences courses in elementary schools. From the activity system, we could understand the components in the elementary natural sciences learning activities.

Based on the activity system, the purpose of this study aims to redesign a definite ASPM, which considers user behaviors as the top priority and meets the needs of teachers/ students, as shown in Figure 3. The proposed ARBL system is created by following the ASPM. In the following section, the environments and fields that the learning held would be contemplated, as well as the restrictions and rules over different fields and environments. Once the object, subject, and community are clearly defined, it comes to the selections of tools, which shall include the materials by using computer technology (PowerPoint slides, videos, animations, AR or VR, etc.) and the displaying devices (textbooks, blackboards, projectors, tablets, or any other mobile devices, etc.). After determining tools for use, it is the review of whether the application of selected tools under the community is appropriate and followed by proper adjustments. According to different demands of users, different operation methods are designed, as well as collating the community of designed learning method and the proposed learning system. After designing the learning method and system, it should go back to the subject, community, and tools to refine and confirm whether the designed learning method and system are suitable. When the learning method and system are determined, the next step is implementing the learning system based on the chosen tools and the system design. Upon completing the system implementation, have a few targeted users check if the learning system is accomplished or needs
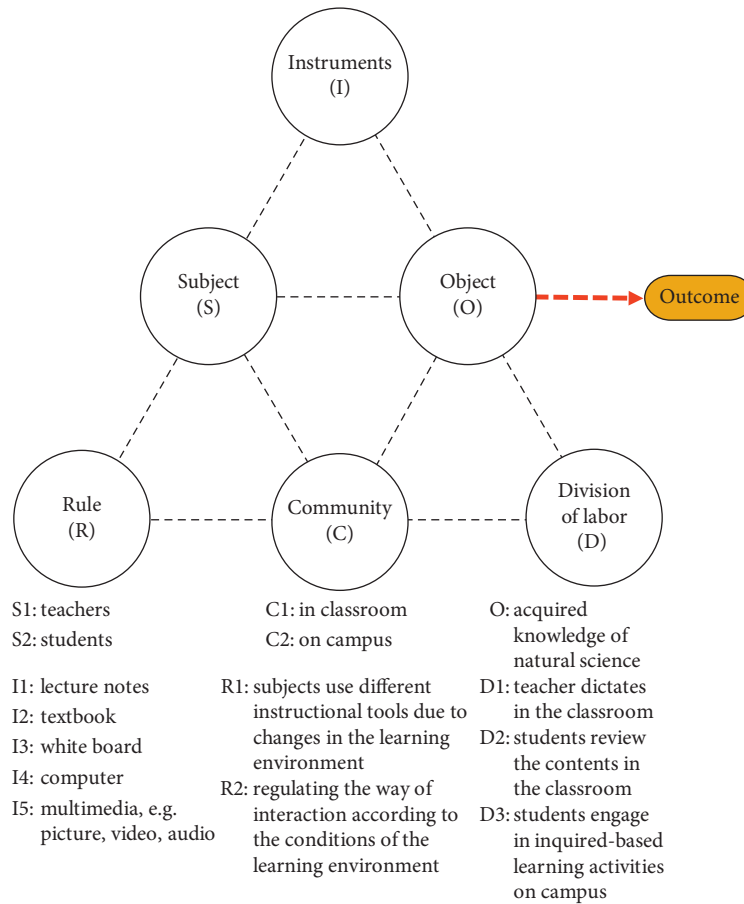
FIGURE 2: The activity system of the blended learning of natural science course in elementary.

further improvement for user behaviors. Only when the implementation of the learning system is completed, the system is then officially allowed in the actual teaching classes, outdoor exploration, and other learning activities, etc. We shall further discuss its effects when the process is done.

3.2. The Elements of AR Technology and Expanding the Usability.
AR technology provides near-real-world operations, which enable users to interact with virtual contents in physical environments, offering an immersive interactive experience and visualizing invisible phenomena. In addition, the technology allows users to interact with virtual objects that could arouse user experience on phenomena that might be difficult to explore in real life. Based on the characteristics of an AR system, we will look for the structure of AR technology. We defined the principles of designing an AR system composed of four elements, including a physical object, virtual object, interaction, and display object. Table 2 is a summary of the AR elements that find the rules to develop an AR system.

3.3. Designing the Blended Learning with the AR by Using the ASPM.
For learning natural sciences, the designing and planning ARBL elaborated with the ASPM is shown in Figure 4, and the detailed explanation is described as follows.

3.3.1. Object.
For the ARBL, the teachers could not only use the lectures and multimedia learning activities but also utilize an AR-based learning activity to assist in instructing the 3D constructs of leaf arrangements in natural sciences courses. Furthermore, students could use AR-based learning materials to explore the learning contents of outdoor learning activities.

3.3.2. Community.
For the traditional classroom learning environments, the AR learning activities allow students to interact with virtual objects and understand the leaf arrangements from the 3D animation perspectives. For learning natural sciences, the campus would be a suitable area for learning environments; teachers could use this to conduct an outdoor learning activity. However, learning in open-air environments will pose the problem of environmental interference and distractions. Using the AR learning activities in the outdoor learning environments would stimulate students to focus on things in the observation, reducing the teacher's guiding workloads and enhancing the spontaneous learning of students.

3.3.3. Rule.
Several interactions in the ARBL system allow users to change their interactive ways with virtual objects in different environments, such as holding mobile devices and rotating markers to see different views of the 3D models in
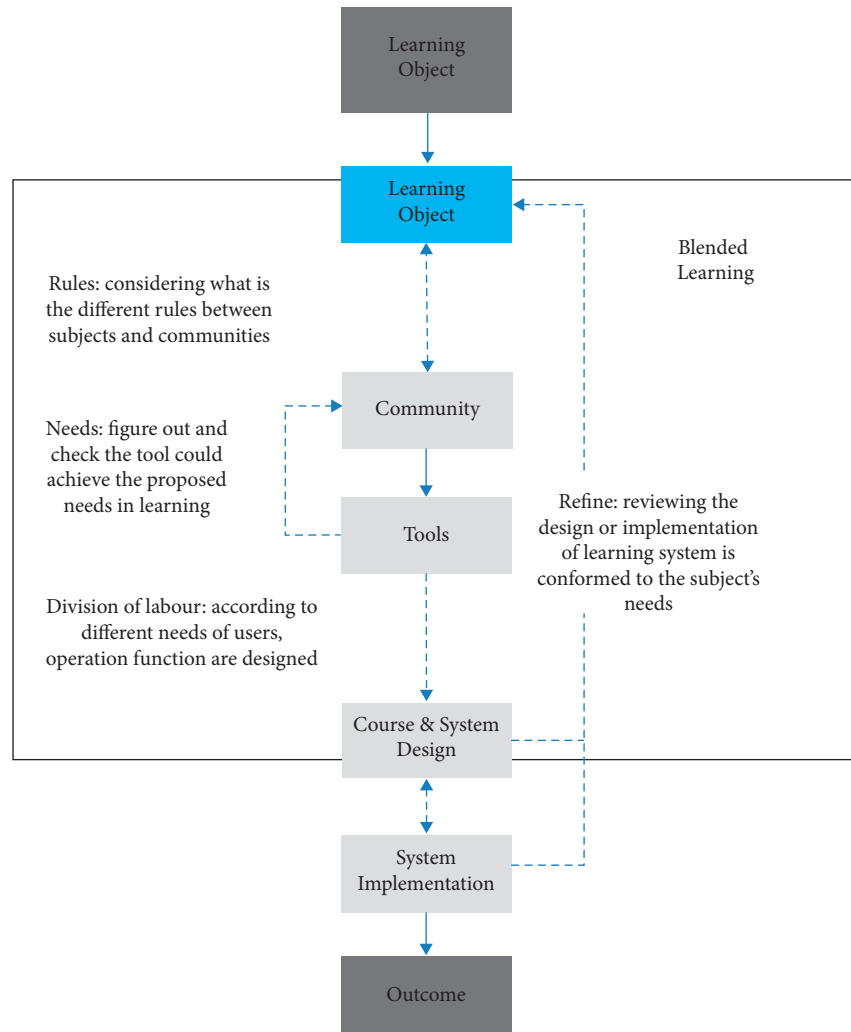
FIGURE 3: The improved ASPM for the blended learning.

TABLE 2: A summary of the AR elements.

Elements	Statement	Implementation
Physical object	The objects that users could move and rotate for particular manipulation.	Meaningful markers, related images or real objects.
Virtual object	The objects that are used to deliver the knowledge, concept, or information.	2D images, 3D models, 3D animations, videos, or audio.
Interaction	How the users could interact with the physical objects or displayed objects.	The users could manipulate the physical or displayed objects to obtain feedback.
Display object	A device that is used to present the contents.	Mobile devices, head-mounted displays, or projectors.

the classroom, touching the screen to view the introduction about the leaf in the classroom, or using mobile devices to observe the real plants on campus, etc.

3.3.4. Instruments/Tools. This part contains objects in traditional learning, such as textbooks and whiteboards. In the AR-based blended learning, the multimedia content of the course is transformed into virtual objects (the 3D model of the leaf and the 3D animation of the leaf arrangement) and the physical objects (the picture of the leaf), and using the

AR technology to present the learning materials. The display mode could change in various ways, including projectors, mobile devices, head-mounted goggles, etc.

3.3.5. Subject. The main targeted users are the teacher and the students; it would be clearer for the users in the ARBL to know about how to use the AR learning materials and conduct the learning activities through the following two scenarios. We would illustrate the learning scenarios used in this study. The scenarios of learning activities are planned
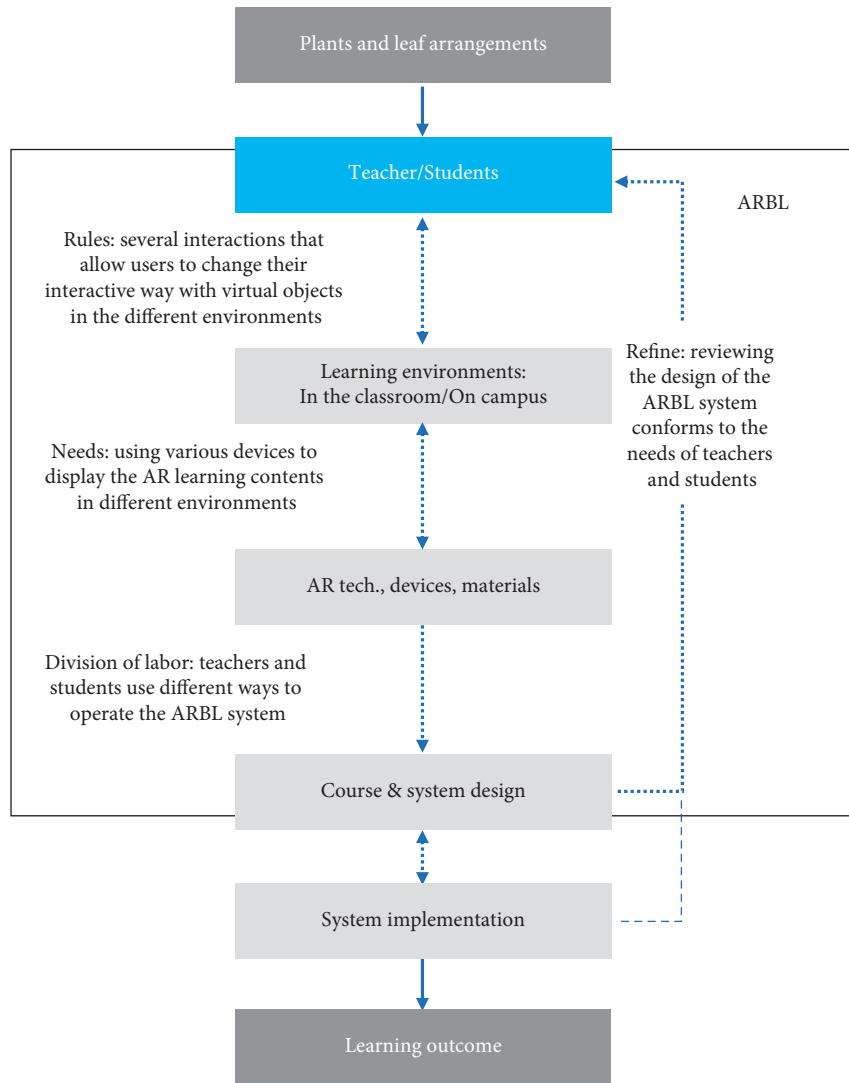
Figure 4: Designing the ARBL by using the ASPM.

and discussed with the teachers who have more than seven years' teaching experience in elementary schools. The learning scenarios are designed as an appropriate learning activity based on the learning environments.

3.3.6. Division of Labor. In the ARBL activities, what roles students and teachers play during the learning activity in the classrooms and on campus? For example, in the classroom, the teachers decide the lessons of the plant and leaf arrangements in the classrooms using textbooks, PowerPoint materials, and the ARBL system. On the other hand, the students could review learning contents with the ARBL system in the classrooms, and they could observe on campus by themselves using the ARBL system.

After constructing the ARBL using the ASPM, three learning scenarios are proposed according to different users and learning environments, as shown in Figure 5. Designing the ARBL based on the plant and leaf arrangement topic, the learning scenarios are discussed with three natural science teachers in the elementary schools to confirm their needs for

learning activities. The three learning scenarios are described as follows:

(i) Scenario I: designing the usage of the ARBL for the teachers to teach the course in the classroom

Because the teachers need to teach the learning contents to all students in the classroom, teachers have to use cameras, projectors, and plant pictures to operate the ARBL system. Furthermore, the teachers demonstrate the targeted contents systematically from easy to advanced level by projecting them on the screen, as shown in Figure 6. The students are divided into several groups, with about four to five students in each group.

In the teaching process, the teachers would use the ARBL system in their teaching methods and courses that need to sequentially introduce the knowledge of various plants, the leaf shapes of plants, and there are different types of arrangements around the leaf stems, including alternate, opposite, whorled, and fasciculate, etc.
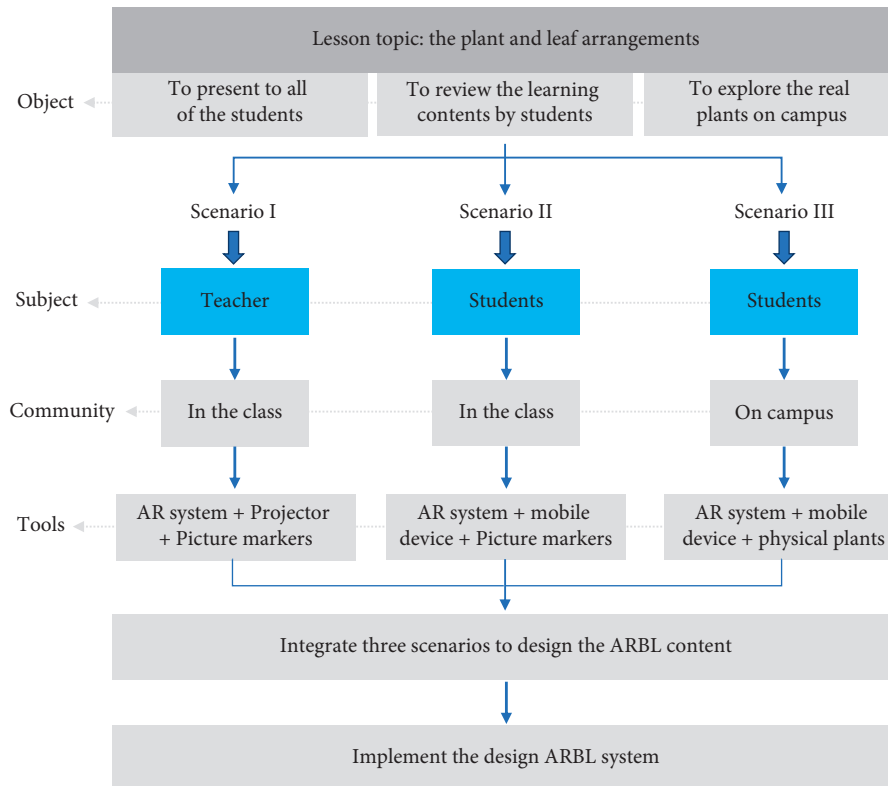
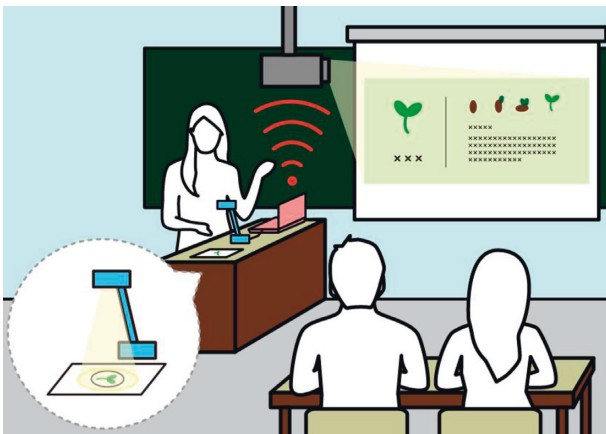Figure 5: The three scenarios designed from the ASPM.

Figure 6: The sketch of the teacher using the ARBL system in the classroom.

Using the ARBL system to present the knowledge of various plants, the students could observe the 3D structures of various plants clearer than using the 2D images, PowerPoint presentations, and videos to present the same learning contents.

(ii) Scenario II: designing the usage of the ARBL for the students to practice activities in the classroom

After the course, the teachers give the plant pictures and the mobile devices to each group. When the students take the mobile devices, they could use the ARBL system and review the learning contents systematically from easy to the advanced levels, as shown in Figure 7.

In the manipulated processes of students, they could sequentially touch the virtual models on the screens, and the related knowledge would pop out accordingly. As a result, students could review the target contents again by themselves in the classroom.

(iii) Scenario III: designing the usage of the ARBL for the students to explore the knowledge on campus

In order to provide a concrete experience in exploring the knowledge of plants and leaf arrangements in real-world environments, teachers take all of the students to the ecological environment on the campus, as shown in Figure 8. Before the exploring activity, all of the students would receive the learning sheets for this topic. Students are separated into several groups, and each group will observe the knowledge of plants and leaf arrangements specified in the ecological environment in turn.

When the students observe the real plants, they could see the virtual objects of related information attached to the plants by using the ARBL system on their mobile devices, such as when the camera of the tablet captures the plants that had already been introduced in the class, the name of that plant will appear on the screen. After the section, the names of leaf veins appear on the leaves of the screen; by touching the names, information about leaf veins will be provided. Only after reviewing the leaf veins,

FIGURE 7: The sketch of the student using the ARBL system in the classroom.

FIGURE 8: The sketch of the student using the ARBL system on campus.

names of the leaf arrangements will show on the screen, enabling the students to observe the live arrangements of leaves. By this learning activity, students could strengthen their focus on the course and improve their impressions of the learning contents. After the students observe each plant, they would draw the characteristics of leaf arrangements and shapes, use them to evaluate and understand their learning achievements in this science course. According to the three scenarios mentioned above, the study would use these scenarios to implement the ARBL system in the next article.

3.4. Augmented Reality-Based Blended Learning (ARBL) Design and Implementation. In this study, the ARBL system is developed to enhance blended learning with technology-mediated instructions and help students explore the learning contents in the learning activities. The learning topic in the instructional course is "the plant and leaf arrangements," which includes the shapes of leaves and the leaf arrangements. The learning materials of this study are based on the textbooks from the elementary school, and the topic of plant and leaf arrangements is a required learning subject in elementary school.

The learning contents of the leaf arrangements are abstract and complex concepts. Students use the ARBL system in blended learning activities, and the ARBL system could explicitly represent the concepts of the patterns of leaf arrangements for students. The developers of the ARBL system have discussed the instructional contents of the course with three teachers who have more than seven years' experience teaching science.

There are five units in the ARBL system used in blended learning, including the display, tracking, coding unit, the 3D database, and the user. Each unit in the ARBL system is described as follows:

(i) The display: this part uses a mobile device with a webcam to capture the targeted card and send information to the tracking unit for further process. The processing result will be shown on the screen of the mobile device immediately.

(ii) The tracking unit: this unit is responsible for tracking the latest positions of targeted cards and their 3D object representations.

(iii) The coding unit: this unit is responsible for coding the targeted cards. The pictures of the plants are printed on the cards for encoding. If the tracking unit recognized a targeted card of a particular plant, this unit would start to search through the 3D database to find the corresponding 3D object of the targeted card. The decoded information is further sent to the display unit to show a decoded result.

(iv) The 3D database: all of the 3D objects are built by using a 3D scanner. Using the 3D scanner could capture the fine details and textures of a physical object and build the 3D object of leaf in more details to look like real.

Because of the advanced development of computer hardware and software and the popularity of mobile devices, mobile devices are used to conduct learning activities in blended learning. The proposed ARBL system used Vuforia™ and Unity software to implement the ARBL system and used a 3D scanner to build the 3D objects. The Vuforia™ is used to build the database of the targeted cards for encoding the cards with corresponding 3D objects, while the Unity software is used to implement the ARBL environment for tracking and encoder/decoder parts.

3.4.1. The Operation and Learning Content Design of ARBL. In the class activities, the students are divided into several groups, and each group has four to five students. On the desk of each group, there is a plant marker of the learning content. Through the ARBL system, students are allowed to interact with the learning contents, from which they would acquire the basic knowledge concerning the plants, concepts of leaf veins, and leaf arrangements. When the table camera captures the targeted marker, the plant model matches with the targeted marker and the name of that plant appears on the screen. After selecting and touching the name of the plant on the interface, a basic knowledge introduction of that plant

appears on the screen. When finishing learning the basic knowledge and closing the interface, a question mark will pop up on top of the leaf, guiding students to learn the shapes of leaves and patterns of leaf veins. After completing this learning phase, another question mark appears, which guides students to study the leaf arrangements further. After touching the question mark on the screen, an animation about the array of leaves is instantly shown, informing the students about the varied array schemes of leaf arrangements on the stems. After learning, all of the introductions and detailed knowledge about plants will stay on the interface of the leaf model; by selecting from the interface, students undergo the process of knowledge reviews. The detailed operation steps in the ARBL learning activity by the students are shown in Figure 9.

After the learning activities in the classroom, the students explore on campus by using the tablets together with the learning sheets for active exploratory learning. When the tablet camera captures the plants introduced in the class, the name of that plant will appear on the screen for students to review by actual objects. After learning, the names of the leaf veins made by the 3D information objects appear at the precise position of the leaves on the screen; by touching the names, the knowledge about the leaf veins are introduced. After reviewing the leaf veins, the names of the leaf arrangements made by the 3D information objects will be shown at the precise positions on the screen, enabling students to observe the live array of leaves. When completing the student observation, all acquired knowledge will be filled in the learning sheets, serving as proof of later testing. Figure 10 shows the situation that students operate the ARBL system on campus.

4. Method

4.1. Research Design.
In this study, an ARBL system is integrated into blended learning to assist students in learning activities for learning contents. The purpose of the study attempts to investigate the effect on students' learning achievements and learning attitude of the ARBL. Moreover, this study also investigates the effectiveness between genders in the ARBL and the TBL. The research design of this study is shown in Figure 11, where the independent variables are the learning methods and gender, and the dependent variables are learning achievements and learning attitude. This study employs the quasi-experimental method to explore whether there are significant differences between the control group (TBL) and the experimental group (ARBL). The TBL group used the traditional blended learning approach, while the ARBL group used the AR-based blended learning approach in the natural sciences course.

4.2. Participants.
There are 109 third-grade elementary school students aged nine to ten years old in southern Taiwan in this study. Prior to the experiment, the two classes were randomly divided into the experimental group and the control group. The experimental group consists of 57 students, which has 33 boys and 24 girls, who would learn with the ARBL approach, while the control group is made up of 52 students, which has 29 boys and 23 girls, who would learn with the TBL approach. The same instructor teaches both groups to reduce external influences on the results.

4.3. Experimental Learning Design.
The course topic, the plant and leaf arrangements, is chosen from the natural science course in the elementary school. The course design and learning strategies employed in this study are shown in Figure 12. The learning materials for the TBL and the ARBL approaches are the same and include pictures, contents, and the profiles of the learning course. The instructor used the ARBL system in a blended learning approach for instructing the experimental group while using the traditional face-to-face learning approach in the case of the control group. Moreover, the ARBL system could assist the experimental group students in observing the patterns of leaf arrangements and the shapes of the leaves on campus while the control group students would observe the leaves on their own. After observing, they need to fill up the learning sheets that require the students to draw the patterns of leaf arrangement and describe the shapes of the leaves.

The ARBL and the TBL share the same contents of teaching courses; the difference is the way of presenting the courses. In traditional teaching, students are grouped by four to five persons; each group would have a live plant as the subject of teaching. When the teacher's lecture is finished, students of each group will hold the plant for observation and learning in turn. Students go on for exploratory learning on campus with the learning sheets in hand when finished with the classes. Once students find the exact plant that the teacher instructed in the class, the students would start the observation and fill out the learning sheets until the exploration of plants is completed.

4.4. Experimental Instruments

4.4.1. Learning Achievements.
The learning achievement exams include a pretest and a posttest. The pretest is to determine whether the two groups have equivalent prior knowledge of the learning contents. On the other hand, the pretest verifies that the two groups exhibit similar related background before conducting the experimental learning. The questions of the pretest are chosen from several reference textbooks according to the course learning objectives. After the learning experiment, a posttest would examine the students' learning achievements toward the course and compare the grades between the two groups. The maximum score of both tests is 100 points. Both of the tests are developed by teachers who have more than seven years' teaching experience in science to ensure expert validity.

4.4.2. Learning Attitude Questionnaire.
The learning attitude questionnaire consists of 21 items from the questionnaire developed by Hwang, Wu, and Kuo [54]; it uses a five-point Likert scale: 1 = strongly disagree and 5 = strongly agree. The learning attitude questionnaire evaluates
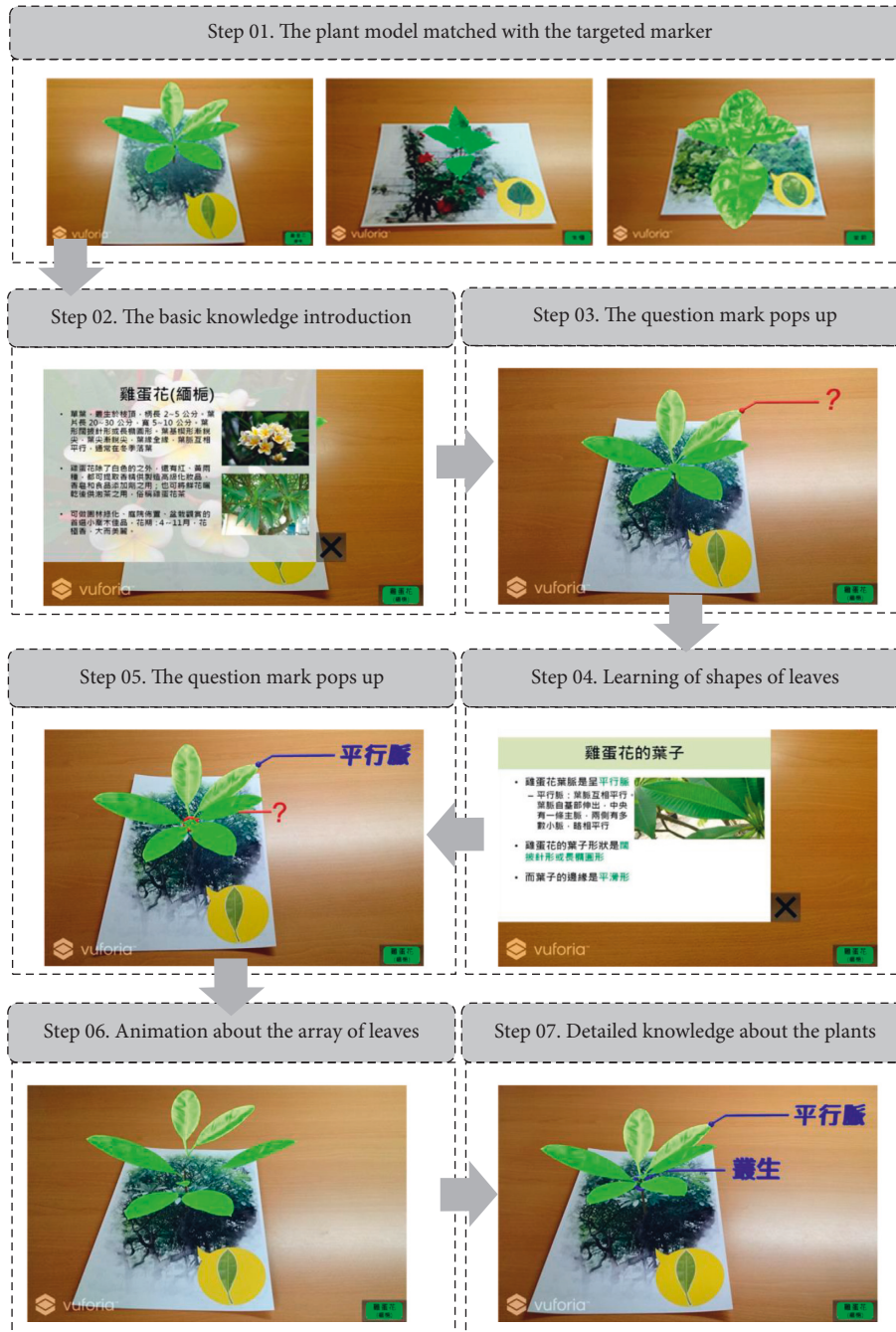
FIGURE 9: The detailed operation steps in the ARBL system.

students' learning attitude toward the natural sciences course after the experimental learning. Cronbach's alpha for the questionnaire was 0.82, and the questionnaire is reviewed by the experts, teachers who have more than seven years' teaching experience in science, to ensure content validity.

4.5. Experimental Procedures. Figure 13 illustrates the experimental procedure of the study. Before the experimental learning, the students of both groups take a pretest that aims to evaluate whether the TBL group and the ARBL group have an equivalent basic prior knowledge of the learning course, as well as completing the prequestionnaire of learning attitude questionnaire. After the pretest and the prequestionnaire, the teacher would teach the leaves course to the control and experimental groups using the TBL and ARBL approaches. Afterwards, a posttest is administrated to both groups. All of the students filled the learning attitude questionnaire to assess the attitudes toward the learning approach they used after the experimental learning.
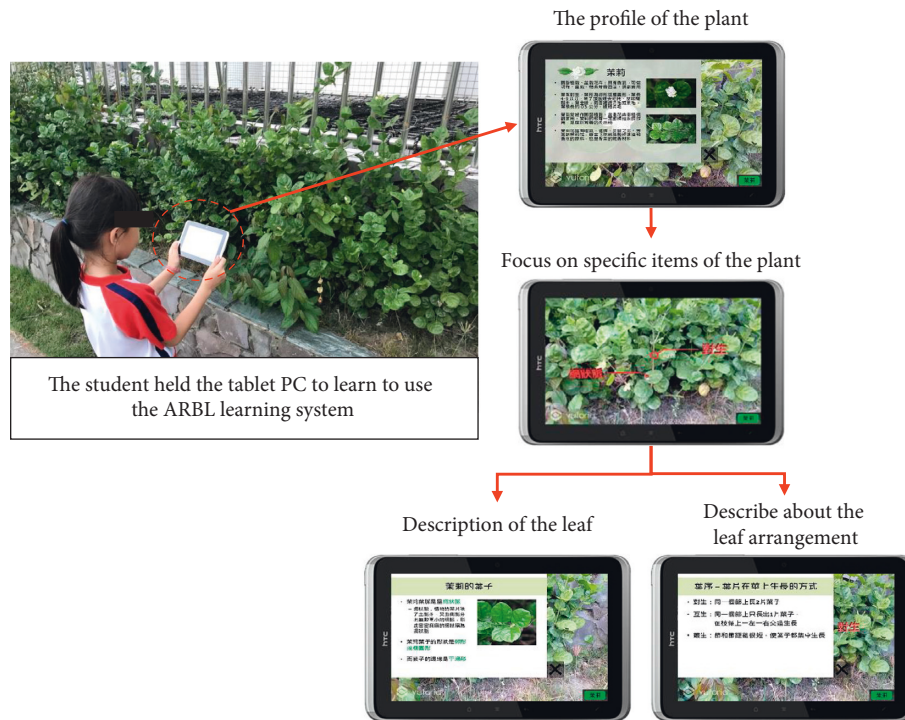
The profile of the plant

The student held the tablet PC to learn to use
the ARBL learning system

Focus on specific items of the plant

Description of the leaf

Describe about the
leaf arrangement

FIGURE 10: The student operates the ARBL system on campus.

Independent variables
• Learning methods (TBL vs. ARBL)
• Gender

Dependent variables
• Learning achievements
• Learning attitude

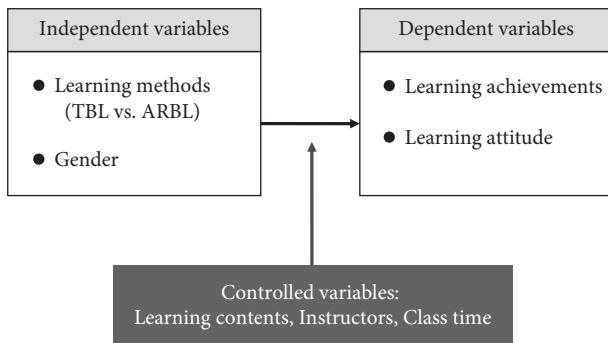Controlled variables:
Learning contents, Instructors, Class time

FIGURE 11: The research structure.

5. Results

This section analyzes the results of the learning experiment, exploring the two different teaching methods, the ARBL and the TBL, and their influences on students' learning effects toward courses of natural sciences. Based on the statistics acquired from this research, a statistical analysis will be conducted using SPSS.

5.1. The Effect of Learning Achievement.
The experiment subject in this study is from the third-grade elementary school students, 109 students in total. There are 57 students in the experiment group with 33 boys and 24 girls; the control group has 52 students, 29 boys and 23 girls.

5.1.1. Comparison of Pretest.
The pretest scores are mainly for the understanding before the experiment; the subjects of the two groups are allocated normally and homogeneously. Kolmogorov–Smirnov verification is introduced into the verification to testify whether the pretest of the experiment group and the control group is normally allocated. The p values of the experimental and control group are both 0.200, which are above the significance level of 0.05. Therefore, it conforms to the basic assumption of normal allocation, as in, the sample has a representative sense. In addition, the test for homogeneity of variances mainly examines whether the pretest scores of the experimental and control groups have equal variances. The F-test is 0.641, and the p value is 0.425, which is greater than the significance level of 0.05. Therefore, we could conclude that the discrepancy between the variation of the two groups is not significant, and the experimental and control groups have equal variances.

Table 3 shows the student scores of each group, the average score of the experimental group is 64.965, the standard deviation value is 14.540; the average score of the control group is 66.346, and the standard deviation value is 16.621. Through the result of the independent sample t-test ($t = -0.463$, $p = 0.645 > 0.05$), there were no significant differences between the students of the ARBL and the TBL groups.

5.1.2. Comparison of Posttest.
From Table 4, the mean score of the experimental group is 90.088, and the standard deviation is 7.084; on the other hand, the mean score of the control group is 81.077, and the standard deviation is 12.304. The t test results for the posttest showed that the ARBL group had significantly better learning achievement than the TBL group ($t = 4.627$, $p \leq 0.001$). Moreover, Cohen's d value (2013) was used to measure the practical significant

FIGURE 12: The learning strategies employed in the TBL and the ARBL.

difference between the two groups, and this was 0.908, showing a large effect size.

The independent variables in this study have two aspects, the learning method and gender. The dependent variable is the learning achievements. Therefore, whether there are cross effects between the two independent variables in two-way ANOVA analysis, a post hoc analysis will be conducted in case the significant measures reach the influential level. Otherwise, it undergoes a comparison of the main effects only. From Table 5, the learning method and gender are under a significance level of 0.05; its p value is 0.523, representing the insignificant cross effects between two

elements. However, the p value of the learning method is less than 0.001, which measures up to a significant influence level, combining with the fact that the p value of gender is 0.419, which did not reach the level of significant influence. Hence, the element of the learning method would undergo an independent sample t-test.

From Table 6, the average and standard deviation of the boys in the experimental and control groups are 88.909, 7.217 and 80.931, 12.592, respectively. The average and standard deviation of the girls in the experimental and the control group are correspondingly 91.708, 6.708, and 81.260, 12.211. In additiona, the t-test of the boy group ($t = 3.107$,
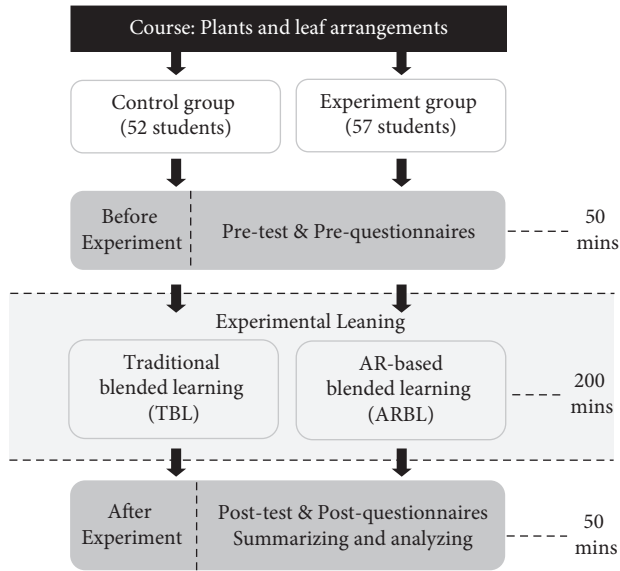
Figure 13: The experimental procedure of the TBL and the ARBL.

Table 3: Independent sample *t*-test of pretest in the ARBL and the TBL.

Group	Mean	SD	*t*
ARBL	64.965	14.540	−0.463
TBL	66.346	16.621	

$\alpha = 0.05$.

Table 4: Independent sample *t*-test of posttest between the ARBL and the TBL.

Group	*N*	Mean	SD	*t*
ARBL	57	90.088	7.084	4.627***
TBL	52	81.077	12.304	

$\alpha = 0.05$, ***$p < 0.01$.

Table 5: Two-way ANOVA of posttest between the learning method and gender.

	SS	df	MS	*F*-test	*p*
Learning method	2264.378	1	2264.378	22.813	0.000***
Gender	65.304	1	65.304	0.658	0.419
Learning method * gender	40.672	1	40.672	0.410	0.523

$\alpha = 0.05$, ***$p < 0.01$.

$p = 0.003 < 0.01$) and the girl group ($t = 3.656$, $p = 0.001 < 0.01$) are both lower than the level of significance, which is 0.05 and measures up to significant influence. The results of learning methods for both boys and girls reveal that the ARBL is better than the TBL.

5.2. *The Effect of Learning Attitude.* This section assesses differences in the learning attitude of both learner groups based on attitude questionnaire results. From Table 7, the result of the *t*-test ($t = 1.915$, $p = 0.058 > 0.05$) shows that the

Table 6: The results of posttest of boys and girls between the ARBL and the TBL.

Gender	Group	*N*	Mean	SD	*t*
Boy	ARBL	33	88.909	7.217	3.107**
	TBL	29	80.931	12.592	
Girl	ARBL	24	91.708	6.708	3.656**
	TBL	23	81.260	12.211	

$\alpha = 0.05$, **$p < 0.01$.

Table 7: The description data and *t*-test of prequestionnaire.

Group	Mean	SD	*t*
ARBL	3.810	0.497	1.915
TBL	3.626	0.503	

$\alpha = 0.05$.

student differences of the ARBL and the TBL in the prequestionnaire of learning attitude are nonsignificant.

Table 8 indicates the result of the postquestionnaire of the attitude, and the mean of the experimental group is 4.190, and the standard deviation is 0.459; the mean of the control group is 3.616, and the standard deviation is 0.630. Through independent sample *t*-test ($t = 5.470$, $p \leq 0.001$), the result indicates that the ARBL learners have a greater learning attitude than those with the TBL. Cohen's *d* value (2013) of learning attitude was 1.049, showing a large effect size.

In Table 9, the learning method and gender are under the significance level, their *p* value is 0.887, and it indicates that the cross-effects between the two factors are nonsignificant. Regarding the learning method, the *p* value is lower than 0.001, which measures up to significant influence. The *p* value of gender is 0.137, not up to the significance level. Hence, the factor of the learning method is to undergo an independent sample *t*-test to determine its influence on learning attitude.

Table 10 shows that the average and standard deviation of the boys in the experimental group are 4.130 and 0.512, respectively; and, they are 3.539 and 0.656 in the control group, respectively. The average and standard deviation of girls in the experimental group are 4.273 and 0.367, respectively, and in the control group are 3.713 and 0.596, respectively. The results of the independent sample *t*-test of the boy group ($t = 3.972$, $p \leq 0.001$) and girl group ($t = 3.901$, $p \leq 0.001$) indicate that after the boys used the ARBL learning method, their attitude is much better than using it with the TBL learning method. Regarding the girls, their attitude with the ARBL is also much greater than with the TBL.

5.3. *Interview.* To understand the further detailed feedback of the learners in the process of learning, we conducted sample interviews among students with the ARBL learning, during which the students spelt out their feelings and feedback on the teaching experiment.

Most of the students expressed that the teaching activity with the ARBL was an interesting and appealing learning

Table 8: The *t*-test of postquestionnaire between the ARBL and the TBL.

Group	N	Mean	SD	t
ARBL	57	4.190	0.459	
TBL	52	3.616	0.630	5.470***

$\alpha = 0.05$, ***$p < 0.01$.

Table 9: Two-way ANOVA of postquestionnaire between the learning method and gender.

	SS	df	MS	F-test	p
Learning method	8.831	1	8.831	29.566	0.000***
Gender	0.672	1	0.672	2.249	0.137
Learning method * gender	0.006	1	0.006	0.020	0.887

$\alpha = 0.05$, ***$p < 0.01$.

Table 10: The *t*-test of postquestionnaire of boys and girls between the ARBL and the TBL.

Gender	Group	N	Mean	SD	t
Boy	ARBL	33	4.130	0.512	
	TBL	29	3.539	0.656	3.972***
Girl	ARBL	24	4.273	0.367	
	TBL	23	3.713	0.596	3.901***

$\alpha = 0.05$, ***$p < 0.01$.

method, in which they found the teaching materials were lively and the teaching contents were comprehensible. Therefore, most of them were fond of natural sciences classes with this learning method. In addition, most of the students mentioned that apart from paying attention to the 3D model and motion pictures, they could also engage with the subjects in the teaching materials and achieve the target of deepening the impressions of learning materials.

In outdoor activities, students can view real plants through the tablet, and through the assisted guide lines and instructions on the tablet, help students to understand more clearly how the leaves are arranged during the growth process. In addition, in recognizing the shapes of leaves, students could recognize different leaves' shapes through the AR teaching materials and there was no need to check the textbooks for confirming the correctness.

Moreover, most of the students expressed that using the AR teaching materials turned the classes more comprehensible, vivid, lively, and interesting; their desire to continue using such instructional materials has grown stronger.

6. Discussion and Conclusion

This study proposes a new perspective to redesign and plan systematic blended learning that would integrate AR technology into learning activities. This study has developed an ARBL system based on the AT that designs and develops to meet the needs of natural sciences teaching. From the results of experimental learning, it is found that the ARBL enhances students' learning effectiveness. According to the learning achievement, the learning effect of the experimental group is significantly better than that of the control group. The use of

AR enhances the natural sciences' learning effectiveness of students. This result supports the previous studies and indicates that appropriate visualization tools could greatly help the presentation of conceptual learning contents [49, 55]. Furthermore, the experimental learning results of learning achievements show that gender has no significant effects on learning methods. This result indicates that boys and girls are not significantly affected by ARBL or TBL. Although some previous studies conclude that the boys' learning effectiveness after the AR engaged in learning activities is better than that of the girls' learning effectiveness [28–30]. However, some studies also state that gender does not affect the effectiveness of engaging in AR learning activities [31–33], and the results of this study are more consistent with the latter.

In the aspect of the learning attitude, from the postquestionnaires of the learning attitude after the learning experiment, the learning attitude of the experimental group is significantly higher than that of the control group; it means that the students who participated in the ARBL are more positive toward natural science learning. The previous studies have also supported this result that AR learning activities has a positive attitude toward students' natural sciences due to their novelty [28, 56]. Furthermore, the results of the learning experiment also present that students of different genders have no significant influence on the learning attitude of both the ARBL and the TBL. Boys' and girls' groups both have positive learning attitudes toward the ARBL and are both better than the groups for the TBL learning attitude. Other research has used AR technology to improve students' laboratory skills, as well as assisting them in keeping a positive learning attitude toward physical laboratories. However, in their research, it is also found that there are no differences between genders in the learning attitude [53].

The learning experiment results of this study present that the learning attitude questionnaire outcome shows that the students have a positive learning attitude. Moreover, interview results suggest that students' feelings about the use of the ARBL could help them learn the abstract contents of the natural sciences and make the learning materials easier to understand and more enjoyable. Therefore, students are willing to continue participating in the ARBL activities. We also believe that AR technology has the immersive ability to help students maintain greater attention and interest in learning contents. Some studies have also mentioned that the positive impact of the AR teaching activities on students could lead students to achieve a higher level of participation in the learning activities [22, 57, 58].

By bringing the ARBL activities into natural sciences learning, abstract learning materials are more straightforward and more explicit, in addition to the fact that the spatial concepts and stereoscopic images that require emphases are a key presentation by the AR. Furthermore, the model for designing the natural sciences learning activities present by this research is based on the AT, and the activity system is a reliable process model for designing and maneuvering the learning systems. Through repeated reviews and designs of the model and the revision of the learning system, a learning

system that focuses on the teaching demands is developed, assisting the teachers in organizing the contents of the courses and effectively strengthening students' learning outputs. Although the preparation of AR learning activities is more time-consuming in comparison with the conventional ones, due to a lack of program designing and the system developing experience and techniques of elementary school teachers, it has a strong craving for assistance and cross-region cooperation to complete in making such supplementary teaching materials. Therefore, during this research, after carrying out the activities of the ARBL, a systematic activity process model is followed to design the learning system and assist teachers and students. The research demonstrates that when a new technology mingles with blended learning, one should design and maneuver the learning systems through systematic process models to enable the developers to continuously inspect users' needs and the integrity of the learning system.

In this research, the deployed device is a tablet. As it is a trend for bigger screen-sized smartphones, the using rate would increase and be more popular gradually. Therefore, in utilizing the learning activities of AR in the future, the learning method by activity learning might be made available to students with smart phones, adding as well as a combination with at-home previews and reviews. As the smartphones are getting more powerful, more people will use them for online learning activities. In the future, provided that the machine learning and the deep learning are combined, smartphones shall act as agents to record the likes and the dislikes of different learners or learning modules in order to strengthen students' personalized learning activities, ultimately achieving a resilient and personalized learning method. Learning devices with the ARBL might be costly for some elementary schools, which is another challenge for the popularity of AR. The research regarding the ARBL system is limited, and the results of this study are capable of rendering the references for the future ARBL studies.

The limitations of this research reside in its exploration of natural sciences. There are more challenges in the future in other realms of the ARBL, a more specific and conceptualizeable course subject should be chosen. In designing the ARBL learning materials, to design both the learning materials and the interactions is an important factor that will influence interaction [59] between students and learning materials. In the designing of learning materials, attention should be paid to whether the [60] contents are clear and understandable. During interaction design, make more detailed planning for interaction methods and user needs. Therefore, in designing the learning activities with AR, it is worthy to pay more efforts and target at designing the systematic process models and maneuvering the learning systems.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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