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PAPER

Effects of Inquiry-Based Teaching on Learning Efficiency in an Augmented Reality Environment

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ABSTRACT

Virtual reality (VR) creates a realistic learning environment to immerse users, meet scenario requirements and natural interaction of learning media, and offer learners a highly immersible virtual-real mixed environment. To analyze the effects of inquiry-based teaching on learning efficiency of learners in an augmented reality (AR) environment, a questionnaire survey was given to 278 undergraduates in 4 grades from 6 universities in Wuhan. Contextual learning theory and flow theory were used as the theoretical basis to analyze the effects of the four aspects of inquiry-based teaching on learning efficiency of learners in AR environments. Differences in learning efficiency caused by different degrees of familiarity of learners with AR equipment were measured using analysis of variance (ANOVA). Results show that Cronbach's α of the questionnaire, which was developed based on existing research questionnaires, is 0.909 and the KMO value is 0.869, indicating that the questionnaire has very good reliability and validity. Posing problems, collecting evidence, and proposing explanations for an inquiry-based teaching mode have significant influences on learning efficiency of learners: under 5%, 1%, and 1% levels, respectively. The degree of familiarity of learners with AR equipment has significant influence on learning efficiency at the 0.01% level. Results herein provide important guidance for promoting the fusion of AR and teaching activities, enriching the application of scientific teaching with AR technology in universities, and designing and developing ways to use AR teaching resources in different disciplines.

KEYWORDS

AR, inquiry-based teaching, learners, learning efficiency, variance of analysis, questionnaire technology

1 INTRODUCTION

The rapid pace of today's scientific and technological developments have shifted, and continue to shift, the lives of everyday people. With the rapid development of the internet and the accessibility brought about by mobile surfing, informatization and intelligence have become burgeoning topics in education research. Technology

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and teaching are deeply intertwined in the discipline, leading to the development of many emerging teaching modes. Traditional teaching modes can no longer meet students' great demands for knowledge in today's information era. Building a virtual 3D environment based on augmented reality (AR) technology combines virtuality and reality to stimulate student interests and enthusiasm, thus improving their learning efficiency and promoting pedagogical reforms. AR is a high-level and novel technology that adds relevant graphs by using orientation and perspective through vivid camera videos and creates a new generation of technological means in the "seamless" fusion between real-world and virtual-reality data. The main goal of AR technology is to embed the virtual-reality (VR) world into the real social work for interaction. AR technology is applied to practical teaching activities, where it has been proven to improve students' sense of participation and immersion by providing multi-sensory perceptual effects. Moreover, AR technology helps students better understand and apply their lessons by providing a more real teaching scenario. Obviously, AR technology helps students enjoy a more autonomous and interactive cooperative learning experience in the VR integrated scenario. The technology is poised to create new teaching methods and modes upon its integration with subject teaching.

A new educational idea for universities emphasizes the dominant role of students and the guiding role of teachers. It develops teaching by utilizing both the enthusiasm of students and an education-oriented core philosophy. The fusion of AR technology and subject teaching fits with such a new educational idea. Concerns about the learning efficiency of students have prompted research into the degree of the development of students' subjectivity. Moreover, teaching supported by AR technology is a double-edged sword as far as learning efficiency. Although the learning efficiency of students in AR technology–supported teaching is obviously higher than that receiving traditional teaching, multi-sensory stimuli may increase the cognitive loads of students and distract them, resulting in poor learning. Thus, learning efficiency of students must be considered in studies on integrating AR technology and subject teaching. In the teaching process, teachers must try to stimulate and keep students' desire for inquiry and provide students opportunities for exploration. Teachers shall also serve as instructors and guide students to explore the results of problems through problem exploration, help them acquire knowledge and learn exploration, stimulate their curiosity of exploration, and promote the positive exploration of knowledge. During exploration, students or teams formulate experimental hypotheses, design experimental schemes, and finally get experimental conclusions. The exploration process of students is also a process of knowledge acquisition, and knowledge is the result of exploration. After finishing the exploration, students communicate mutually and summarize their experimental conclusions, ultimately having their learning efficiency largely influenced by the process.

2 THEORETICAL BASIS AND HYPOTHESIS DEVELOPMENT

2.1 Theoretical basis

Ackermann [1] analyzed the constructivism teaching theory proposed by psychologist Jean Piaget. On one hand, the constructivism learning theory believes that knowledge acquisition is produced by the interaction between external stimuli and internal processing of learners. It describes learning as a process of knowledge acquisition where students acquire knowledge through meaningful construction in the scenarios built by teachers by using learning materials and primary knowledge experiences. In this process, the guidance of teachers is indispensable. On the other hand, constructivism also emphasizes the dominant role of students, the need for student-centered teaching activities, and the combination of learning and practice. Constructivism refers to learner-centered learning. The psychological process of learning includes learning, thinking, forgetting, and verbal memory. Therefore, teachers can predict or test when students are prepared to learn new concepts or new skills. This underscores that education should be prepared, based on developments of students, and that teaching is a process of exploration and integrating new materials rather than a process of rote memorization for learning materials or knowledge inculcated by teachers or textbooks.

Taylor [2] believed that humanism emphasizes studying the psychology of human based on nature of human beings, advocates creativity of developers, and realizes self-value of individuals. Teachers are expected to provide students learning tools or means rather than teaching knowledge, while the rest is decided by students themselves. From this perspective, humanism concerns the most intrinsic problem of learning, i.e., the relationship between learning and learners, and between individual achievements and social reform. Learning based on technology has become an indispensable part in the educational experiences of students. By expanding learning context and providing learning experience opportunities of self-guidance, self-stimulation, and self-assessment, technological advancements make learners the physical product of promoting experiential cognitive modes and, simultaneously, the cognitive product of promoting reflective cognitive modes. Nevertheless, it is the method, not the technology, that determines the effective use of computers in improving meaningful learning. This is true for all modern technologies: from the internet to the mobile phone, technology is only the means that connects human beings. The humanistic learning theory believes that the use of technologies promotes independent, meaningful, and experiential learning.

2.2 Hypothesis development

Inquiry-based teaching is a more effective education mode. Because of inquiry-based teaching of university courses, university students no longer receive learning blindly. Once launched, inquiry-based teaching promotes changes in learning modes of university students to some extent and helps university students improve the quality of their deep ideology. Scholars worldwide have discussed the meaning of inquiry-based teaching and making inquiry-based teaching. Early scholars found that inquiry-based teaching is both conducive to improving the academic performances of primary and secondary school students and is beneficial for them to understand and master the scientific mode and train in scientific psychology.

This contrasts the insights outlined by many researchers. Specifically, Oliver et al. [3] conducted a comparative analysis on scientific literacy and inquiry-based teaching of 15-year-old students from 6 Organisation for Economic Co-operation and Development countries that participated in the Program for International Student Assessment (PISA) in 2015. The study's analysis showed that students who used the inquiry strategies frequently in class always showed a lower scientific literacy among their counterparts from the other countries and that the frequency of teachers' instruction and inquiry-based teaching strategy had a strong positive relationship with scientific literacy of the students.

Powell-Moman et al. [4] discussed the effects of a 2-year professional-development plan on self-efficacy of teachers in inquiry-based teaching. Results demonstrated that inquiry-based teaching improved self-efficacy and that teachers paid more attention to depth of contents after finishing the course. Scott et al. [5] pointed out that inquiry-based education improves the critical-thinking skills of learners and their ability of flexibly when solving problems. Silm et al. [6] investigated 497 teachers from 10 countries and found that teachers with higher efficacy before training were more positive towards inquiry-based teaching. Inquiry-based teaching is an appropriate way to promote the improvement of the training teaching effect for teachers.

Chichekian et al. [7] argued that the success of inquiry-based teaching was decided by the teachers' understanding level on such teaching modes. Shih et al. [8] proposed a digital support system using mobile devices and wireless communication and guided primary students to make mobile exploration learning in social science activities. Results showed that an inquiry-based teaching mode developed significant positive effects for students in learning. Almuntasheri et al. [9] carried out a teaching experiment on 167 6th-grade students in Saudi Arabia. Students' understanding and explanation to density were evaluated through one-way analysis of variance (ANOVA) and repeat analysis. Results showed that compared with teacher-instruction conditions, students receiving inquiry-based teaching achieved significantly higher conceptual understanding and explanation of density. Teig et al. [10] demonstrated that inquiry-based teaching had a curvilinear relationship with students' performance in science, which showed a positive correlation with academic achievements. However, the frequency of inquiry-based activities presented a negative correlation with academic achievements. Peters-Burton et al. [11] pointed out that in-service teachers may change their opinions on inquiry-based teaching at all research stages and that they also kept a relatively high self-efficiency.

Onyema et al. [12] demonstrated that in the context of the close relationships between students and mobile devices such as smart phones, tablet PCs, and laptops, these mobile devices often have appealing characteristics, applications, and functions that stimulate learners to connect to internet and exercise their critical-thinking skills. The effectiveness of this inquiry-based learning method can be improved to a large extent through mobile technology. Data from Ješková et al. [13] showed how inquiry-based teaching significantly improved the exam performance of learners and that it obviously increases learning efficiency at large. Kandil et al. [14] discussed the effects of inquiry-based teaching focusing on paper-folding activities on geometric reflection symmetry and self-efficacy of 7th-grade students and showed that inquiry-based teaching focusing on paper-folding activities had significantly positive effects on their geometric reflection symmetry and self-efficacy.

Richardson et al. [15] investigated inquiry-based teaching and the belief in self-efficacy of students and teachers and found that an inquiry-based teaching mode improves the efficacy of pre-service teachers. Nadelson et al. [16] discovered that inquiry-based teaching, under the concept of STEM philosophy, promotes learning efficacy. Wang [17] perfected the teaching mode of financial management using online and offline inquiry-based teaching. These practices proved that the proposed new teaching method could help students increase learning efficiency and strengthen their problem-solving abilities. Following existing studies, different studies have different interpretations to inquiry-based teaching. A review on the current state of the literature shows inquiry-based teaching to include mainly four aspects: namely, Posing Problems, Collecting Evidence, Proposing Explanations, and Evaluating Explanations. Hence, four hypotheses are proposed:

H1: Posing problems can improve learning efficiency of learners significantly.
H2: Collecting evidence can improve learning efficiency of learners significantly.
H3: Proposing explanations can improve learning efficiency of learners significantly.
H4: Evaluating explanations can improve learning efficiency of learners significantly.

3 METHODOLOGY

3.1 Questionnaire design

An inquiry-based teaching mode differs from traditional teaching modes, as it pays more attention to help learners make collaborative and independent inquires. Many researchers have since discussed the collaborative inquiry-based teaching mode and proposed and reconstructed appropriate collaborative inquiry-based teaching modes in their own studies. Hence, a questionnaire scale of the Effects of Inquiry-based Teaching on Learning Efficiency of Learners in an AR Environment was designed based on these existing studies. Part I provides the general information analysis of respondents, including five questions on gender, university, subject, grade, and degree of familiarity with AR devices. Part II measures inquiry-based teaching in an AR environment. A questionnaire composed of 29 Likert-scale questions was developed following Aydeniz et al. [18]. This questionnaire mainly used the self-efficacy of inquiry-based teaching of primary school teachers. The consistency coefficient was 0.97, indicating that the scale has robust reliability.

Following Erickson [19] and Tan et al. [20], this study determined that the innovative mode of inquiry-based teaching has four links: Posing Problems, Collecting Evidence, Proposing Explanations, Evaluating Explanations. These four links correspond to 5, 4, 4, and 4 questions, respectively. Finally, Part III measures learning efficiency and applies 4 questions on self-efficiency taken from Tsai et al. [21].

3.2 Respondents

Hubei is a Chinese province with a relatively developed higher education portfolio and thus has good higher education resources. In particular, the province has invested considerable funds to construct a VR training base for colleges and universities in recent decade. A questionnaire survey was carried out during the second semester of the academic year 2022–2023 in 6 undergraduate universities (Wenhua College, Wuchang Institute of Technology, Wuhan University, Jianghan University, Hubei University, and Hubei University of Technology) located in Wuhan, Hubei Province. The questionnaire was produced using the common questionnaire survey website (www.wjx.cn) in China and was sent to these universities through he study's team members. The questionnaire survey lasted for one week. A total of 368 questionnaires were collected, and 278 were determined to be valid, reflecting an effective recovery rate of 75.54%. Details are listed in Table 1.

Table 1. Descriptive statistical results of respondents

Name	Options	Frequency	Percentage (%)	Cumulative Percentage (%)
Gender	Male	167	60.07	60.07
	Female	111	39.93	100
Subject	Theory of Law	4	1.44	1.44
	Regional Economics	14	5.04	6.47
	Chinese Philology	35	12.59	19.06
	Environmental Engineering	66	23.74	42.81
	Civil Engineering	70	25.18	67.99
	Urban and Rural Planning and Design	54	19.42	87.41
	Building Technology Science	35	12.59	100
Grade	Freshman	37	13.31	13.31
	Sophomore	74	26.62	39.93
	Junior	121	43.53	83.45
	Senior	46	16.55	100
Universities	Wenhua College	39	14.03	14.03
	Wuchang Institute of Technology	58	20.86	34.89
	Wuhan University	51	18.35	53.24
	Jianghan University	34	12.23	65.47
	Hubei University	27	9.71	75.18
	Hubei University of Technology	69	24.82	100
Degree of familiarity with AR devices	Frequently used	17	6.12	6.12
	Moderate	112	40.29	46.4
	Familiar	76	27.34	73.74
	No contact	73	26.26	100
Total		278	100	100

Table 1 shows that male respondents account for about 60.07% of the total respondents, which is a high proportion of the study's sample. Most respondents majored in engineering and were also juniors, accounting for 43.53%. The proportion of respondents was relatively balanced among the six universities. The percentage of those who were moderately familiar with AR devices was also relatively high (40.29%).

4 RESULTS ANALYSIS

4.1 Reliability and validity Tests

Reliability and validity are often used during construction, evaluation and measurement. Essentially, reliability is the degree of reliability of measuring data and conclusions. Validity ensures that the measuring tools indeed can reflect the measuring contents.

Table 2. Reliability test results

Type of Variables	Name of Variables	Number of Measurement Problems	Cronbach's α	Cronbach's α
Independent variables	Posing Problems	5	0.914	0.909
	Data Gathering	4	0.884	
	Proposing Explanations	4	0.886	
	Evaluating Explanations	4	0.957	
Dependent variables	Learning efficiency	4	0.928	

Table 2 shows that the reliability coefficient is 0.909 (>0.9), indicating that the research data has very high reliability. The Cronbach's α of four independent variables and one dependent variable is also higher than 0.8.

Table 3. Validity test results

Question No.	Factor-Loading Coefficients					Communality (Common Factor Variance)
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	
A1	0.801	0.157	0.088	0.129	0.105	0.701
A2	0.763	0.112	0.096	0.125	0.062	0.624
A3	0.868	0.204	0.08	0.103	0.077	0.818
A4	0.838	0.262	0.141	0.12	0.106	0.816
A5	0.853	0.161	0.162	0.137	0.052	0.802
B1	0.097	0.114	0.086	0.879	0.163	0.829
B2	0.182	0.117	0.127	0.87	0.09	0.828
B3	0.127	0.063	0.09	0.92	0.069	0.879
B4	0.129	0.093	–0.005	0.629	0.194	0.459
C1	0.069	–0.039	0.09	0.251	0.823	0.754
C2	0.099	0.005	0.102	0.176	0.844	0.763
C3	0.064	0.102	0.047	0.059	0.919	0.864
C4	0.137	0.381	0.044	0.066	0.765	0.756

(Continued)

Table 3. Validity test results *(Continued)*

Question No.	Factor-Loading Coefficients					Communality (Common Factor Variance)
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	
D1	0.225	0.885	0.137	0.149	0.056	0.877
D2	0.253	0.887	0.173	0.078	0.109	0.899
D3	0.201	0.877	0.193	0.127	0.087	0.871
D4	0.211	0.886	0.222	0.092	0.105	0.898
Y1	0.079	0.206	0.865	0.069	0.055	0.805
Y2	0.151	0.148	0.891	0.071	0.103	0.854
Y3	0.07	0.134	0.881	0.084	0.081	0.813
Y4	0.216	0.15	0.872	0.071	0.043	0.837
Characteristic root (before rotation)	7.619	2.83	2.397	2.073	1.828	–
Variance interpretation rate % (before rotation)	36.280%	13.478%	11.413%	9.871%	8.703%	–
Cumulative variance interpretation rate % (before rotation)	36.280%	49.758%	61.171%	71.043%	79.746%	–
Characteristic root (after rotation)	3.8	3.598	3.338	3.025	2.986	–
Variance interpretation rate % (after rotation)	18.094%	17.133%	15.895%	14.404%	14.219%	–
Cumulative variance interpretation rate % (before rotation)	18.094%	35.227%	51.122%	65.527%	79.746%	–
KMO value	0.869					–
Bartlett's sphericity test value	4978.166					–
df	210					–
p value	0					–

Table 3 shows that communality values of all research items are higher than 0.4, indicating that information of all research items can be extracted effectively. Additionally, validity was verified through KMO and Bartlett's sphericity test. The KMO value is 0.869 (>0.6), indicating that information of data can be extracted effectively. Variance interpretation rates of 5 factors are 18.094%, 17.133%, 15.895%, 14.404%, and 14.219%, respectively. The cumulative variance interpretation rate after rotation was 79.746% > 50%, implying that information of research items can be extracted effectively.

4.2 Linear regression results

Table 4. Linear regression results

Variables	Standardization Coefficient	*t*	*p*	VIF
Constants	–	0.313	0.755	–
Posing Problems	0.238	2.423	0.016*	1.386
Collecting Evidences	0.547	6.665	0.000**	2.404
Proposing Explanations	0.473	5.609	0.000**	2.294
Evaluating Explanations	0.226	1.318	0.189	1.321
R^2	0.952			
Adjusted R^2	0.951			
F	F (4,273) = 1357.827, p = 0.000			
D-W value	1.932			
$^*p < 0.05$, $^{**}p < 0.01$				

Notes: *significance under the 5% significance level; **significance under the 1% significance level.

Table 4 shows that R2 of the model is 0.952, indicating that 4 independent variables can interpret 95.2% of changes of dependent variables. According to the *F* test of the model, the model passes through the *F* test (F = 1357.827, p = 0.000, <0.05). This means at least one of four independent variables may affect the dependent variable and that the D-W value is near 2. This also means that the model has no autocorrelation and there is no association among sample data; thus, the model is relatively good.

H1 is supported. Posing problems can improve learning efficiency of learners significantly. This is mainly because the first step of inquiry-based teaching is for teachers to pose problems. In universities, teachers generally have a high education background and help students to generate puzzles based on a teaching scenario, propose scientific problem that they want to explore, and forward solvable problems within the ability of students and the existence of their exploration values. If students have limited cognitive ability, teachers then guide students to analyze and review, discuss collaboratively, and determine the problem that has to be explored. Therefore, the inquiry process starts from when teachers propose problems scientifically that students can solve—which is the impetus of thinking activities. Based on the proposed problem, students can discover blind spots and gaps in the knowledge and activate their thinking. The inquiry problem is then based on existing knowledge and life experiences of students and is thus solvable and scientific. Teaching scenarios can be used to present problems, because putting problems in the teaching scenario can stimulate stronger inquisitive desires by the students. In inquiry-based teaching of subjects in different universities, teachers then master teaching key and difficult concepts according to teaching content and targets, design the problem situation that can help students to generate cognitive conflicts, stimulate students' desire for knowledge, and help them discover and pose problems independently. Teachers and students can then discuss and determine problems with inquiry value together.

H2 is supported. Collecting evidence can improve learning efficiency of learners significantly. This is mainly because students can positively collect evidence after comprehending the problems proposed by teachers. They then take the initiative to think and explore in solving the scientific problem, analyze the contents, determine the quantity and methods for evidence collection, and gain valuable evidence through different pathways and forms, such as a field survey, controlled experiment, or literature review. Because evidence is the basis for inquiry activities and the orientation of thinking activities, university students can thus implement inquiry activities according to ideas and methods of evidence acquisition. There are diversified pathways for university students to acquire evidence; these include using surveys, performing experiments, and researching the history of professional science or scientific research results, factual data, etc. All pathways require comparison and classification of comprehensive uses, comprehensive analysis, creation of summaries, and other high-order scientific thinking methods. In inquiry-based teaching for professional courses of university students, teachers must attend to the process by which students acquire evidence, design the principal line of problems, quickly recognize students' understanding of professional knowledge along with their handling and solving situations of the problem, and guide students to solve the problems using appropriate scientific thinking methods and logical reasoning typically employed by the discipline.

H3 is supported. Proposing explanations can improve learning efficiency of learners significantly. When proposing explanations, university students review and analyze evidence, connect it with existing knowledge and experiences, reason and demonstrate with scientific evidence, summarize observations and results, employ other thinking methods, and then form logical scientific explanations to solve scientific problems. Given the problem proposed by teachers, the core of inquiry activities is that university students form their own explanations, which is an external expression of thinking activities. By making scientific explanation to problems, university students can show their own thinking process, especially their scientific reasoning process, including the process of evidence acquisition and process of proving preliminary conclusions based on evidence. In inquiry-based teaching of disciplines in universities, teachers focus on the explanation process of university students; strengthen their awareness of evidence; guide them in reasoning and demonstration based on facts and evidence; establish relationships among facts, evidence, and conclusions; independently build the significance of professional knowledge; and improve logical thinking and language-expression ability.

H4 is proven false and is thus unsupported. Evaluating explanations cannot significantly improve learning efficiency of learners. This seems to contrast with existing studies to some extent. Potential reasons can be discovered after a careful analysis. Students have to reflect whether they have formulated a reasonable inquiry plan and also collected reliable evidence strictly according to the plan when Evaluating Explanations. However, Posing Problems, Collecting Evidence, and Proposing Explanations already accounts for about 90% of teaching time for university students. Thus, there is insufficient time for Evaluating Explanations. Teacher-student evaluations and student-student evaluations then mainly end up as questionnaire forms. Moreover, Evaluating Explanations, which is the self-evaluation of students, is a correction of inquiry activities and is a regulation of thinking activities. Generally, university students give high scores when performing self-evaluation, without further reflection on the important role of critical thinking. This conclusion should also inspire university teachers to pay attention to self-evaluation of students during teaching in a VR environment, guide students to criticize and doubt, train critical thinking, help students improve their self-reflection and self-control, and control their thinking activities. These ultimately enable students to correct and perfect explanations and obtain a correct understanding on core professional concepts, principles, and fundamentals of subjects.

4.3 Analysis of variance

Table 5. Results of analysis of variance

Learning efficacy	Degree of familiarity with AR devices (mean±SD)				F	p
	Frequent and skilled use (n = 17)	Very (n = 112)	Moderate (n = 76)	No contact (n = 73)		
	5.06±0.72	4.54±1.10	4.03±1.05	4.54±1.03	6.429	0.000**
$^*p < 0.05$, $^{**}p < 0.01$						

Notes: *significance under the 5% significance level; **significance under the 1% significance level.

Table 5 shows that learners who use AR devices frequently have higher learning efficiency than others. This is mainly because frequency and skilled use of AR technology can improve learning enthusiasm of students. Using AR technology–based learning, students can make real-time interaction with AR, have real-time communication with teachers, and realize student-student mutual help and collaborative learning. By enhancing the authenticity of this realistic scene, AR improves the sense of immediacy of students in interactive situational teaching and generates virtual objects by using computers and helps students build knowledge positively through contact and changes with AR, ultimately stimulating their learning motivations. Application in AR teaching can effectively stimulate learning motivations, strengthen learning experiences by creating learning scenarios, and help students perceive psychological immersion, thereby helping them realize the goal of learning. The application advantages of AR can provide students an extensive learning space where they can learn various resources, at any time and any place, and review it at any time, thus realizing the goal of understanding and consolidating knowledge.

University teachers need to pay attention to students' familiarity with AR devices. University teachers must comprehensively learn the constructivism learning theory and explore application schemes of the designed and developed AR resources in teaching different subjects in universities by analyzing teachers' and students' needs and teaching contents. This can, to some extent, innovate inquiry-based teaching of subjects in universities and promote the development of AR technology combined with teaching in universities.

5 CONCLUSIONS

AR technology connects the real world and virtual world to allow learners to operate simulation models in the virtual environment and acquire new knowledge through superimposed user experiences. The application scope of AR technology in the field of higher education remains ever increasing with the continuous improvement of AR technology, thus facilitating development of information-based teaching. AR educational resources have also been developed continuously. However, AR technology's influence on learning efficiency of learners in an inquiry-based teaching mode of universities still has to be further analyzed. In this study, a questionnaire survey was administered to 278 undergraduates from 6 universities in Wuhan, Hubei Province, where the effects of four links of inquiry-based teaching in AR environment on learning efficiency of learners were measured. Moreover, differences in learning efficiency according to different degrees of familiarity with AR devices were analyzed. Some major conclusions were drawn. First, the Cronbach's α and KMO value of the questionnaire were 0.909 and 0.869, respectively. Second, Posing Problems, Collecting Evidence, and Proposing Explanations using an inquiry-based teaching mode all promote learning efficiency of learners. Third, degree of familiarity with AR devices shows significant differences in learning efficiency of learners ($F = 6.429$, $p = 0.000$). It is therefore suggested to further discuss educational resources developed based on AR technology, the short- and long-term dynamic relations between AR technology and learning outcome, and differences in AR-assisted teaching effects among different grades.

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