PBL-based VR course for preservice teachers' designing skills in applied university under coronavirus

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ABSTRACT

Smart education and ubiquitous learning have come over globally, especially under coronavirus regime. Visual media and interactive operation can draw children's attention and interests, so the VR educational software becomes a prominent trend for training children. However, in K12 education, the VR technology is just in its initial period. In the face of global coronavirus context, and children's visual learning characteristics, training preservice teachers with abilities to develop the VR educational software is crucial. In the project, it designs the VR course for preservice teachers in applied university that cultivates preservice teachers, trains them to develop the VR educational software, and enables them to develop it. It designs the VR course to accomplish the above two objectives in two aspects: creating PBL-based VR teaching cases to give them a sense of achievement and leading them to develop the VR educational software as the summarizing test. The results are presented in three views. Firstly, their developed VR educational software shows that the PBL cases are effective in training students' ability of developing the VR educational software. Secondly, it investigates the effectiveness of PBL-based VR course by t-test. Finally, it surveys their satisfaction for the course, ideas about what other technologies they want to learn, what subjects they want to develop for, and what types of software they want to design to guide course research in the future.

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Influence of coronavirus to education; virtual reality; PBL-based course design; applied university; preservice teachers' developing skills

1. Introduction

1.1. VR educational software for children

The popularization of Internet technology, big data, artificial intelligence and other information or communication technologies has brought tremendous changes in many industries such as health-care, education, finance, telecommunication, agriculture, and traffic, etc. (Lu, 2019). United Nations Educational, Scientific and Cultural Organization (UNESCO, 2011) classifies education into 9 levels: early childhood education, primary education, lower secondary education, upper secondary education, post-secondary, non-tertiary education, tertiary education including short-cycle tertiary education, bachelor's, master's, and Doctor's. Among them, children currently in early childhood and primary education are indigenous to cyberspace as they are roughly age from 2 to 11, whose birth years are naturally connected with Internet spirit that enables them to integrate Internet and daily life automatically and logically (Bickham, 2017). Therefore, ubiquitous learning (u-learning) is suitable for children because they are Internet aboriginals. u-learning uses digital content, mobile devices, and wireless communication to provide a teaching and learning experience for anyone,

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anytime, anywhere, and by any device that are simplified as 4A, which represents a new learning model (Shapsough & Zualkernan, 2020).

But, visual media is a good technique to guide children's attention in a visual learning environment in that their thinking and learning mode is mainly based on the imagery form that is an instinctive and important thinking process to reflect and understand the world (Kissler et al., 2020; Doron, 2017). What is more, this thinking mode can cultivate children's imagination capacity that is essential for building their creativity and innovation ability that is very crucial for their long-term development (Gündoğan, 2019; Celume et al., 2017).

At last, by long-term isolated life caused by this year's worldwide coronavirus epidemic, the paper published by Harvard University on Science shown calls for VR education and VR medical treatment to develop as quickly as possible.

Therefore, the VR educational software, featured by u-learning and visual media, is really effective for children in pre-school and primary school and for adapting to isolated life. Firstly, it can run in a variety of platforms especially in mobile platforms such as iOS and Android, which enable children to use it freely anytime and anywhere that conforms to u-learning principle. Secondly, it provides 3D visual media that users can see it, immerse in it, and even interact with it, that is consistent with children's characteristics of imagery thinking. Thirdly, it is urgently called by this year's and long-term isolated life from coronavirus.

However, VR technology is mainly applied in medical area and for undergraduates (Kuehn, 2018; Moro et al., 2017) such that very few literatures are about developing VR educational software for children in kindergartens and primary schools (Wang et al., 2020). Therefore, they are in urgent need of VR educational software, so this project attempts to fill the gap by creating a VR course for training preservice teachers' designing skills of the VR educational software. Its aim is enabling them to develop the VR educational software that is suitable for their future classes and students.

2. Literature review

2.1. Ubiquitous education

Along with the evolution to smart society, more digital natives are using e-learning or u-learning (Li et al., 2018). U-learning, which is permanent, accessible, immediate, interactive, and adaptable, is developed from e-learning and m-learning (Ogata & Yano, 2004), which is characterized through methodology, supporting system, and new trends. For methodology, game-based u-learning is advocated since it improves learning achievement, motivation, and autonomy (Parra-González et al., 2020; Sáez-López et al., 2019). As for its supporting system, teacher orchestration supporting system (Muñoz-Cristóbal et al., 2015) and teaching and learning system (Mehmood et al., 2017) are developed. For its developing trends, personalization, context-awareness (Pimmer et al., 2016; Chen & Lin, 2016) and distributed learning are added to its characteristics (Pishtari et al., 2020).

2.2. Visual media and creative thinking

One study by psychologists indicates that visual thinking has been deeply rooted in the human's brain, while verbal thinking is a relatively new evolution (Reuell, 2017). Another study for children's visual learning characteristics shows that since they are digital natives, audiovisual type of riddle is necessary to them because it satisfies their intellectual and emotional needs, while solving the riddle problems at the same time (Castro, 2011).

The project measuring the relationship between imagery ability and creative thinking discovers that creative thinking relates significantly with imagery ability, which also influences fluency and originality (González et al., 1997). One further experiment demonstrates that creativity can be cultivated and improved by the intervention of role-taking and educational media. The children, who participated in this intervention, score obviously higher in creativity test than who didn't take part in (Doron, 2017).

2.3. VR educational software

The VR technology was first and most applied in the medical field (Solomon et al., 2011; Sharan et al., 2012; Shaun et al., 2018). Then it was gradually used in other areas such as civil engineering (Sampaio et al., 2013) and structural biology (Garcia-Bonete et al., 2019). To begin with medical major, the VR finds many applications in simulating surgical operation (Solomon et al., 2011), post-operative rehabitation (Sharan et al., 2012) and mental health research (Shaun et al., 2018), etc. Next, in civil engineering (Sampaio et al., 2013) 3D modeling and programming technologies are trained for students aiming to support their future professional activities. In structural biology, it trains teachers who don't have a deep knowledge of information technology to design VR or AR (Augmented Reality) educational software (Garcia-Bonete et al., 2019).

2.4. Applied university

The innovation and economical levels of industrialized countries reveal that their efficiency is due to the production of knowledge and its use in industries (Broström, 2020). Thus, innovation and its contribution to economy increasingly appear high on current government agendas (Rupika & Singh, 2016). In applied university, the knowledge, produced under the context of practical use, has become dominant. Accordingly, the undergraduates are trained to meet social requirements and to solve practical problems. After graduation, they are expected to analyze and solve practical problems by using their theoretical knowledge and methods learnt from the university (Li et al., 2019).

For example, Vienna University of Technology has built a situation-based and problem-solving course. This SBL (Scenario-Based Learning) course employs real-world problems to inspire students to learn actively. Students will use their knowledge, cognition, and collaborate with their teammates to solve problems. In other words, this course starts with practical problems and ends with delivered products (Erol et al., 2016). Nevertheless, this approach only allows students to solve practical problems, but without prior training of relevant knowledge and skills, so it reduces learning efficiency.

2.5. Stating problems or weaknesses

Under the popularization of smart education and ubiquitous learning, children's characteristics of Internet natives and imagery thinking, together with the isolated life resulted from coronavirus epidemic, developing VR educational software for children in kindergarten and primary schools are extremely essential and imminent.

Since the responsibility of applied university is to promote social and economic development directly, the graduates trained by these universities have to own practical skills and are able to solve the problems actually happened in their future work (Li et al., 2019). Thus, applied universities are becoming more and more popular both in developed and developing countries and their curriculum is closely related to practice and production. However, they have problems that only include theoretical knowledge without developing really projects, or let students develop projects immediately without knowledge introduction (Erol et al., 2016).

2.6. The purpose and significance

2.6.1. Purpose

The project has two research purposes. First, it designs PBL-based VR cases for the preservice teachers who attend this VR course in applied university to give them a sense of achievement and inspires them with the capability of developing this kind of software in their future work. Second, it instructs them to develop practical VR educational software for children in kindergarten and primary schools, to fit the children's characteristics of visual media learning and imagery thinking, ubiquitous learning background, and the isolated life caused by coronavirus epidemic.

2.6.2. Significance

The research has two significant points. To begin, its developed VR educational software promotes children's interests and efficiency in learning, fills the gap in developing VR educational software for children, and copes with the isolated life resulted from coronavirus epidemic. Secondly, it realizes knowledge transfer from enterprise to university, and then from university to kindergarten and primary school. The knowledge transfer from enterprise to university is that specialists from enterprises give lectures about the most advanced and popular VR technologies. But, the knowledge transfer from university to kindergarten and primary school is developing VR educational software for children of that age. Both of them accelerate social and economic development.

3. VR course design

3.1. General model of the course

This VR course includes four phases of Project-Based Learning (PBL) teaching projects design, PBL and industrial lectures, VR educational software development for children which is a well final summarizing test, and application of the VR educational software designed by these students. The total teaching duration of this course is 16 weeks with 3 teaching hours in each week. As shown in Figure 1.

Firstly, before the 16 teaching weeks, the PBL projects of this VR course have been designed together with senior specialists from an outstanding VR enterprise. In this stage, the teaching team introduces the preliminary 3D knowledge of these preservice teachers to the enterprise specialists. At the same time, the specialists recommend up-to-date and market popular VR technologies presently to the teaching team. Secondly, the PBL teaching section lasts for 10 weeks and each chapter in this section is a practical project case whose difficulty and size increase gradually. The

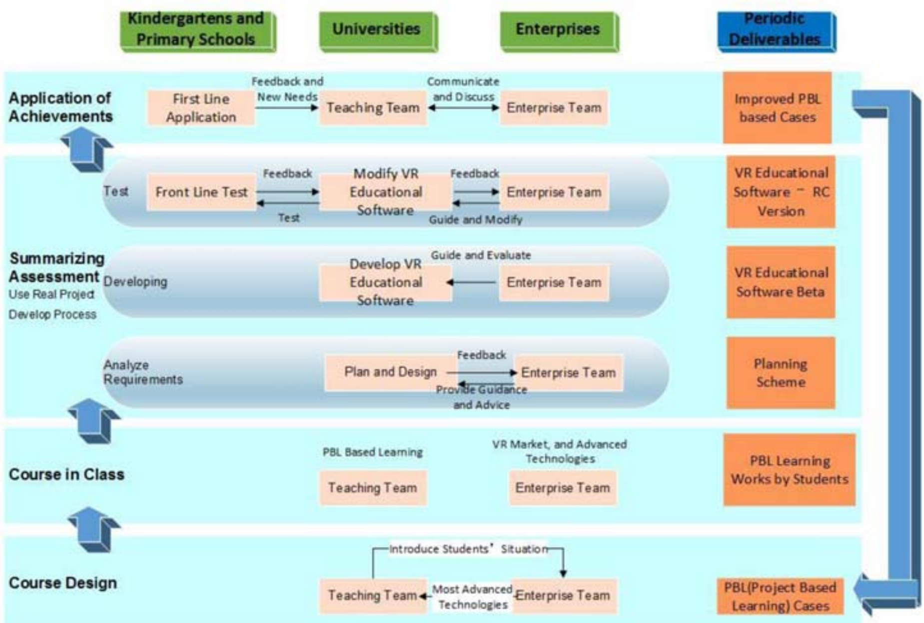


Figure 1. Course design process.

process of realizing these projects is just the procedure of learning the VR technology, training desirable skills, and giving them the sense of achievement. In the following two weeks, the senior specialists from outstanding VR enterprise, who are more excellent in practical technologies, give lectures that bridge the gap between the university and industry. Thirdly, it spends 4 weeks on final summarizing phase of this course. In this phase, it divides the students into several teams and each team develops the VR educational software that is suitable for children in kindergartens or primary schools, which enable them to design VR-aided teaching or learning software according to their real teaching content after they achieve teacher positions. This experience can also enhance their team collaboration and communication skills and give them confidence and sense of fulfillment simultaneously. Finally, their developed VR educational software will be applied for children in kindergartens or primary schools and the feedback for this software will be collected for improvement. The feedback will be used for making the PBL project cases better as well.

3.2. Content and procedure of the course

3.2.1. PBL cases

This course employs unity3D as its platform for developing the VR educational software and designs 5 PBL VR projects for teaching, as illustrated in Figure 2.

The first PBL project is to create a simple 3D scene which includes a terrain that is composed of mountains, valleys, water, trees, flowers, stones, buildings, and environmental elements of lighting, skybox, and fog. This project is meant to familiarize them with Unity3D editor and enable them to construct a simple static 3D scene in it.

The second PBL project includes basic elements of Unity3D. It creates and sets up 3D objects such as cube, sphere, capsule, camera, material, and light source. They are the fundamental technologies that bring the designed 3D scene to display on screen vividly. Furthermore, it creates animation and audio, which enhance the experience in VR.

The third PBL project is about unity script which enables users to interact with the VR application developed by Unity. To begin, it moves and rotates two 3D objects. Then it navigates in VR scene by setting up camera parameters according to users' operation.

The fourth PBL project is adding fire to bullets and controlling tank to shoot bullets and explode. It focuses on the physical components of Unity3D such as rigid body and particle system.

The last PBL project is tank battling game in which my tank walks freely and shoots bullets to enemy tanks, while enemy tanks move on a fixed path and shoots bullets only when their emitted rays reach my tank. If my tank shoots all of the enemy tanks, my tank wins the game. But, if enemy tank shoots my tank, enemy tanks wins the game.

3.2.2. Industrial lecture

The specialists from VR enterprise offer lectures about the developing process of VR software in industry, which has five steps in general, as illustrated in Figure 3.

The first step of developing VR software is to analyze demand and select suitable VR devices such as VR glasses, smart phones, Personal Computers, etc. Then, it comes to prepare art components and construct scenes that can't be employed immediately. Next, it needs to carry out an interactive system of the software that focuses on coding according to the game rules. The last step is to test and release the VR software.

3.2.3. Develop VR educational software

In the summarizing phase, students establish groups where they collaborate to develop the VR educational software. First, they plan and decide the subject of the work which can be applied to kindergartens and primary schools. Next, each member takes on one task they are skilled in. Then, they communicate and collaborate to develop the VR educational software. Finally, they deliver

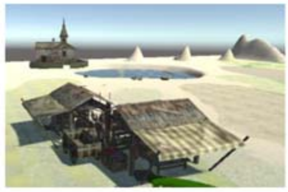
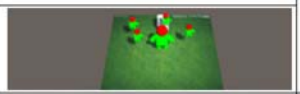
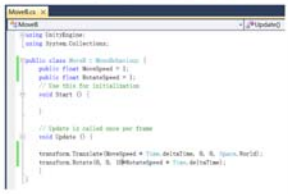
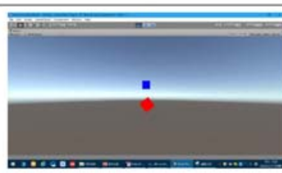
PBL Projects	Objectives	Illustration	Duration
1. Create a simple 3D scene	Create mountains, valleys, flowers, plants, and trees		1 week
	Water, stones, buildings		
	Lighting, skybox and fog		
2. Practice basic elements of Unity3D	Create and setup 3D objects, light sources, materials, cameras, prefabs		1 week
	Animation, audio		
3. Unity script	Script should be bound to the object which will perform the operations. The functions of Start() and Update() are used mostly.		2 weeks
	Object move and rotate script: the blue square moves to the right of the screen while rotating		

Figure 2. PBL teaching cases.

the VR educational software that is practical, and this gives students confidence both in technologies and in communication and collaboration skills.

Three types of the VR educational software containing observation and experience, educational games and scene touring are developed by the preservice teachers who attend this course. In addition, software can run on both Windows system and Android platform. The screenshots and functions of them are shown in the following.

3.2.3.1. Observation and experience type. One group develops VR educational software on the type of observation and experience, with its name "Math 3D". It targets at the 3D graphics knowledge in primary school's Mathematics subject. In this software, children can choose a 3D model from the drop-down list, adjust its parameters, rotate and observe it. The screenshots of this software are shown in Figure 4.

3.2.3.2. VR educational games. Two groups develop VR educational games called "Rubbish Classification" and "Math Calculation", both of which are shown in Figures 5 and 6, respectively.

1. Rubbish Classification

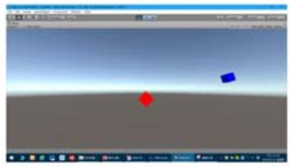
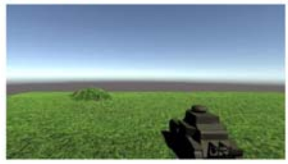
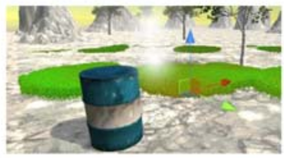
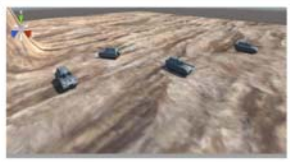
			
	Navigation script: "w" and "s" for move forward and backward; "a" and "d" for left and "right" rotation		
4. Particle system and rigid body collision	Add particle system to barrels		2 weeks
	Shoot bullets and cause explosion		
5. Tanks battling game	Set up scene, import 3D tank models and use First Person Shooting(FPS)		4 weeks
	Write and configure scripts according to the battling rules to control the game progress		

Figure 2. *Continued*

In the "Rubbish Classification" Game, shown in Figure 5, after user perform classification task on a given rubbish, that is, after dragging it into a special rubbish bin, this bin will react by facial expression, sound effect, and the score will be added or subtracted according to whether it is rightly classified. This allows children to learn basic rubbish classification knowledge through this natural way, and cultivate their environmental consciousness.

2. Math Calculation

The "Math Calculation" game, shown in Figure 6, focuses on the calculation of addition, subtraction, multiplication, and division in mathematics subject of primary school. In this game, a helicopter displays a formula and shoots 3 bullets with 3 different answers simultaneously. The user has to choose one answer or bullet before the three bullets touch the floor. If the user chooses one correct answer out of the three in time, the score will increase and be displayed. Otherwise, the score will remain unchanged. After the operation of one formula is completed, it will turn to the next formula by the user clicking "Next one" button.

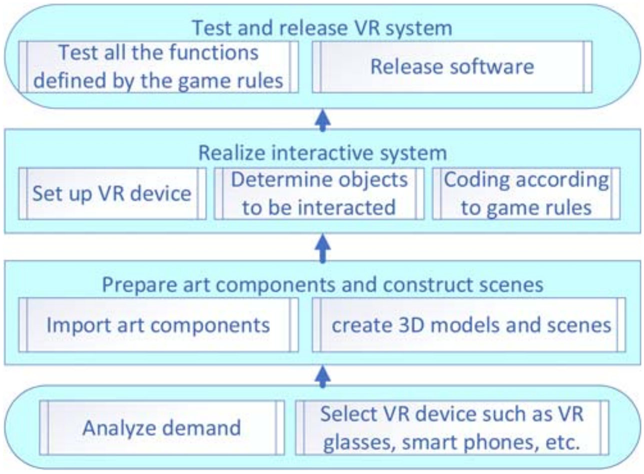


Figure 3. Lecture of the VR software developing process.

3.2.3.3. Sightseeing. One group takes the Forbidden City as the 3D scene for which they develop a touring system that contains two running modes of fixed route and free touring. Furthermore, it provides touring commentaries and appropriate background music, as shown in Figure 7.

In addition to the above works, these students also develop "Test on Romance of the Three Kingdoms", "Famous Paintings Game", and interactive video games of "Ski Introduction" and "Earthquake Prevention".

Figures 4–7 indicate that the VR course model that is composed of PBL-based teaching, specialists' given lectures, and the summarizing VR software development are effective in training preservice teachers' capability of developing the VR educational software.

Figure 4. Math 3D screenshot.

Figure 5. Rubbish classification game.

4. Data analysis

4.1. Participants

The 56 participants in this study are preservice teachers of grade three majored in the digital media technology in an applied university. To analyze the data about them on this research, the authors develop the surveys without sub-divisions that are listed in Appendix and send out by an online survey platform named "wjx". The former two survey questions are about their demographic characteristics which are completed by all participants who attend the course. The survey results indicate that the average age of these participants is 19.74 (SD = 0.58), and 78% of the participants are women. But, the last two questions are descriptive statistics that are carried out as follows. To measure the reliability of their constructs, it performs Cronbach's Alpha by IBM SPSS Statistics Version 26 and the result is .823 which suggests that the constructs have adequate reliability.

Figure 6. Math calculation game.

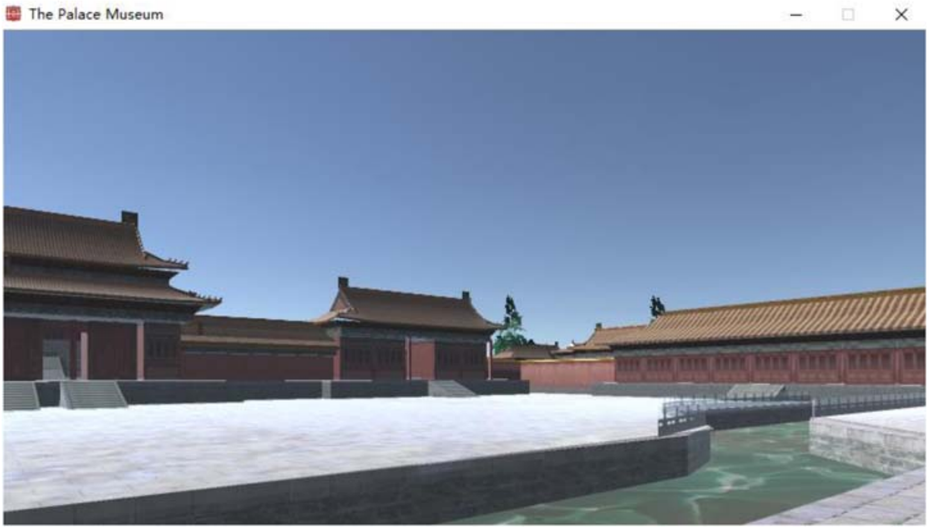


Figure 7. Touring the forbidden city.

4.2. Procedure

The 56 participants are split into two groups with one group for PBL-based VR course experiment and another group for the control condition of non-PBL-based VR course which presents VR technologies without any project cases.

Before the 16 teaching weeks, the participants of the experiment group who will engage in PBL-based VR course complete a pre-test questionnaire of their prior expertise with the VR technology which is listed in the Appendix as the third. The question is about their prior knowledge and developing abilities on the VR technology using Likert response scale from 1(totally disagree) to 5(totally agree). The result is shown in Table 1.

After the 16 teaching weeks, both groups complete an online survey by Likert response with 5 scales for whether they are capable of developing the VR software after the course which is listed in the Appendix as the last question. The survey results are listed in Tables 2 and 3 which are for the experiment group and control group, respectively.

4.3. Measurement and results

4.3.1. Wilcoxon Signed Ranks Test

For the expertise comparison between pre-experiment and post-experiment about the students' expertise to develop the VR software, it uses a non-parametric rank sum test to verify whether these two groups are significantly different, because both samples in these two groups don't conform to normal distribution which are analyzed by Kolmogorov–Smirnov and Shapiro–Wilk test. In addition, it analyzes whether the two groups are statistically significant by IBM SPSS Statistics Version 26 in this study with Wilcoxon Signed Ranks Test since the samples from the two groups are related.

Table 1. Before this VR course, you are familiar with the VR software development.

Options	Selected times	Proportion (%)
Strongly disagree	5	17.86
Disagree	20	71.43
Neither agree nor disagree	3	11.71
Agree	0	0
Strongly agree	0	0
Valid options	28	

Table 2. (Experiment group) After the PBL-based VR course, you are familiar with the VR software development.

Options	Selected times	Proportion (%)
Strongly disagree	1	3.57
Disagree	5	17.86
Neither agree nor disagree	16	57.14
Agree	5	17.86
Strongly agree	1	3.57
Valid options	28	

Table 4 shows the result for Wilcoxon Signed Ranks Test between the pre-experiment and post-experiment according to Tables 1 and 2, respectively. Based on the results in the table, its report is as follows: the PBL-based VR course does statistically significant advancement in students with VR developing expertise ($Z = -4.817$, $p = .000$) because the p-value is less than .05. In addition, the statistic rank of the test is 0, because it is the minimum value of positive and negative ranks shown in the table. Furthermore, this indicates that there's a significant difference between the tests of post-experiment and pre-experiment since it is less than the critical value of 116 (Wilcoxon, 1945). Therefore, it can also be inferred that this PBL teaching method is effective for VR software design.

4.3.2. Control condition and Mann–Whitney U test

Under the control condition of the 16 teaching weeks, there are 28 participants. In this group, it introduces VR course through a traditional method which presents relative knowledge without any project cases. After 16 teaching weeks, this group is asked to complete the fourth survey question in the Appendix that is the same as the experimental group, whose result are in Table 3.

There are four assumptions to use Mann–Whitney *U* test for evaluating the difference between two independent groups. First, the variable should be measured at the ordinal or continuous level. In the research, the ordinal variables include Likert items that the experiment and control groups all agree. Second, the independent variable should consist of two categorical and independent groups with which criteria the two groups are consistent. Third, there should be no relationship between the groups. For example, there must be different participants in each group with no participant being in more than one group. This is also met by both groups. At last, the two variables are not normally distributed that can be measured by Kolmogorov–Smirnov and Shapiro–Wilk test, with which rule is also complied by these two groups. Therefore, it is right to measure the significance about the difference between the experiment and control group according to Tables 2 and 3, which is carried out by IBM SPSS Statistics Version 26 and is listed in Table 5.

Table 5 shows that the significance value is .040, which is less than 0.05. Therefore, it indicates that this PBL-based teaching method for the VR software design is more effective than the traditional approach.

4.4. Discussion

The Wilcoxon Signed Ranks Test before the PBL-based course and after it shows that this PBL-based course is effective in building the VR design and development abilities for preservice teachers. In

Table 3. (Control condition) After the VR course, you are familiar with the VR software development.

Options	Selected times	Proportion (%)
Strongly disagree	3	10.71
Disagree	9	31.24
Neither agree nor disagree	14	50
Agree	2	7.14
Strongly agree	0	0
Valid options	28	

Table 4. (Experiment group) Wilcoxon Signed Ranks Test before and after the PBL-based course.

Ranks				
		N	Mean rank	Sum of ranks
post-experiment–pre-experiment	Negative Ranks	0[a]	.00	.00
	Positive Ranks	26[b]	13.50	351.00
	Ties	2[c]		
	Total	28		

[a]Post-experiment < pre-experiment
[b]Post-experiment > pre-experiment
[c]Post-experiment = pre-experiment

Test statistics[a]

	Post-experiment − pre-experiment
Z	−4.817[b]
Asymp. Sig. (2-tailed)	.000

[a]Wilcoxon Signed Ranks Test.
[b]Based on negative ranks.

addition, the Mann–Whitney Test result from PBL-based course and non-PBL-based VR course shows that the PBL course is much more effective than the non-PBL-based VR course in cultivating their VR educational software development capabilities.

4.4.1. PBL-based course

Compared with Vienna's Industry 4.0 study (Pishtari et al., 2020), this PBL-based course presents some project cases including the most popular technologies before students to develop the realistic VR educational software. But for this Vienna's Industry 4.0 study, its participants simply solve practical problems without any knowledge preparation which is less effective in building basic technologies and in their efficiency of solving practical problems.

In addition to the PBL-based course being applied in engineering education that appears in the paper, it is also applied in a variety of majors such as the medical major. (Stentoft, 2019) proposes the PBL-based course for medical students in the way of group developing projects, instead of example cases. This project-PBL is identical to the PBL-based VR course presented in the paper, which tries to enhance the student engagement and motivation by allowing them to direct their own learning and forcing them to collaborate and regulate learning in settings without a facilitator.

4.4.2. VR software developing course

The Virtual Reality course designed by Ji and Han (2019) use issue-based cases which are similar to PBL cases only, but without the final comprehensive VR software design section that is proposed in this study.

Table 5. Mann–Whitney Test between the experiment and control group.

Ranks				
	Group	N	Mean rank	Sum of ranks
Time	Experiment	28	32.57	912
	Control	28	24.43	684
	Total	56		

Test statistics[a]

	Time
Mann–Whitney U	278.000
Wilcoxon W	684.000
Z	−2.052
Asymp. Sig. (2-tailed)	.040

[a]Grouping Variable: group.

Kang and Kim (2020) provides a study on educational courses dealing with VR content production because it finds the VR-based content industry has significantly grown in many areas, but without sufficient skilled human resources who can develop them. Therefore, it designs an educational model based on cooperative projects from industrial demand customized with industrial companies. Furthermore, it evaluates the effectiveness of the training courses by estimating the operation results of the courses. This VR course design model is similar to the PBL-based VR courses presented in the paper in that it cooperates also with industrial enterprises. However, there is a difference between these two models since the comprehensive VR educational software development only appears in the PBL-based VR course presented in the study.

5. Students' expectation of future VR course

After analyzing the PBL-based VR course design, the study goes a step towards these students' opinion on what other VR technologies they want to learn, the subjects they want to develop for, and the types of the VR educational software they want to develop in the future. The following surveys are prepared and sent by "wjx" as well.

5.1. Survey on other VR technologies they are interested in

The technologies that students want to further study concentrate on unity advanced operations (24%), programming (17%), animation (14%) and AR (augmented reality) (7%), etc., as Figure 8 shows. The project will use these data in the course of the next round.

5.2. Survey on subjects they want to develop VR educational software for

The subject students want to develop the VR educational software for covering a variety of subjects including mathematics, language, science, English, history, geography, biology, art, and so on. Nevertheless, their interests focus on mathematics (38%), language (28%), and science (including geography and biology, 16%) which provide a good understanding on what subjects students may develop in the future, as shown in Figure 9.

5.3. The types of the VR software they want to develop

The VR educational software types that students want to design include observation type (28%), game type (24%), participation and exploration type (17%), scenery touring type (10%), immersive movies (3%), etc., as shown in Figure 10. It provides a basis for what forms of the VR educational software students like to develop in the future.

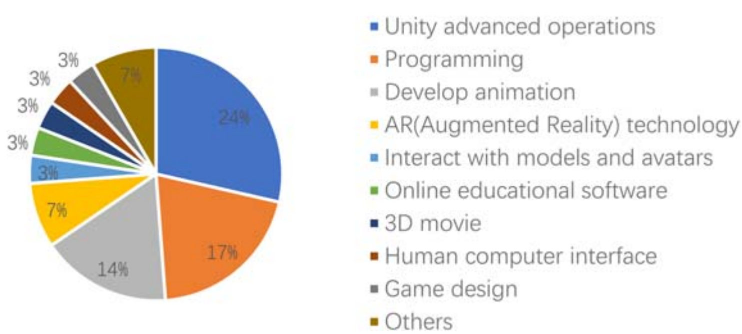


Figure 8. The technologies that students want to study.

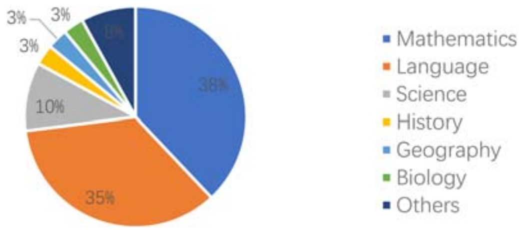


Figure 9. The subjects that these students want to develop the VR educational software for.

5.4. Summary of findings and the interpretations

It can be seen from Figures 8 to 10 that these students have built ideas about the technologies that want to learn further, the subjects that want to develop for, and the types of the VR teaching software they want to make. All of these show that they are very likely to continue developing the VR educational software in their future teaching work.

6. Conclusion

This work designs a PBL-based VR course for preservice teachers in applied universities to cope with smart education, ubiquitous learning, children's learning characteristics of visual media, and the coming long-term isolated life caused by the coronavirus. The course includes PBL project cases in class teaching stage, practical lectures given by enterprise experts, and the summarizing part of developing the practical VR educational software for children in kindergartens and primary schools.

Through the PBL project cases and the enterprise's technical lectures, students are able to develop the VR educational software for children that conforms to their visual learning characteristics. To validate the teaching model of PBL-based VR course, it performs two experiments on the VR software development abilities of the participants: the first experiment indicates the PBL course model is effective in training their VR software design abilities, and the second experiment under control condition shows this course model is better than traditional non-PBL course model.

In addition, it conducts a survey on students' capabilities of this course which includes the technologies they are interested in, and the subjects and the types of the VR software they want to develop. The survey indicates that this VR course has enabled the preservice teachers to build the VR software developing ideas in a certain degree, which facilitate them to develop the VR educational software-related to their teaching subjects in the future.

In the future work, it will investigate the needs for the VR educational software in pre-schools and primary schools, and guide the students in this course to develop a corresponding needed for the VR educational software.

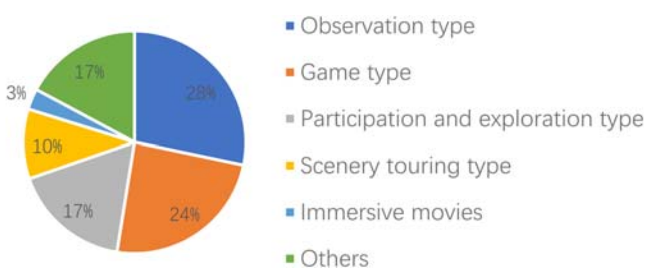


Figure 10. The types of the VR teaching software that students want to make.

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Appendix

1. How old are you when you attend the VR course on autumn term?
    A. 17
    B. 18
    C. 19
    D. 20
    E. 21
    F. 22
    G. 23
    H. 24
    I. 25
    J. 26
2. What is your gender?
    A. Male
    B. Female

3. Before attending the VR course on autumn term, your expertise about developing VR software is excellent, do you agree on this claim?
   A. Strongly disagree
   B. Disagree
   C. Neither agree nor disagree
   D. Agree
   E. Strongly agree
4. After attending the VR course on autumn term, your expertise about developing VR software is excellent, do you agree on this claim?
   A. Strongly disagree
   B. Disagree
   C. Neither agree nor disagree
   D. Agree
   E. Strongly agree