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# A Case Study of Evaluation of Learners' Acceptance of AR_$H_2O_2$ System

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**Abstract:** The AR_ $H_2O_2$ system for simulating decomposition of hydrogen peroxide with augmented reality is presented. Based on Technology Acceptance Model (TAM) enhanced with perceived enjoyment, we designed a questionnaire in order to evaluate the attitude of learners towards AR-based experiment. For empirical study, 50 students in Grade Two at Junior Middle School were involved and completed a survey questionnaire. The result of our study shows that (1) perceived enjoyment and attitude towards using have a comparable effect on the intention to use; (2) perceived enjoyment plays a dominant role in determining the attitude towards using this system; and (3) both perceived usefulness and perceived enjoyment are depended on perceived of using this system.

**Keywords:** augmented reality, evaluation of CAL system, Technology Acceptance Model

## 1. Introduction

With the development of science and technology, information technology is playing a significant role in all aspects of our life. In the contemporary days, education has taken a new turn under this influence as E-learning has driven a revolution for both IT and education. IT revolution process has met many challenges as the effects of these new technologies need to be checked.

The majority of students in middle school have weak ability to think in abstractions. This common confusion is usually settled in the laboratories. However, the experimenting rooms as well as the materials for the trials are in a shortage in most cases. When it comes to enabling learners to think in a rational way of a completely new disciplines like chemistry and physics, teachers and instructors in junior high school always found a sharp difference among students' learning. As a result, the efficiency of the class is low and some students may fail to understand what they need to know.

Augmented reality (AR) is a technology to simulate a natural situation with realistic visual, hearing and touching effects with the support of computers and other portable devices. AR realizes direct natural interactions between the users and the environment and enables users to immerse into the environment through a variety of sensing equipment. In consideration of the situation in middle schools, there comes the need to explore whether bringing AR into classrooms can help solving the problem of shortage in experimenting resources and difference in experimenters' individualized pace.

With the portability of AR devices, students are allowed to learn the points anywhere following their own learning paces. This convenience plays an important role in places where the laboratories are not available and deals with the challenge brought by individualized learning. AR, as a natural interactive way, can help students better involved in the experiment and corresponding knowledge as well as deepen their understanding of the experimental operations. For example, the knowledge of particles of atoms and molecules, ions and atoms such as micro structure has been regarded as an aporia in chemistry. As students found it difficult to visualize the abstract micro particle image, it becomes demanding and time-consuming for students to learn this part. The introduction of AR into classroom helps the visualization of abstract problem (Cai, Wang, & Chiang, 2014).

## 2. Literature Review

The application of AR to middle school teaching has become a hot issue. In secondary school textbooks, some experiments cannot be carried out because of slow reaction rates, lack of chemicals and instrumental resources. The risk of poisonous gases and explosion has to be taken into consideration when hazardous chemicals are in use. AR can solve these problems by not only describing the experimental phenomenon, but also enhancing students' interaction with experimenting devices and their partners. In this way, it is possible to improve students' self-learning and cooperation skills, provoke their thoughts and deepen their understanding during AR experiments.

The introduction of AR is helpful for students to learn disciplinary knowledge. Some researchers used AR to simulate the mechanical movement. The results show that the technology can assist students in learning kinematics (Baritz, Cotoros, & Moraru, 2007). Cai et al. (Cai et al., 2016) combined the AR and Kinect equipment to design the motion-sensing instructional software to help students learn physics in high school. The results show that AR can improve the efficiency and effectiveness of students' learning.

At present, it is found that AR would affect students' motivation and interest for learning. Chang et al. (Chang, Wu, & Hsu, 2013) carried out their study to support students to learn in hot spots of society like nuclear energy. The study found that students' perceptions of AR activity have a vital influence on the shift in attitudes toward nuclear and that AR may affect the learner's emotional attitude towards real-world problems. Di Serio et al. (Serio, Ibáñez, & Kloos, 2013) developed Instructional Materials Motivation Survey (IMMS) based on the ARCS motivation model. The results indicate that AR has a positive impact on the motivation of middle school students.

Previous studies have explored a lot on the influence of AR system on students' academic performance, learning interest and motivation while few of them focused on students' attitude. It is obvious that the students' attitude towards AR have an important impact on the AR system's use, maintenance, promotion and other aspects. There are some relevant researches on students' acceptance of AR. Wojciechowski and Cellary (2013) used ARIES system to set up the scene of a chemistry experiment. The questionnaire to evaluate the experimenters' attitude towards learning in ARIES AR environments has been designed as well. Technology Acceptance Model (TAM) expanded dimensions of measurement to perceived enjoyment. By constructing friendly interfaces, it is found that perceived usefulness and enjoyment had a comparable effect on the learners' attitude toward using AR environments. Perceived enjoyment played a dominant role in experimenters' determination on whether to use AR. Ibanez et al. (Ibanez, Serio, Villaran, & Delgadokloos, 2016) investigated the attitude of learners towards an AR activity that is designed to help engineering students solve electromagnetic problems. Based on TAM model, the results of the evaluation show that the intention to use the system is dependent on perceived enjoyment, rather than on perceived usefulness of the learning tools. Students' technology acceptance towards the system is also an important measurement. However, owing to the lack of study in this field, there does not exist such a systematic model measuring the influence of students' acceptance towards the new technology.

## 3. System Design

In this section, a tool for building AR-based learning environments, called AR_ $H_2O_2$, is presented. AR_ $H_2O_2$ is developed to simulate decomposition of hydrogen peroxide with AR technology by supplying learners with vivid real-time demos. Therefore, AR_ $H_2O_2$ can be used as an alternative tool to help learners in rural areas where cannot meet the experimental to do experiments.

### *3.1 AR System Introduction*

AR_ $H_2O_2$ contains AR software and four markers. The software contains three processes of hydrogen peroxide decomposition, and the effects of reaction temperature, concentration and catalyzer on decomposition rates are investigated respectively.

The markers are used to interact with this software. Each set contains four markers printed with particular textures, which are selectively applicable to different applications. When the software runs, learners can manipulate markers to investigate the effects of different factors on the reaction rates referring the documentation and further generalize concepts and conclusions.

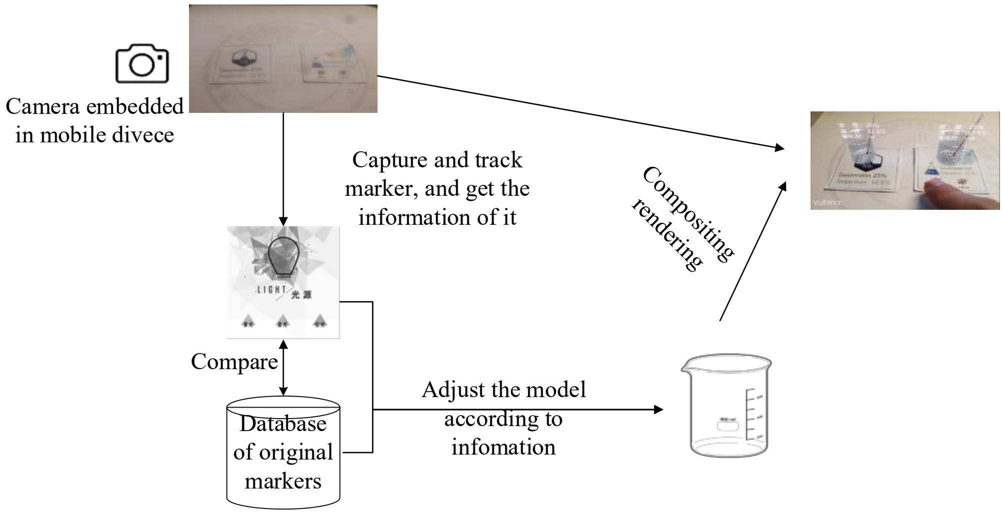



Figure 1. AR_ $H_2O_2$ overview

### 3.2 Design and Development of AR_ $H_2O_2$

The development of AR_ $H_2O_2$ can be divided into three phases: capture real scene, track and compare the marker, and compositing rendering, as shown in Figure 1. The models built-in the software is built in 3DS Max platform, and software is programmed by using Unity3D editor and scripting using C#. Besides, we adjust the co-ordinate system and the interactive mode between users and the models. AR software development kit (SDK) called Vuforia is implemented to make sure AR_ $H_2O_2$ can render the real scene and virtual models to create a real-time mixed reality environment. As a convenience to learners, we install virtual button in specific areas, which could help learners to manipulate the reaction factors (including the valve of temperature, concentration and catalyzer), while the valve of reaction factors is shown in label built-in the soft, as shown in Figure 2. Figure 2 (a)(b)(c) shows process of hydrogen peroxide decomposition which is influenced by temperature, concentration and catalyzer respectively.

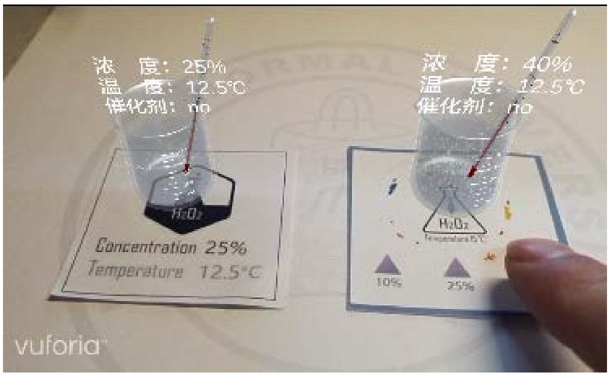
## 4. Description of Experiment

### 4.1 Research Model

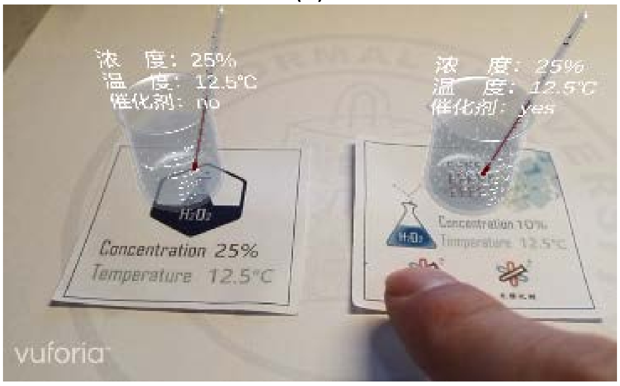
The aim of the experiment is to evaluate the learners' attitude towards the AR devices. Therefore, this study adopts the Technology Acceptance Model to explore the determinants of learners' acceptance toward AR devices. Technology acceptance models are widely used in technology acceptance studies.

Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance". In our research, it represents the user believes that the AR system would yield positive benefits for chemistry learning. Perceived ease of use refers to "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989). In our study, it means the operation of using this system for chemical learning is simple and clear.

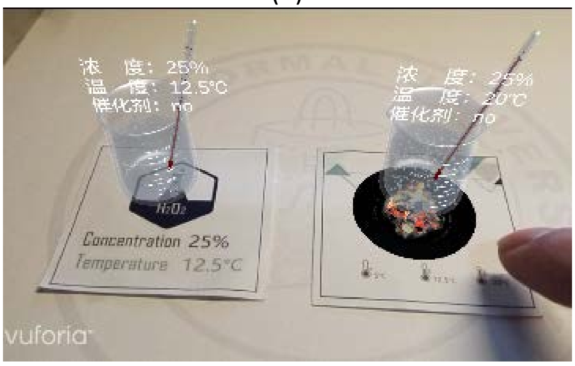
Davis et al. proposed an improved version of the Technology Acceptance Model, suggesting perceived enjoyment as an intrinsic motivation indicator of attitudes. Perceived enjoyment is defined as "the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated" (Davis, Bagozzi, & Warshaw, 1992). Many studies have confirmed that perceived enjoyment has a significant effect on attitudes, so perceived enjoyment should be considered as an indicator in the TAM model (Dickinger, Arami, & Meyer, 2008; Sun & Zhang, 2005; Teo & Noyes, 2011).




(a)




(b)




(c)

Figure 2. The effect of maps of AR_ $H_2O_2$

In this study, we selected the Davis' enhanced version of TAM model with perceived enjoyment. The indicators that impact students' attitude of the AR system are presented in Figure 3. According to the model, perceived usefulness and perceived enjoyment directly influence attitude toward using and intention to use the system. Furthermore, perceived ease of use may directly affect perceived usefulness and perceived enjoyment, and the attitude toward using. At the same time, the intention to use is directly affected by perceived usefulness, perceived enjoyment and the attitude towards using.

The following research hypotheses were formulated on the basis of the research model:

- H1. Perceived ease of use (PEU) will positively affect perceived usefulness (PU).
- H2. Perceived ease of use (PEU) will positively affect perceived enjoyment (PE).
- H3. Perceived ease of use (PEU) will positively affect attitude toward using (ATU).
- H4. Perceived enjoyment (PE) will positively affect attitude toward using (ATU).
- H5. Perceived usefulness (PU) will positively affect attitude toward using (ATU).
- H6. Perceived usefulness (PU) will positively affect intention to use (ITU).
- H7. Perceived enjoyment (PE) will positively affect intention to use (ITU).

- H8. Attitude toward using (ATU) will positively affect intention to use (ITU).

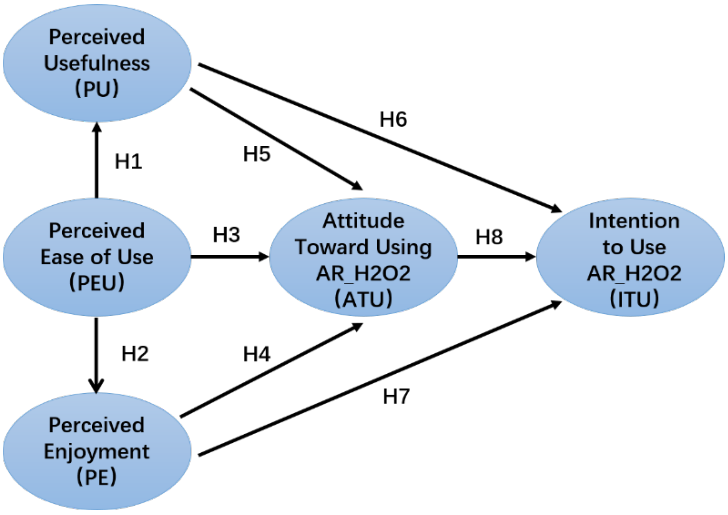



Figure 3. Research model based on TAM

### 4.2 Participants

50 students of 13-15 years old from a middle school were chose in this study. The chemistry curriculum for the third year of junior high school includes factors that influence the rate of chemical reactions. Therefore, the experiments chosen in this study involve the factors that influence the rate of chemical reaction, which is consistent with the student's current curriculum.

### 4.3 Procedure

At the beginning of the experiment, the AR technology was introduced as a course introduction. After that, students filled out a 15-minute test paper about the factors influencing the reaction rate of the decomposition of hydrogen peroxide. Then, as shown in Figure 4, three students form a group using the AR system to learn chemical knowledge as well as doing the relevant virtual experiments. All 50 participants completed the experiment successfully. After completing the experiment, the students completed the same chemistry test as before. After the test, the participants were asked to fill out an anonymous questionnaire with statements about working with the AR system and the attitude toward using such a system in the learning process in the future.

Figure 4 Students are using AR_ $H_2O_2$

According to the research model in Figure 3, we designed and developed the research questionnaire. The participants needed to fill in personal information and 15 questions were divided into five groups representing the indicators of the research model. The questionnaire referred to the relevant questionnaire of the TAM model in the previous study and was adjusted according to the AR environment. Each statement in the questionnaire was measured according to a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with the exception of one reversed item for attitude toward using, which was measured in a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree).

## 5. Data Analysis and Results

### 5.1 Procedure

The statements of the questionnaire and the descriptive statistics for each statement are presented in Table 1. All mean values are within a range of 2.78 and 4.48. The standard deviation ranges from 0.526 to 1.577.

Table 1: The Questionnaire Statement and the Means Standard Deviations of the Answer

| Questionnaire statements | M | S.D. |
|---|---|---|
| Perceived usefulness (PU) | | |
| The use of such a system improves learning in the classroom. | 4.48 | 0.847 |
| Using the system during lessons would facilitate understanding of certain concepts. | 4.48 | 0.784 |
| I believe that the system is helpful when learning. | 4.53 | 0.816 |
| Perceived ease of use (PEU) | | |
| I think the system is easy to use. | 4.53 | 0.751 |
| Learning to use the system is not a problem. | 4.70 | 0.648 |
| Operation with the system is clear and understandable. | 4.68 | 0.526 |
| Perceived enjoyment (PE) | | |
| I think the system allows learning by playing. | 4.45 | 1.037 |
| I enjoyed using the system. | 4.45 | 0.959 |
| Learning with such a system is entertainment. | 4.70 | 0.758 |
| Attitude toward using (ATU) | | |
| The use of such a system makes learning more interesting. | 4.60 | 0.744 |
| Learning through the system was boring (reversed item). | 2.78 | 1.577 |
| I believe that using such a system in the classroom is a good idea. | 4.60 | 0.744 |
| Intention to use (ITU) | | |
| I would like to use the system in the future if I had the opportunity. | 4.45 | 0.904 |
| Using such a system would allow me to perform chemical experiments on my own. | 4.50 | 0.784 |
| I would like to use the system to learn chemistry and other subjects. | 4.52 | 0.751 |

To measure the internal consistency of statements, a coefficient Cronbach alpha was calculated for the statements belonging to each construct specified in the research model. To consider the internal reliability of statements concerning the same construct as satisfactory Cronbach alpha should be greater than 0.7. The obtained Cronbach alpha values for each construct except ATU are at a satisfactory level, as shown in Table 2. In the case of ATU, the value is slightly lower, which may indicate minor differences between the statements formulated regarding attitude toward using. This discrepancy could be influenced by the fact that one of the three statements was a reversed item phrased in the opposite semantic direction from the other statements. Negative statements used together with positive statements can decrease the degree of internal consistency, because the negative items may not be considered the exact opposite of the positive ones.

Table 2: The Cronbach Alpha Values

| Variable | Cronbach alpha |
|---|---|
| Perceived usefulness (PU) | 0.858 |
| Perceived ease of use (PEU) | 0.788 |
| Perceived enjoyment (PE) | 0.845 |
| Attitude toward using (ATU) | 0.351 |
| Intention to use (ITU) | 0.892 |

### *5.2 System Evaluation*

In order to validate hypotheses H1 and H2, we used regression analysis to examine the relationships between pairs of the appropriate constructs defined in research model. The results of the regression analysis are presented in Table 3.

Table 3: The results of regression analysis

| Dependent variable | Independent variable | Coef | $R^2$ | p-value |
|---|---|---|---|---|
| Perceived usefulness (PU) | Perceived ease of use (PEU) | 0.906 | 0.454 | <0.001 |
| Perceived enjoyment (PE) | Perceived ease of use (PEU) | 0.998 | 0.435 | <0.001 |

Following the empirical study, for the hypotheses H1 and H2 we rejected the null hypothesis denoting the lack of dependence, since the p-value was less than the assumed significance level of 0.05. Perceived usefulness was dependent to perceived ease of use ($R^2 = 0.454$) and perceived enjoyment also depends on perceived ease of use ($R^2 = 0.435$). Therefore, the hypotheses H1 and H2 were supported based on the regression values.

For the purpose of studying factors that influence attitude toward the using and intention to use, we used stepwise multiple regression analysis to obtain the best models. The results of the stepwise multiple regression analysis are shown in Table 4.

Table 4: The result of the stepwise multiple regressions analysis

| Dependent variable | Independent variable | Coef | $R^2$ | p-value |
|---|---|---|---|---|
| Intention to use (ITU) | Perceived enjoyment (PE) | 0.536 | 0.625 | <0.001 |
| | Attitude toward using (ATU) | 0.294 | | <0.03 |
| Attitude toward using (ATU) | Perceived enjoyment (PE) | 0.525 | 0.329 | <0.001 |

The results of the stepwise multiple regression analysis show that intention to use depends on perceived enjoyment and attitude towards using ($R^2 = 0.625$), supporting the hypotheses H7 and H8. Perceived ease of use is excluded by stepwise multiple regression analysis because of the high p-value ($p = 0.88$). This suggested that the hypothesis H6 was not supported. As a result, user's perceived enjoyment and attitude towards using positively affect their intention to use. Besides, based on the step-wise multiple regression analysis, attitude towards using was depended on perceived enjoyment ($R^2 = 0.329$), indicating the hypothesis H4 is supported. From the model, attitude towards using is expected to increase by 0.525 when perceived enjoyment increases by one.

## 6. Conclusion

It is concluded that perceived ease of use has a significant impact on perceived usefulness and perceived enjoyment. The attitude towards using is directly related to perceived enjoyment, and the intention to use is influenced by perceived enjoyment and attitude towards using. Therefore, system should be user-friendly to ensure the interface profile, logical clarity and color appearance so that students using the system can get more enjoyment of perception.

Using the AR system, students can combine the virtual environment with the real environment. This system can also reduce the cost of experiment and improve the safety of the experiment. Besides, it can also reduce the experimental space and increase the freedom of experiment compared with the traditional study. In addition, AR technology enables students to better situated learning, which can deepen the contact between learning content and real world.

This study investigates students' technical acceptance degree and the determinants that influence students' attitudes. Future research can investigate using AR technology whether students actually acquire knowledge or compare them to traditional learning styles researching learning outcomes, satisfaction and other indicators.

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## References

Baritz, M., Cotoros, D., & Moraru, O. (2007). Virtual and augmented reality for mechanism motion modeling in technical applications. Paper presented at the Wseas International Conference on Signal Processing, Computational Geometry & Artificial Vision.

Cai, S., Chiang, F. K., Sun, Y., Lin, C., & Lee, J. J. (2016). Applications of augmented reality-based natural interactive learning in magnetic field instruction. Interactive Learning Environments, 1-14.

Cai, S., Wang, X., & Chiang, F. K. (2014). A case study of Augmented Reality simulation system application in a chemistry course. Computers in Human Behavior, 37(37), 31–40.

Chang, H. Y., Wu, H. K., & Hsu, Y. S. (2013). Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue. British Journal of Educational Technology, 44(3), E95–E99.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology: Society for Information Management and The Management Information Systems Research Center.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. Journal of Applied Social Psychology, 22(14), 1111-1132.

Dickinger, A., Arami, M., & Meyer, D. (2008). The role of perceived enjoyment and social norm in the adoption of technology with network externalities. European Journal of Information Systems, 17(1), 4-11.

Ibanez, M. B., Serio, A. D., Villaran, D., & Delgadokloos, C. (2016). The Acceptance of Learning Augmented Reality Environments: A Case Study. Paper presented at the IEEE International Conference on Advanced Learning Technologies.

Serio, Á. D., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course: Elsevier Science Ltd.

Sun, H., & Zhang, P. (2005). An empirical study on the causal relationships between perceived enjoyment and perceived ease of use: Alternative approaches. Paper presented at the Pre-Icis Workshop on Hci Research in Mis.

Teo, T., & Noyes, J. (2011). An assessment of the influence of perceived enjoyment and attitude on the intention to use technology among pre-service teachers: A structural equation modeling approach. Computers & Education, 57(2), 1645-1653.

Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. Computers & Education, 68, 570-585.