

Chinese K-12 Teachers' Acceptance of Augmented Reality based on Technology Acceptance Model

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Abstract—As the means to display abstract concepts and provide interactive experience, augmented reality (AR) has shown unparalleled superiority in educational domain. A sample of 213 Chinese K-12 teachers participated in our study. The results show that: 1. The external environment, self-efficacy, perceived usefulness, and perceived ease of use directly affect the teachers' intention to use AR; 2. System characteristics indirectly affect the teachers' intention to use AR through intermediary variables. 3. Perceived ease of use indirectly affects the teachers' intention to use AR by affecting perceived usefulness and self-efficacy. The research has certain theoretical significance for AR application in teaching.

Keywords—AR, K-12 education, technology acceptance model

I. INTRODUCTION

Augmented reality (AR) technology can overlay virtual information on the real world through enhanced components, which creates an interactive environment for users [1]. According to Azuma et al. [1], AR has three main characteristics: virtual reality fusion, human-computer interaction, and three-dimensional registration, which make AR show great potential in the educational domain by visualizing the abstract content and presenting the invisible or dangerous experimental phenomenon [2]. In the horizon report released by the New Media Alliance (NMC), AR and VR are the key technologies that have attracted much attention in the past decade, which instruct the new informatization reform of the future elementary education.

As the organizers and instructors of classroom activities, teachers are the important implementers and promoters of educational technology in practical teaching. Their information literacy, personal characteristics, and educational needs have a certain impact on the application and promotion of AR technology in education. After training by the national training program and education informatization program, teachers' attitude, cognition, and self-efficacy of AR need to be discussed. It is meaningful to explore which factors would affect teachers' acceptance and adoption of AR? What are the relationships between these factors?

This study used TAM3 model to explore K-12 teachers' acceptance of AR technology in China. The second part summarizes the application of TAM model in the field of educational technology. The third part puts forward the

research hypothesis based on the existing research results. The fourth part verifies the model through data collection and analysis. Finally, the research results are discussed.

II. LITERATURE REVIEW

A. TAM Model and its Application in Educational Technology

Technology Acceptance Model (TAM) was proposed by Davis (1985), which is widely used to study the user's acceptance of a certain information technology. Based on the theory of rational behavior in social psychology, this model points out that perceived usefulness and perceived ease of use directly affect the user's intention to use technology [3]. After that, several studies tried to add other variables to expand the TAM model. Venkatesh and Davis (2000) developed the expansion model TAM2, which uses social influence and cognitive process to explain users' intention to use technology [4]. A few years later, Venkatesh and Bala (2008) integrated TAM2 to form TAM3 by including four additional external variables: individual difference, system characteristics, community influence, and convenience. These external variables affect users' perceived usefulness and perceived ease of use, and thereby affect their use intention and use behavior [5]. The TAM3 model reveals why and how users adopt a certain information technology from an overall perspective.

Currently, researchers mainly utilized the TAM model to explore teachers' acceptance of the application of emerging educational technology. For example, Emin ibili et al. [6] studied the acceptance of mathematics teachers on an AR tutoring system and found that teachers' perceived ease of use of AR system directly affected their perceived usefulness, and their use attitude directly affected their use intention. Chen et al. [7] revealed that teachers' self-efficacy, subjective norms, system quality, information quality, and service quality of VR learning system directly affect teachers' perceived usefulness, perceived ease of use, and perceived entertainment. With regard to teachers' intention and attitude toward virtual reality, the effect of perceived entertainment is more significant. Yuen and Ma [8] used TAM3 model to investigate the technology acceptance of 152 primary and secondary school teachers, the results showed that perceived usefulness has little effect on the determination of behavioral intention, while perceived ease of use has a greater influence,

and subjective norms and self-efficacy affect behavioral intention through perceived ease of use. Wong [9] surveyed 185 primary school teachers in Hong Kong and concluded that the perceived usefulness and ease of use of technology had no significant impact on behavioral intention, while convenience was a major determinant.

From the above studies, the findings of different studies are mixed. For example, most studies showed that perceived usefulness and perceived ease of use are the key factors to predict behavioral intention. However, Wong's study was opposed to this finding, and Yuen's study also indicates that perceived usefulness has little effect on behavioral intention. Technology acceptance may be influenced by different technological and cultural backgrounds, resulting in different research conclusions. Therefore, this study believes that the existing research conclusions cannot be directly applied to teachers' acceptance of the application of AR in K-12 education in China, and new discussions should be carried out according to the technical characteristics and educational and cultural background.

III. RESEARCH MODEL AND RESEARCH HYPOTHESIS

As shown in Figure 1, we designed the conceptual model by combining TAM3 model, and put forward 10 research hypotheses.

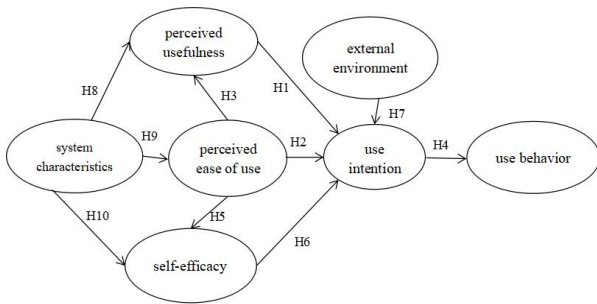


Fig 1. Schematic diagram of the research model

Hypothesis 1: Teachers' perceived usefulness of AR positively affects their use intention.

Hypothesis 2: Teachers' perceived ease of use of AR positively affects their use intention.

Hypothesis 3: The perceived ease of use positively affects perceived usefulness.

Hypothesis 4: Teachers' intention to use AR positively affect their use behavior.

Hypothesis 5: Teachers' perceived ease of use of AR positively affects teachers' self-efficacy.

Hypothesis 6: Teachers' self-efficacy positively affects their use intention.

Hypothesis 7: External environment positively affects teachers' use intention.

Hypothesis 8: System characteristics positively affect teachers' perceived usefulness.

Hypothesis 9: System characteristics positively affect teachers' perceived ease of use.

Hypothesis 10: system characteristics positively affect teachers' self-efficacy..

IV. DATA COLLECTION AND ANALYSIS

A. Questionnaire Compilation and Measurement

Based on the measures of Venkatesh [5] and Delone and McLean [10], we developed the questionnaire from seven dimensions: perceived usefulness (PU), perceived ease of use (PEOU), self-efficacy (SE), external environment (EE), system characteristics (SC), use intention (UI), and use behavior of AR (UB). All the questions in the questionnaire use 5-point Likert scale, and the answers range from 1 "totally disagree" to 5 "totally agree".

After the completion of the questionnaire, 232 questionnaires were collected from Chinese K-12 teachers who have experience in using AR learning system. After cleaning the data and excluding invalid questionnaires, 213 valid questionnaires were obtained, and the questionnaire effective rate was 91.81%. In addition, in order to further understand the teachers' views of AR, this study conducted a semi-structured interview with teachers who have experience in using AR technology. A total of 15 teachers were interviewed. The interviews focused on "what do you feel after using AR learning system", "what are your thoughts and suggestions on the application of AR in teaching".

B. Analysis of Questionnaire Data

In this study, partial least squares structural equation modeling (PLS-SEM) was utilized to perform regression analysis. PLS-SEM is a multivariable analysis method used to test the structural model by minimizing the residual error of the dependent variables of the whole model. The analysis tool is smartpls 3.2.6. As depicted by Chin [11], the PLS-SEM is a supplement to the covariance-based structural equation modeling (CBSEM) by putting a smaller requirement on the amount of data. To this end, it is suitable for exploratory research.

1) Analysis of Reliability and Validity

The overall Cronbach's α value of the questionnaire in this study is 0.923, and the Cronbach's α value of each factor are greater than 0.7, indicating the high reliability of this study. The items of the questionnaire are based on the classic measures and have been reviewed by experts, thus the questionnaire has high content validity. In addition, the factor load of each item is greater than 0.7, the combination reliability is greater than 0.7, and the average sampling variation is greater than 0.5, which indicating that the convergent validity of the questionnaire is well. What's more, the discriminant validity of the questionnaire meets Fornell and larker's [12] requirements in which the square root of AVE of each potential variable must be higher than that of AVE of other potential variables. This implies the discriminant validity of the questionnaire is within the acceptable range.

2) Analysis of Structural Model Results

The standardized root mean square residual (SRMR) is used to evaluate the fit of the structural model. The SRMR value measured in this study was 0.063, which was lower than the critical value (0.08), and the T statistical value was $8.142 > 1.96$, $P < 0.001$, indicating that the model fit was within the acceptable range. An important indicator for evaluating the PLS model is the coefficient of determination of the endogenous latent variable, which represents the ratio of the explainable variance of the endogenous latent variable to the total variance. The larger the value is, the higher the

TABLE I. DETERMINATION COEFFICIENTS OF ENDOGENOUS LATENT VARIABLES

	R ²	Mean	STDEV	T statistic (O/STDEV)	P	Q ²
UI	0.629	0.638	0.047	13.311	0.000	0.445
UB	0.334	0.339	0.047	7.073	0.000	0.363
PEOU	0.298	0.303	0.060	4.948	0.000	0.453
PU	0.485	0.491	0.062	7.831	0.000	0.418
SE	0.556	0.562	0.050	11.223	0.000	0.427

3) Path Analysis

In this study, bootstrapping was used to extract a large number of subsamples ($k = 5000$) from the original samples for the significance test. The results are shown in Table 2. From the p-value of path coefficient, the 10 research hypotheses of this study are valid at different significance levels, among which hypothesis 3, 5, and 7 are significant at 0.05 level, and hypothesis 1, 2, 4, 6, 8, 9, and 10 are significant at 0.001 level.

TABLE II. BOOTSTRAP 95% CONFIDENCE INTERVAL PATH TEST (K = 5000 SUBSAMPLES)

Hypothesis	Path coefficient	Mean	STDEV	T statistic	P	Whether support hypothesis
H1: UI → UB	0.578	0.581	0.041	14.125	0.000	Y
H2: PU → UI	0.340	0.341	0.08	4.236	0.000	Y
H3: PEOU → UI	0.140	0.136	0.064	2.172	0.030	Y
H4: PEOU → PU	0.434	0.434	0.067	6.518	0.000	Y
H5: SE → UI	0.218	0.217	0.077	2.841	0.005	Y
H6: PEOU → SE	0.252	0.254	0.063	3.989	0.000	Y
H7: EE → UI	0.238	0.239	0.070	3.393	0.001	Y
H8: SC → PU	0.357	0.357	0.064	5.550	0.000	Y
H9: SC → PEOU	0.546	0.548	0.056	9.832	0.000	Y
H10: SC → SE	0.578	0.577	0.064	9.003	0.000	Y

V. ANALYSIS OF INTERVIEW DATA

According to the interview data, the views of teachers on AR technology can be summarized as follows:

(1) The 15 teachers interviewed all affirmed the educational application value of AR technology and hoped to apply it to the classroom if conditions allow. For example, teacher T14 said: “AR technology is an important presentation form of future education resources, which can not only attract students’ attention but also present knowledge more vividly.” Teacher T6 said: “I hope AR application can be popularized as soon as possible and widely used in students’ daily learning.” Teacher T2 said: “I hope the government and the Ministry of education will attach more importance to AR technology.”

(2) Among them, 10 teachers thought that it is very important for relevant departments to train teachers about

AR technology. For example, teacher T3 said: “*I’m short of ICT skills. I hope someone can give me some guidance and help in using AR. I’m willing to learn.*” Teachers T9 and T10 mentioned: “*we hope to have technicians and expert teams to follow and guide for a long time.*”

(3) Some teachers put forward requirements for the function design of AR teaching system. For example, teacher T11: “AR learning resources should meet the needs of personalized learning, we should develop more interesting and rich content to attract students’ interest and imagination.” Teacher T12 said: “AR application is not only used for knowledge teaching, but also for interactive teaching.” Teacher T1 said: “The AR application should make the operation more simple, clear and convenient.”

(4) In addition, some teachers have concerns about the educational application of AR, such as: “*if the AR headwear equipment is used for a long time, it will cause dizziness and discomfort.*” Teacher T10 mentioned: “*due to the shortage of equipment, AR technology has not been put into teaching on a large scale*”

Generally speaking, these teachers have a positive attitude towards the educational application of AR technology, and fully affirmed the teaching value of AR, but there are also issues, e.g., “lack of technical training”, “low resource adaptability”, “few capital and equipment investments”.

VI. CONCLUSION

Based on the TAM3 model, this study proposed the influencing factors model of K-12 teachers' acceptance of AR technology from the perspective of Social Cognitive Theory, analyzed the data with PLS-SEM method, finalized the structural model in Figure 2, and drew the following conclusions:

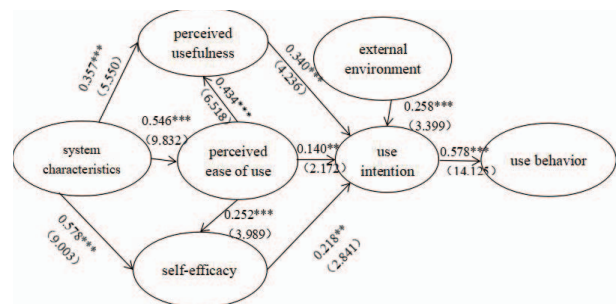


Fig 2. Structural model path coefficient diagram

1. The research model is effective. The results show that the research model is satisfactory at the data level, the reliability of each measurement item and the combined reliability value reach the effective standard, each potential variable has high internal consistency and reliability, and the construction validity of the measurement model is within the acceptable range. In addition, each endogenous latent variable has a medium to high explanatory variable ability.

2. PU and PEOU significantly affect teachers' UI. The hypothesis H1-H4 are consistent with Davis's findings, that is, teachers' PU and PEOU of AR have a positive impact on teachers' UI, and then affect their UB. In addition, PEOU

has a positive effect on PU, which has been confirmed in the previous studies [13-15]. From the perspective of standard path coefficient and explanatory variance ability, H2: PU \rightarrow UI ($E = 0.340$, $P < 0.001$, explanatory variance 22.85%), H3: PEOU \rightarrow UI ($E = 0.140$, $P < 0.05$, explanatory variance 9.41%) indicate that PU has a greater direct impact on teachers' UI, which is considered as a "firm" conclusion in a TAM meta-analysis [16]. From the data level: PEOU not only directly affects the UI but also indirectly affects the UI through PEOU and SE, which leads to the decrease of its direct impact value on the UI. From the practical level: the findings showed that teachers pay more attention to the practical teaching value of AR in teaching. If teachers think that AR is helpful for their work and beneficial to students' learning, they are willing to spend energy to learn and use it even if the operation process is complex.

3. SE and EE significantly affect teachers' UI. Based on Social Cognitive Theory, this study puts forward hypothesis H5-H7, and the results proved that the three hypotheses are valid. According to the result, the SE (individual level; $E = 0.218$, $P < 0.001$, explanatory variance 14.65%) and EE (environmental level; $E = 0.238$, $P < 0.001$, explanatory variance 15.99%) both showed significant and similar effects on teachers' UI. This finding is in line with the basic view of Social Cognitive Theory that individual factors and environmental factors jointly affect individual behavior decision-making. Previous studies have concluded that the EE mainly affects PU and PEOU [17]. Based on the Social Cognitive Theory, this study believes that the EE has a direct positive impact on teachers' UI, which has been verified. Hypothesis H6: PEOU \rightarrow SE ($E = 0.252$, $P < 0.001$, explained variance 16.88%) proves that the more convenient the AR learning system is, the more confident the teachers are to use it. This more consistent the conclusion is with the theory of self-efficacy.

4. SC are the external variables that affect teachers' UI. The research results show that the hypothesis H8-H10, that is, the external features presented by the AR learning system will directly affect teachers' PU and PEOU of the system, thereby affecting teachers' UI, which is consistent with the research conclusion based on the information system success model [18]. In addition, this study also found that SC will positively affect teachers' SE. Therefore, the quality of AR learning system is a pre-requisite for teachers to use. If the content of AR learning system is attractive, the information presented is scientific and rigorous, and the learning materials fit the actual teaching needs, then teachers are more willing to apply it to teaching.

Through literature review, this study found that AR technology has not yet taken root in the field of education, and K-12 teachers are an important research object to understand the application dilemma of AR education. To this end, starting from teachers' cognition and self-efficacy, this study used TAM3 model to explore teachers' acceptance of augmented reality application and performed PLS-SEM analysis on the model. The results once again proved the effectiveness of the TAM3 model, and verified the research hypothesis.

As for the limitation of the study, we only used a few variables to evaluate the hypotheses, and the sample size of the study was relatively small. In this regard, we should 1)

recruit more participants and, 2) take into consideration more external variables of TAM model, e.g., social impact, convenience, in the future study.

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