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A Study on the Development and Learning Effectiveness Evaluation of Problem-based Learning (PBL) Virtual Reality Course Based on Intelligence Network and Situational Learning

Hui-Ying Chang

Department of Information Technology and Management
Fooying University
151 Jinxue Rd., Daliao, Kaohsiung, 831, Taiwan
angela38658@gmail.com

Chih-Chao Chung

General Research Service Center
National Pingtung University of Science and Technology
1 Shuefue Rd., Neipu, Pingtung, 912, Taiwan
ccchung@g4e.npust.edu.tw

Yuh-Ming Cheng

Department of Computer Science and Information Engineering
Shu-Te University
59 Hengshan Rd., Yanchao, Kaohsiung, 824, Taiwan
cymer@stu.edu.tw

Shi-Jer Lou*

Graduate Institute of Technological and Vocational Education
National Pingtung University of Science and Technology
1 Shuefue Rd., Neipu, Pingtung, 912, Taiwan
Corresponding Author: lou@mail.npust.edu.tw

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Abstract. *This study aims to explore the development of the PBL virtual reality course of intelligence network and situational learning and analyze its learning effectiveness. With students as the learning center, this study innovatively integrated intelligence network technology, situational learning mode, and project-based learning. It also developed a virtual reality project practical course that guides students' peer cooperative learning and stimulates them in actively exploring and solving problems and providing real-time intelligent feedback. This study adopted the case study method to collect qualitative data, such as teachers' observations, students' feedback, project works, and pre-test and post-test evaluations to explore the status of students' learning effectiveness. The subjects of this study are 48 students of the "virtual reality course" from a case university of science and technology. After 18 weeks of experimental teaching and case study, the result showed that the "PBL virtual reality course of intelligence network and situational learning" could guide students in learning virtual reality knowledge and technology through real-time feedback of intelligent networks and situational and thematic strategies. Most students performed well in the seven abilities of virtual reality projects. The post-test scores of most students in the virtual reality course learning effectiveness were significantly higher than the pre-test scores, indicating that intelligence networks, situational learning, and PBL are help students learn virtual reality knowledge and improve their practical ability. Furthermore, the research results can be used as an important reference for future development of the Metaverse concept in teaching. Moreover, specific suggestions were put forward based on the research results for students, teachers, and future research.*
Keywords: PBL; Situated learning; Virtual reality; Education reform; Intelligence Network.

1. **Introduction.** The second virtual parallel space and time has been created in the human world with the advent of the Metaverse digital era. People can socialize, entertain and even conduct consumer expenditures through virtual identity. The issues of Metaverse are also listed in the top ten international financial events in 2021 if we look back. This upsurge has made software and hardware engineers like AR, VR, and AI, as well as cross-field technical talents, the hottest industrial talents in modern times. In order to cultivate digital talents with emerging technologies, the education authorities have also started to promote relevant talent cultivation programs from the school side, such as Textbook Development and Teaching Implementation Plan of Virtual Reality Teaching Application, and Innovation and Entrepreneurship Career Development - Augmented Reality Multimedia Design Plan [1-3]. Virtual reality technology breaks the boundary between reality and virtuality and becomes one of the essential technologies of the Metaverse. Shouldering the responsibility of educating industry talents, the university of science and technology sets up virtual reality courses which conform to the trend of the industry. Through course design and arrangement of the theme and content, the university aims to create a multivariate eligibility learning field which allows students to learn to use emerging technologies for independent learning and topic exploration and to experience the virtual reality industry innovation. Furthermore, cross-domain innovative design talents are cultivated through these courses to meet the needs of the workplace in the future.

Virtual Reality (VR) is a modern computer technology with application potential. Coupled with the technological break-through of the VR head-mounted display (HMD) and the mature development of software and hardware, since its inception in 2016, VR has been widely applied in various industrial fields in advanced countries [4, 5]. The 2019 annual report of the International Data Corporation (IDC)[6] predicts that augmentation and VR will have explosive growth from 2020 to 2025, especially in cross-disciplinary applications, such as entertainment, medical care, education, and industry, among which the application in education is one of the key projects promoted by educational institutions in various countries.

As the characteristics of VR are suitable for education, it is applied to teaching and learning. Many studies have proved that the virtual learning environment and high interaction have considerable potential in improving students' learning ability [7-9]. The effect of virtual reality applied to teaching conforms to the situational learning theory, which holds that knowledge learning has contextual significance. The construction of knowledge is the product of human interaction in the cultural context. Virtual reality technology enables students to integrate into the realistic learning situation and actively interact with it; the technology also stimulates students' learning motivation and helps them develop cognitive abilities in the new 3D technology [10, 11]; students who learn new technology implementation skills in a VR learning environment can achieve the effect of active learning and cultivate the correct learning attitude [12-14]. Therefore, developing VR courses based on Situated learning theory and cultivating students' VR technology ability can meet the trend of future science and technology education.

However, it is challenging to cultivate students' ability to develop VR technology. Thus, facilitating students' learning how to operate the software and hardware required for VR emerging technology, and addressing their fear of writing programs, are worthy of consideration and attention by educational institutions at present. In recent years, project-oriented learning has been applied to medicine, architecture, chemical engineering, nature, mathematics, nursing, and other fields of education and has obtained positive results. Project-oriented learning is a student-centered learning teaching method. The inquiry process of learning encourages students to change from passive to active learning. Students confirm the nature of the problem from different perspectives and collect data to organize and summarize to obtain knowledge related to the problem. In turn, this inspires students' thinking and problem-solving abilities and cultivates students' spirit of constantly pursuing new knowledge to achieve the purpose of lifelong learning [15]. Lee and Yang [16] pointed out that the application of thematic oriented learning has a positive effect in improving students' operational thinking ability in robot program learning. Therefore, project-oriented learning is a feasible approach in the field of information technology education. Thus, this study combined situated learning and project-based learning (PBL) as the teaching strategies, developed VR courses, designed digital teaching materials, took VR project production as the core and encouraged students to discuss in groups, carry out special projects, and complete their works, in order to cultivate VR talents. The purposes of this study are as follows:

(1) Develop PBL VR courses based on situated learning suitable for universities of science and technology.

(2) Explore the influence of PBL VR courses based on situated learning on students' project implementation performance.

(3) Explore the influence of PBL VR courses based on situated learning courses on students' learning effectiveness.

2. **Literature Review.** This study discussed literature according to the research purpose. Situated learning theory, VR issues and related research, and the meaning of PBL theory are detailed, as follows:

2.1. **Situated Learning Theory.** Situated learning theory originated from Suchman's situational action viewpoint [17]. Brown et al. [18] put forward situated cognition and pointed out that knowledge exists in the context of learning and learning activities, and learners must actively interact with the situation and construct their own knowledge from the context of knowledge. McLellan [8] also indicated that students can acquire knowledge according to the context in the learning situation, and the learning situation includes "the actual work setting", "a highly realistic or virtual surrogate of the actual work environment", and "an anchoring context, such as a video or multimedia program"[19]. Furthermore, Situated learning theory includes three cores, namely, "the learner's situation needs to be related to the real society", "the problems encountered by the learner need to be similar to the real world", and "the learner must learn how to deal with and solve those problems". Therefore, learning is based on the interaction of "activity" and "culture" [20]; learning without "social interaction", meaning without participation in learning activities, can introduce a purely new concept, but its content cannot be transformed into real knowledge and experience; while VR learning can provide an interactive virtual situation, use visual effects to present abstract problems, and provide learners with opportunities to actively operate and practice repeatedly. McLellan suggested that learning situations can be real or virtual situations, and learners can learn in the situations generated by computer multimedia [8]. To sum up, knowledge exists in the situation, and learners can understand the significance and practicality of knowledge through active operation and exploration of learning materials in the learning situation. Therefore, this study adopted situated learning to implement VR curriculum planning, in order that students could construct knowledge through interactions with reallife situations, and provided interactive virtual learning situations for learners to actively construct knowledge.

2.2. **Connotation and Related Research of VR.** VR began in 1860 when artists presented landscapes and depictions of wars and historical events with three-dimensional panoramic frescoes. In 1968, the first head-mounted display device came out, which generated situations through the brain and interacted with scenes through human movements [21], and attracted the attention of game manufacturers. Since 2016, the related industries of head-mounted display devices have become the main force of the development of the global technology industry, and VR technology has been applied in education, commerce, film, medical care, general industries, and other high risk and high cost industries to simulate scenarios [22]. In addition, because virtual reality can bring people an immersive sense of reality, the application of virtual reality technology will gradually cross over to the cultural, art, and entertainment markets in the future, such as immersive virtual reality games, virtual landscape roaming, and virtual art stage performance. In order to achieve better interactive effects and artistic sensory experience in art scenes, it is necessary to improve the accuracy of human motion recognition in VR human-computer interaction applications. Zhang et al. [23] proposed a motion classification and recognition algorithm based on linear decision and support vector machine (SVM). This method can effectively and accurately recognize human movements after being proved empirically.

As VR needs to meet the three characteristics of interactive, imaginative, and immersive, it takes a lot of time and high costs to develop a complete VR course or game [24]. Interactivity refers to the human-computer interaction generated by the user through the operation interface and virtual reality. In other words, the virtual environment needs to present real-time, dynamic, and interactive scenes, and the user's actions must be responded to in real-time in the shortest time. Imagination means that the production of virtual reality can provide users with imagination space to create lively themes and enhance users' willingness to use. Immersion means that users can integrate into the 3D virtual environment generated by using computer-related software and hardware technologies so that users can have a feeling of "believing it to be true" [15]. Furthermore, the value of VR can only be highlighted when VR scenes are difficult to reach, difficult to obtain, costly, require repeated practice, or are highly dangerous and even harmful to the human body in practice [25]. Therefore, VR must have high fidelity, in or-der that users can learn technology or experience activities that cannot be experienced in the real world after operation.

In the education field, medical education combines computer graphics and VR technology to assist preoperative training and education, and provide doctors with realtime guidance and reference during surgery [26]. Lau used an immersive virtual environment to provide students with a heuristic and highly interactive simulation environment to enhance their learning experience [27]. Exploration and fun are important components of students' learning experience in VR.

To sum up, it is proved that VR provides students with a heuristic and highly interactive virtual environment, which can enhance their learning experience; therefore, the planning of VR related courses is very important. This course design includes hardware and software building, virtual learning environment experience activities, and a game-like environment, which helps students develop positive learning behavior in the learning process and trains students to have crossdomain VR technology ability.

2.3. **Theoretical Implication and Related Research of PBL..** Project-based learning echoes John Dewey's emphasis on learning by doing. The theoretical basis of PBL is based on cooperative learning, situated learning, and constructivism, takes activities, projects, and problem solving as the main learning axes, constructs reallife situations, solves problems in groups, and cultivates problem solving skills [28]. At the beginning of the 20th century, in light of Dewey's idea that "education itself is life", American educator William H. Kilpatrick put forward that schools should plan special courses, in order that learners can choose problems that can produce learning purposes and meanings, are related to life, and can guide students to use their knowledge and skills flexibly by exploring tasks of different knowledge points, peer cooperative learning, and problem solving [29].

Project-based learning is similar to Constructivism theory, which advocates that knowledge is not obtained through transmission, but constructed by students during the cognitive process, thus, the establishment of knowledge is the result of the interaction be-tween students' own knowledge and the learning environment [5]. The contents of the topic, the evaluation of the topic, and learner-centered learning activities have been used to guide group peer cooperative learning to solve problems and present the learning results of specific works [30]. Therefore, many studies have shown that PBL can improve students' learning of knowledge, technology, and collaborative skills, as well as their ability to integrate, apply and practice knowledge [5, 28-30].

To sum up, the VR course in this study adopted Project-based learning to implement teaching and created special topics by means of peer mutual assistance and cooperation. The teachers encouraged students to explore project tasks, apply VR technology to solve the problems encountered in project production, complete project works through group cooperation, and strengthen their application of VR knowledge.

3. Research Method and Design.

3.1. **Research Process and Structure.** With literature review as the theoretical basis of the VR curriculum design, this study developed a PBL VR course based on a situated learning curriculum suitable for universities of science and technology. This research framework, as shown in Figure 1, carried out a qualitative analysis of students' learning effectiveness through curriculum development and teaching field implementation. The implementation process of this study is described, as follows: In the "planning stage", through literature review of related research, this study dis-cussed the meaning of PBL theory, the topic of VR, learning effectiveness, and the theoretical model of an innovative curriculum. Regarding the "curriculum development stage", this curriculum design includes the curriculum design theory, curriculum objectives, curriculum framework, teaching activities, and evaluation methods. According to the purpose of this study, the research plan and curriculum outline were compiled, and scholars and experts were invited to review and build a new VR course suitable for the new developments of universities of science and technology. Furthermore, evaluation tools were developed to evaluate students' learning effectiveness through pre-test, post-test, study sheets, observation logs, and reflections. In the "teaching implementation stage", curriculum implementation included teaching content, observations, reflections, evaluations, and final works. After continuous reflection, the course was revised in a rolling manner. In the "data analysis stage", through qualitative interviews, observations, study sheets, and re-flection sheets, the development model was analyzed, and conclusions and suggestions were made.

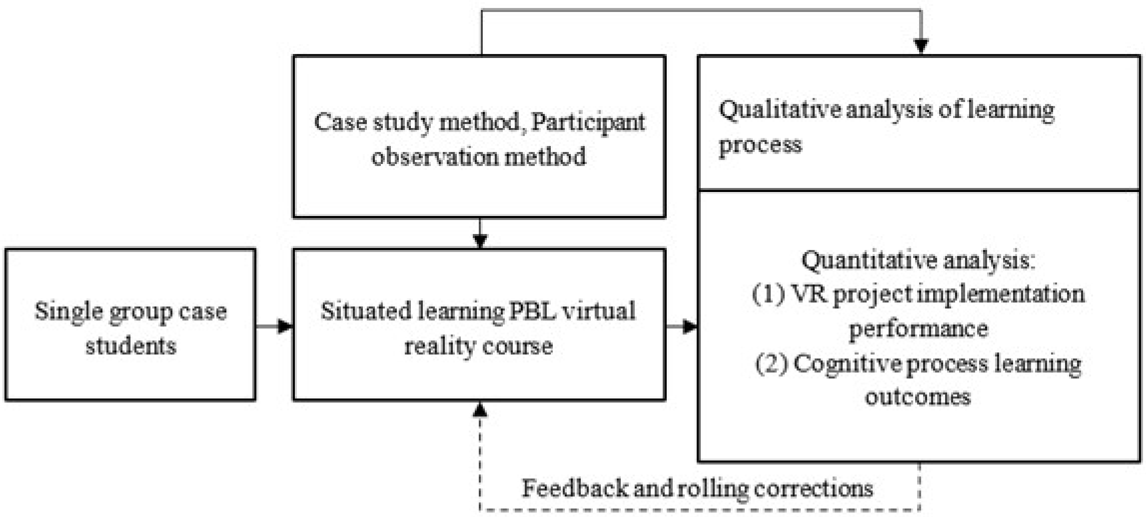

Figure 1. Research Structure

3.2. **Research Method.** This study intended to develop the "PBL VR Course based on Situated learning" and explore the students' learning process and learning effectiveness. Case study and participatory observation methods were used to collect and analyze the data, which are explained, as follows:

3.2.1. *Case study method.* Case studies are exploratory studies that focus on a single environment and gain in-sight into research strategies that may change [31]. In the process, in order to find the truth and objectively understand the facts, we explore, understand, recognize, measure, analyze, and verify all relevant factual data [32]. The implementation of case studies must use multiple evidence sources, build a database of case studies, and maintain the relevance of evidence [33]. In response to the trend of the application of VR in the field of education, many scholars have carried out exploratory research on the development, design, and teaching effect of a VR curriculum; therefore, the case study method is used to collect and analyze multiparty data for reference by follow up researchers.

3.2.2. *Participant observation method.* Participant Observation means that observers need to think, infer, and filter, meaning observers must consciously reflect on their inferences and separate inference from observation [34]. This study collected students' learning observations and teachers' logs in a VR classroom and outdoor teaching. In the "Virtual Reality Theme Pavilion", the investigation of the Daliao field was planned, including the observation fields of the Wu Family Ancestral Homestead and the Chien Family Ancestral Homestead in Daliao as the main topics. Students were encouraged to make 3D models of the Daliao ancestral homesteads, and complete a special production of creative ancestral homesteads through Unity technology.
To sum up, in this study, the case study and the observed text data were tested by data triangulation and simultaneously observed from the three angles of time, space and object, in order to test the consistency of the same source. Then, a variety of data search methods were used to test the consistency of the findings. Furthermore, teachers, students, and teaching assistants were regarded as research subjects and teaching case study observation was implemented to test the consistency of the same resources.

3.3. **Research Subjects.** This research course is an 18-week elective general education course (two sessions/week) in the case schools, and the enrollment targets are the first-year students of various departments who are interested in VR/AR but have no foundation. According to the computer random sampling of the case school, the students taking the course include 1 from the department of bio-technology, 1 department of environmental engineering and 1 department of beauty, 2 departments of child care, 2 departments of chemistry, 2 departments of nursing and materials, 3 departments of foreign affairs, and 36 departments of asset management, totaling 50; two students dropped out of school after the mid-term exam, thus, the research samples totaled 48 people.

3.4. **Research Tools.** The qualitative and quantitative research tools employed in this study included the quantitative analysis tools of the "VR Thematic Implementation Scale" and "Cognitive Process Dimension", and qualitative data collection tools, such as "Teacher Observation Log", "Virtual Reality Learning Sheets", and the "Interview Outline". In the course of developing the above research tools, scholars and experts were invited to review and revise the curriculum content opinions regarding the correctness, representativeness, and GAI of each tool content, in order to establish expert validity, which are described, as follows:

3.4.1. *VR thematic implementation scale.* This study designed the "VR Project Implementation Scale" to explore students' performance in creating projects based on VR. This VR thematic implementation scale includes seven aspects: "Understand VR Knowledge", "Master VR Technology", "Under-stand VR Issues", "Apply VR Knowledge", "Apply VR Ability", "Understand VR Application in Industry", and "Solve VR Issues". Cronbach's Alpha of reliability analysis of each aspect is between 0.762 and 0.874, as shown in Table 1, and the overall reliability Cronbach's Alpha is 0.912, which shows that this survey is credible and with high consistency. Furthermore, the suggestions of experts were summarized, and a proportion of points was assigned to each aspect, totaling 53 points.

3.4.2. *Cognitive Process Dimension.* In the aspect of the test analysis of students before and after learning the VR course, this study adopted the learning and education classification method of Bloom's taxonomy and divided the cognitive process dimension into six categories: memory, understanding, application, analysis, evaluation, and creation. The test questions were designed according to six teaching materials of the VR course, "Basic Virtual Reality Concept", "Development Pre-assignment", "Virtual Reality Design", "Resource Object Design", "Virtual Reality Display", and "Execution Setting Release".

Table 1. Reliability Analysis of VR Thematic Implementation Scale

S/n	Item	Score	Cronbach's Alpha	Overall
(1)	Understand VR Knowledge	15	0.762	0.912
(2)	Master VR Technology	5	0.848	
(3)	Understand VR Issues	5	0.841	
(4)	Apply VR Knowledge	5	0.796	
(5)	Apply VR Capability	15	0.788	
(6)	Understand VR Application in Industry	4	0.874	
(7)	Ability to solve VR issues	4	0.814	
	Total	53		

Regarding reliability analysis, Cronbach's Alpha of the six dimensions is be-tween 0.814 and 0.875, as shown in Table 2, and the overall reliability is 0.912, which shows that this survey is credible and with high consistency. After reliability analysis, the inappropriate items were deleted. There were 30 questions in the overall table, with a total score of 100 points. The students were tested before and after the study, and T-testing was conducted for paired samples to understand students' learning effectiveness.

Table 2. Analysis of Cognitive Process Dimension

Textbook content	Basic VR Concept	Development pre-assignment	VR Design	Resource Object Design	VR Display	Execution Setting Release	Overall
Cronbach's Alpha	0.814	0.846	0.858	0.875	0.832	0.849	0.893
Memory	0	1	1	1	1	1	0.5
Understanding	0	1	1	1	1	1	5
Application	1	1	2	1	1	1	7
Analysis	0	0	1	1	1	1	4
Evaluation	0	1	1	1	1	1	5
Creation	0	0	1	1	1	1	4
Total	1	4	7	6	6	6	30

3.4.3. *Qualitative research tools.* This study developed the "Teacher Observation Journal", "Virtual Reality Learning Sheet", and "Interview Outline", as shown in Table 3, as qualitative data collection tools. After the first draft of the tool was completed, 3 practitioners and 5 experts were invited to examine the correctness, representativeness, and GAI of the content, and give opinions and suggestions to establish expert validity. The data coding rules and codes of this study include students' learning experience (SL), teachers' logs (D), teaching observation records (D), students' works (SW), special topics (PJ), time (year, month, and day), and serial number (two digits). Example code SL-20201004-01 represents the learning experience of students numbered 01 on October 4, 2020, and example code D-20201016-01 represents a teacher log numbered 01 on October 16, 2020.

3.5. **Curriculum Planning.** Regarding the 18-week teaching topic schedule of this research plan, as shown in Table 4, the contents include understanding VR, basic operation of Unity, basic geometry of Unity, use of prefabricated objects, use of the Asset Store resource library, use of lights, use of cameras, basic animation of Unity Mecanim, basic operation of state, interactive settings and space movement, and a special report of the

Table 3. Outline of Qualitative Data Observation and Interview

S/n	Outline	Orientation
(1)	What is the most profound thing in the process of implementing VR projects?	Thematic implementation
(2)	What are the difficulties encountered by the team in implementing the VR project process? How to solve it?	Thematic implementation
(3)	Does the final VR work achieve the desired results? What has changed the most?	Thematic implementation
(4)	How to discuss and communicate in the team? Have you ever disagreed?	Teamwork
(5)	What is the team's gain when performing VR projects?	Teamwork
(6)	What is the biggest gain for you from performing VR projects?	Learning outcomes

Virtual Reality Theme Pavilion, in order to train students to master VR knowledge and skills.

4. **Results and Discussion.** After 18 weeks of experimental teaching, this study collected the textual data of students' learning activities and made qualitative analysis and descriptions. Furthermore, this study collected students' pre-test and post-test questionnaires for statistical analysis, in order to understand students' learning status of the "Virtual Reality Theme Pavilion", and employed quality analysis and cross-comparison to confirm the effectiveness of curriculum implementation, which can be used as a reference for revising the curriculum, which are described as follows:

4.1. **Analysis of the Implementation Process of the "Virtual Reality Theme Pavilion.".** According to Situated learning theory and the implementation focus of PBL, this study analyzed students' learning feedback in the stages of asking questions and redefining questions, collecting and analyzing data, designing and making, experimenting and verifying, forming and sharing, which are described, as follows:

4.1.1. *Determine the conceptual goal of the virtual reality course and students' ability to construct virtual reality knowledge independently.* This study developed a PBL VR course, as based on a situated learning curriculum, to guide students in the VR theme pro-duction according to the curriculum concept objectives and elaboration, and allow them to understand what they have learned. This basic course plan includes hardware installation, software Unity installation, basic geometry, preset object use, 3D material search and use, downloading Asset store resources, lighting, mapping, camera, and other operations. During this course, teachers adopted cooperative learning to implement teaching activities, and encouraged students to work together to complete tasks, such as VR works, posters, triple leaflets, briefings, and curriculum objectives (D-20201003-01). Feedback from students:

- Group students come from different departments and majors. With a clear description of course objectives, it is convenient for group students to integrate the division of labor and cooperation among group members (SL-20210122-03).
- After several weeks of cooperation, students can understand that the whole VR project needs team members to work together (SL-20210122-01).

During the course, students actively discussed VR production knowledge and operation technology and used Line group to communicate VR special production planning and production problem solving after class, in order to build a special work of and Virtual Reality

Theme Pavilion (D-20201007-02) through cooperative learning. Therefore, students built their VR-related knowledge and skills through the objectives of this VR course.

4.1.2. *Planning situated learning to guide problems in PBL virtual reality courses, and cultivate students' ability to identify and redefine problems.* This PBL VR course, as based on situated learning curriculum planning, uses questions to stimulate students' curiosity to participate in the project and ask questions. The course guides students to apply the basic operation ability of Unity to build 3D scenes, comprehensive application of resource acquisition and object setting, VR space navigation, and photo display, thus, emphasizing the importance of implementation. In the classroom, the teacher put forward the driving question of "How do we con-struct the Virtual Reality Theme Pavilion of Daliao ancestral homesteads?" (D-20201003-01).
Feedback from students:

- Through on-the-spot visits to the Wu Family Ancestral Homestead and the Chien Family Ancestral Homestead in Daliao, what are the external characteristics of ancestral homesteads? What is the composition of the ancestral home-steads? (SL-20201006-19)
- What are the Unity software functions that can be applied? What is the origin of ancestral homesteads? (SL-20201006-20).

Based on the above-mentioned problem finding, the student team collected relevant information for in-depth discussion (D-20201010-02). Therefore, through teamwork, students can find data, share experiences, exchange discussions, and form a group consensus to improve their ability to identify problems and redefine them.

4.1.3. *Students lead the production and design of VR topics, and implement team cooperative learning.* This PBL VR course based on situated learning course plans student-oriented VR project production and design activities. The course focuses on downloading and importing a 3D Warehouse model, making a 3D model, practicing camera operation, and exhibiting and practicing the design of a museum guide field. The teacher is the course guide, and the groups of students make assumptions and design plans according to the previous questions and definitions (D-20201110-01).
Feedback from students:

- The scene of ancestral homesteads can be completed by a 3D modeling function (SL-20201022-21).
- The color of the exterior wall of the ancestral homesteads should be made with material balls (SL-20201022-06).
- 360-degree landscape shooting (SL-20201022-17) is necessary for the tour of ancestral homesteads.

Through the above assumptions and design planning, students carried out a professional division of labor. In the process, they learned the history and details of related ancestral homesteads, the operation and application of Unity, scene construction from scratch, and made works together (D-20201117-02), as shown in Figure 2. Therefore, in the process of VR project production, students learned the knowledge and skills covered by solving problems through cooperative learning.

Table 4. Topic Schedule

Week	Teaching theme	Teaching content
1	Understand VR	Present situation, application, and fut
2	Understand hardware equipment	Erect and experience the Oculus helm HTC VIVE helmet installation, and e Samsung Gear glasses
3	Install hardware	HTC Vive headgear, speaker, e-sports
4	Install software	Unity2017.1.1 (1) Resource object settings (2) Basic geometry of Unity (3) Use of prefabricated objects (4) Search and use of 3D materials
5	Import the Steam VR SDK	Set the VIVE controller button defini Introduce VRTK SDK into VIVE VR
6-7	Material setting	Map setting skills Lighting setting skills Use of AssetStore resources Use of lights
8-9	Basic operations	Unity operational fundamentals cours Set Unity scene floor and erect the en Skills of importing external objects in
10-13	Advanced operation	Object displacement, rotation, scaling Skills of downloading and importing t Make basic 3D model and camera ope Exhibition and design of museum gui
14-18	Special topic production and achievement publication	Use Unity special topic production Publish VR works

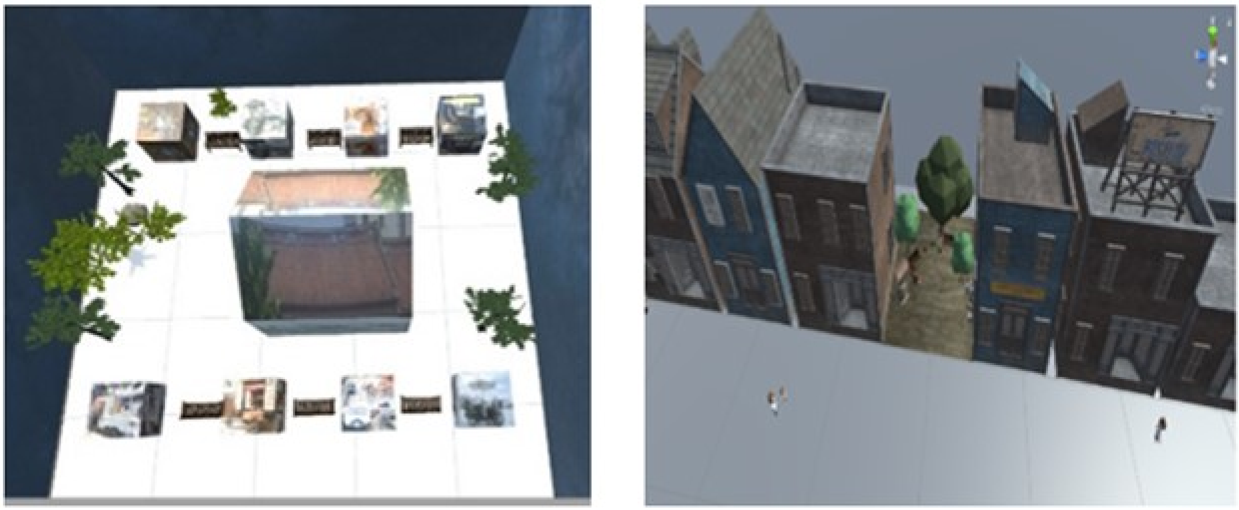

Figure 2. Student Work SW-20201119-02 and SW-20201119-03

4.1.4. *Implement VR special works and innovate the implementation and verification of problem solutions.* This PBL VR course based on a situated learning course emphasizes students' hands-on implementation and produces concrete and feasible innovative VR projects. Based on the theory and technology of this course, students apply what they have learned to the practical work of project making, and use their problem solving and project planning skills. Through the above da-ta collection and project design, the groups of students began to produce project works (D-20201101-01).
Feedback from students:

• The creative approach of our special production was to try to combine the real scene of Daliao ancestral homesteads with the VR ancestral homesteads, such as Figure 3 (SL-20201116-25).

• Through implementation experiments, we verified the feasibility and effectiveness of the scheme by combining real scene pictures with VR scenes, such as Figure 4 (SL-20201116-17).

In the process, students discussed together, gave full play to their creativity, and solved the problems encountered (D-20201108-02); therefore, students learned how to make innovative and feasible VR projects.

4.1.5. *Share the production results of the PBL virtual reality course in situated learning and exchange peer innovation experiences.* In the performance report of this PBL VR course based on the situated learning plan, each group must report and share their innovative works and things learned. When the final results were published, each group of student teams presented their VR special results through written reports, PPT, posters, films, and VR works, (D-20210119-01), as shown in Figure 5 and Figure 6. Feedback from students:

• During the briefing, we explained the innovative design concept of our group, the application skills of Unity, and the sharing of practical experiences, such as using Google Cardboard to present Daliao ancestral homesteads (SL-20210119-12).

• We shared practical experiences, such as problems encountered in the production process of special topics, solutions, and team cooperation (SL-20210119-18).

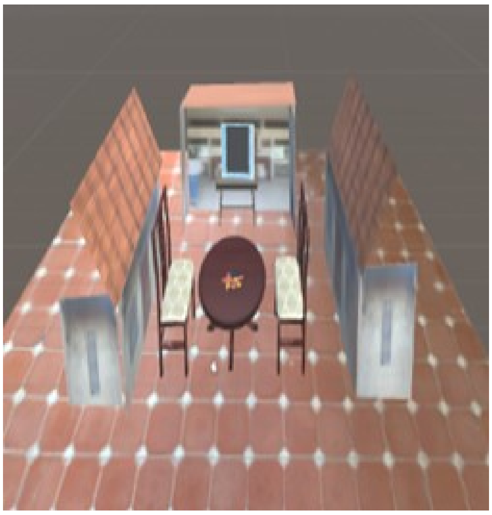

FIGURE 3. Student VR Works SW-20210119-02

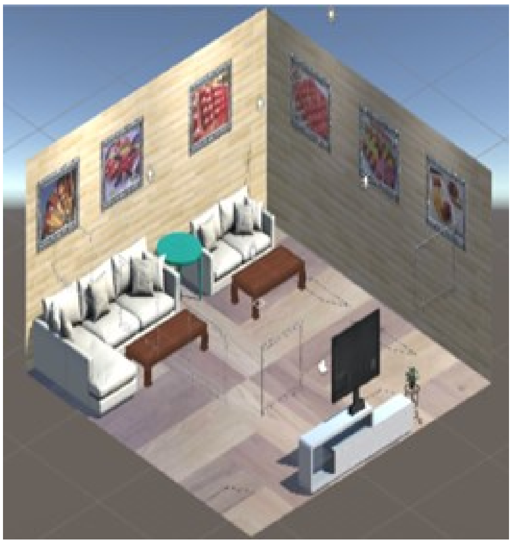

FIGURE 4. Student VR Works SW-20210119-03

In the briefings, students learned about the creative essence of each groups' VR special works, their VR knowledge, and the skills applied (D-20210119-02). At the same time, they also accepted the advice and judgment of peers and teachers as a reference for the improvement of VR works in the future. Therefore, through peer sharing and experience exchange, students can improve their ability to gather data, summarize key points, communicate effectively, and think creatively.

4.2. **Student VR project implementation evaluation.** After the course, all students were tested by the "VR Project Implementation Scale" to explore students' performances in creating projects based on VR. The VR project performances of the six groups of students, as shown in Table 5, are explained according to the "scores of each group" and "average test of each item", as follows:

4.2.1. *Score analysis of each group.* From the analysis of the scores of each group, according to the proportion, the project scores and total scores were proportional, and the fifth group received the highest score, with an average total score of 48.4 points, and a score ratio of 91

FIGURE 5. Student Poster SW-20210119-02

FIGURE 6. Student Poster SW-20210119-03

TABLE 5. VR Thematic Implementation Scale

Item	1	2	3	4	5	6
(1) Understand VR Knowledge (15 points)	10.0	11.0	13.0	12.0	13.0	12.0
(2) Master VR Technology (5 points)	4.0	4.0	4.0	5.0	4.0	5.0
(3) Understand VR Issues (5 points)	4.0	4.0	5.0	5.0	5.0	5.0
(4) Apply VR Knowledge (5 points)	5.0	3.0	4.0	5.0	4.0	4.0
(5) Apply VR Capability (15 points)	12.0	4.0	13.0	12.0	10.0	12.0
(6) Understand VR Application in Industry (4 points)	4.0	4.0	2.4	2.4	0.8	2.4
(7) Ability to Solve VR Problems (4 points)	4.0	3.2	4.0	1.6	1.6	3.2
Total score of each group	43.0	33.2	45.4	43.0	48.4	43.6
Percentage of scores in each group	81.1%	62.6%	85.7%	81.1%	91.3%	82.3%

4.2.2. *Average test of each item.* According to the average analysis of students in each test item, the average score ratio of 7 special projects is 42.77, and the compliance rate is 80.7%, as shown in Table 5 and Figure 7. Most students received the highest score in the special implementation project of "Understand VR Issues", with a score of 4.67, accounting for 93.3%, followed by "Master VR Technology" (with a score of 4.33, accounting for 86.7%) and "Apply VR Knowledge" (with a score of 4.17, accounting for 83.3%). Among them, in "Understand VR Application in Industry", the score is only 2.67, and the compliance rate is only 66.7%, which is less than 70% but can be further strengthened during this course.

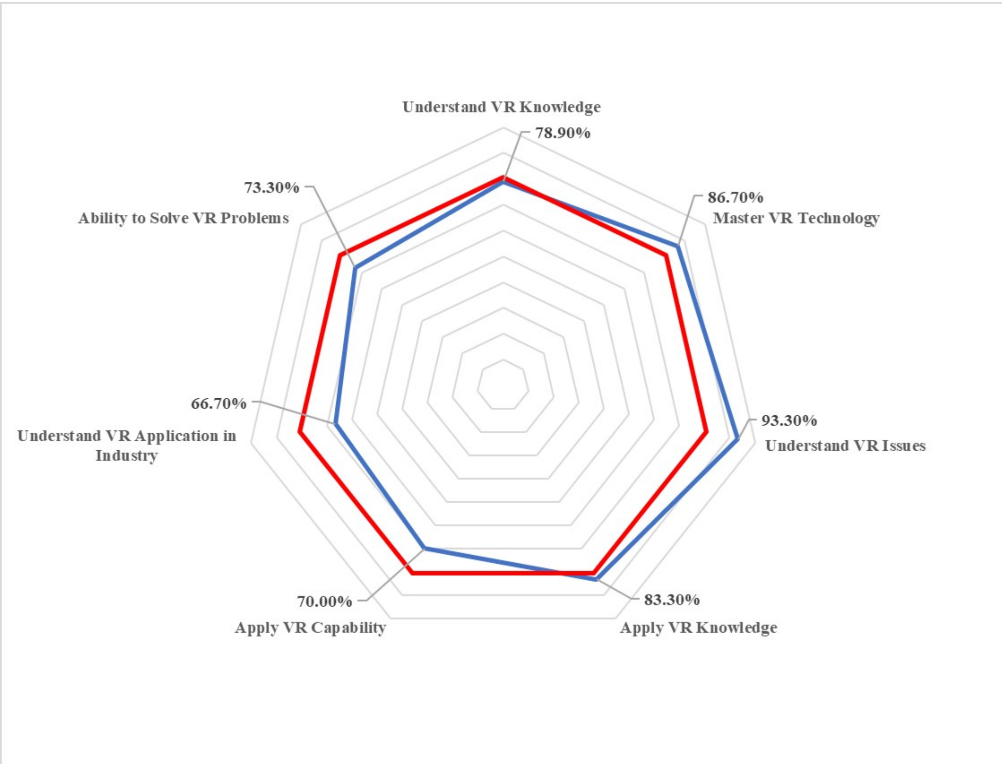

FIGURE 7. Thematic Implementation Project Test Radar Chart

4.3. **Pre and post-test analysis of students' cognitive process.** Regarding the aspect of learning effectiveness analysis of students' cognitive process in this VR course, this study adopted the learning and education classification of Bloom's taxonomy, as developed in the Cognitive Process Dimension, and implemented paired sample t-testing to analyze students' preand post-test status, in order to understand students' learning effectiveness and serve as an important reference for the improvement of this course.

After 18 weeks of experimental teaching, the average score of the pre-test and post-test of the 48 students taking the course were 53.41 (SD=17. 55) and 72.63 (SD=21. 63), respectively. Then, t-test analysis of paired samples was further implemented, as shown in Table 6. The post-test scores are higher than the pre-test scores, with an average value of -19.22 (SD=8.81) and a t value of -13.97, which is a significant difference, and shows that most students had positive improvement after learning the content of the VR textbooks.

Table 6. t-test Analysis of Paired Samples of Students' Cognitive Process Learning Effect

Item	Average	Standard deviation	Average	Standard deviation	t
Pre-test	53.41	17.55	-19.22	-8.81	-13.97***
Post-test	72.63	21.45			

4.4. **Comprehensive discussion.** Based on the quality analysis results of teachers' observation and students' feedback in the special production process of a "Virtual Reality Theme Pavilion", this study discussed and summarized three curriculum characteristics, which are explained, as follows:

4.4.1. *Create a friendly learning environment with students as the center and teachers as the guide.* This course was designed as a student-centered "PBL VR course based on situated learning", which focuses on benign inter-action and communication between teachers, students, and peers. Teachers created a friendly learning environment, including sharing VR innovative application cases, designed outdoor teaching courses for field visits to ancestral homesteads, and planned special production activities, and the students stated that they liked this course [35]. When the students encountered difficulties in learning the course, such as Unity software operation, Cardboard, 360-degree camera hardware equipment settings, and special topic production issues, they were willing to discuss with classmates or consult teachers. Teachers provided guidance for students' learning process, cultivated students' problem-solving ability, and enhanced students' interest and effectiveness in learning, which echo the findings of Hiroshi et al. [36].

4.4.2. *Plan situated learning PBL project production activities from the basic to more in-depth content, and feature peer cooperative learning.* At the beginning of this VR course, we planned software and hardware related teaching units, including the use of Unity software, integrated VR technical capabilities, such as 3D modelling, 2D pictures, sound effects, and movies, and developed VR special works. In the teaching process, students were guided from the basic to more in-depth content, were taught in accordance with their aptitude, and were encouraged to ask questions or fill out learning feedback forms immediately when they encountered problems. Thus, teachers and researchers were able to understand students' learning problems and implement rolling teaching adjustments [37, 38]. Furthermore, this study adopted situated learning and PBL design teaching activities to stimulate students' interest in learning, strengthened students' cooperative learning, and achieved learning goals through special topic making and peer grouping. After this course, analysis shows that most students performed well in VR project implementation and achieved the expected learning goals, and these results echo the findings of Huang et al. [11, 39].

4.4.3. *Design the curriculum content and evaluation tools of the cognitive process dimension in accordance with Bloom's taxonomy.* The VR curriculum design of this study adopted Bloom's taxonomy learning and education classification to plan the units, which provided students with learning in line with cognitive processes, such as memory, understanding, application, analysis, evaluation, and creation, and designed a cognitive process dimension evaluation tool. Through the instructional design and planning of this study, students' motivation to learn Unity software and new technology tools was stimulated, and they stated that they loved this course and devoted themselves to the special project production activities [40]. After pre-test and post-test analysis, most students' learning of the VR course content showed a positive improvement effect, which echo the research results of Chung et al. [8].

5. **Conclusions and Suggestions.** The main research conclusions and suggestions are summarized according to the results of research analysis and discussion, as follows:

5.1. **Conclusion.** The following learning effect conclusions are summarized according to the research purpose, the development of the VR curriculum, and course curriculum implementation and discussion results:

5.1.1. *PBL virtual reality course based on situated learning guides students to learn virtual reality knowledge and technology in a situational and thematic manner.* According to the curriculum objectives, this study adopted the case study method and developed a PBL VR course based on situated learning curriculum through rolling revision courses, including planning, observation, reflection, and implementation. This course planned the topic of "Virtual Reality Theme Pavilion", and guided students to use Android smartphones to develop portable Cardboard Theme Pavilion navigation projects. The content design of this course focused on students' autonomous learning and the construction of conceptual knowledge, and led students to implement thematic-oriented learning from searching for data, collecting theme knowledge connotations, and using Unity software, to completing special works and presenting VR works on stage. In this way, students were trained to collect VR knowledge and present special project production ability.

5.1.2. *The student teams performed well in the seven projects of thematic implementation of PBL virtual reality course in situated learning.* The planned course content of this study focused on the learning and application of VR knowledge and skills. With a PBL-driven theme, students can understand the current situation and future development of VR, Unity software operation, and the innovative production of Daliao ancestral homesteads. In addition, students were guided to explore the actual field and experience the process of thinking, planning, designing, and implementing special designs. In this way, the performance of the student teams in seven topics, including "Understand VR Knowledge", "Master VR Technology", "Understand VR Issues", "Apply VR Knowledge", "Apply VR Capability", "Understand VR Application in Industry", and "Ability to Solve VR Problems", was evaluated. The evaluation results show that the student teams had excellent project implementation performance, which indicates that most student teams have the ability to implement and construct VR projects.

5.1.3. *Most students' post-test scores of learning effectiveness of PBL virtual reality course in situated learning are significantly higher than those in pre-test scores.* This study adopted the learning and education classification of Bloom's taxonomy and carried out pre-test and post-test analysis on six units of a PBL VR course based on situated learning, including "Basic Virtual Reality Concept", "Development Pre-assignment", "Virtual Reality Design", "Resource Object Design", "Virtual Reality Dis-play", and "Execution Setting Release", and the results show that most students had significant improvement effect. After learning the basic ability of Unity and how to make special projects, most students were able to apply their knowledge to the special production, from the investigation of Daliao field, and the proposal of special projects, to the de-sign and production of VR special projects. Thus, the learning effect of students' VR course was enhanced.

5.2. **Suggestions.** Based on the above conclusions, the suggestions for students, teachers, and future re-search are summarized, as follows:

5.2.1. *Promote PBL virtual reality courses based on situated learning and cultivate virtual reality talents for the market.* The application of VR is a growing trend in various industries; however, while de-mand is high, VR talents are in short supply. Therefore, this course planned situated learning with special practical training and collaborative teaching between course teachers and practitioners, which can cultivate students with VR professional skills, including the application development of pre-prepared knowledge and information ability, as well as the implementation of VR Cardboard and game designs, in order to enhance students' practical ability and self-confidence and improve their competitiveness in the workplace.

5.2.2. *Improve teachers' professional ability and accomplishments in virtual reality, and show the effect of a PBL virtual reality course based on situated learning.* In order to teach professional knowledge and technology, teachers must keep pace with the times and learn new topics and skills to achieve the purpose of cultivating excel-lent students. It is suggested that teachers should participate in VR teaching camps, professional communities, reading clubs, etc. to enhance their professional knowledge and skills in VR. Teachers can refer to and apply the results of this study to provide students with a topic-oriented VR learning environment with situated learning.

5.2.3. *Suggestions for different research topics in the future.* VR technology has matured with the development of computer science and technology, and the PBL Virtual Reality Course of Situated learning developed in this study has achieved remarkable results. It is suggested that future researchers can develop other VR scenes into topic-oriented thematic courses, where the expertise attributes of each department are the focus, and explore the implementation effect of PBL VR courses based on situated learning, which will facilitate the development of VR courses in various fields and train more cross-disciplinary VR professionals.

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