A Study on Application of AR Three-Dimensional Touch Interaction in Children Education

Yu-Yi Ding[1], Jing-Hua Han[1(✉)], Qi Cao[1], and Chao Liu[2]

[1] Beijing Forestry University, Beijing, China
hanjing013@126.com
[2] Baidu University, Beijing, China
liuchao05@baidu.com

Abstract. This essay presents knowledge that application validity and reasonability of AR technology based on three-dimensional (3-D) touch interaction in children education were investigated. Plants were selected as the theme to design a children education mode dependent on AR 3-D touch interaction; through comparative experiments, impacts of 4 learning styles on knowledge learning effects were respectively compared, book reading, AR visual content display, AR screen multi-touch interaction and AR 3-D touch interaction. This article shows that learning by means of AR 3-D touch interaction is more effective and such a method has the ability to keep users interested in learning and enhance their understanding and memory of advanced knowledge. Although the pure AR visual content display plays a certain promotion role in children education, information content about the knowledge displayed is low accompanied with a single interactive mode. In a word, AR visual content display has certain defects. By contrast, children who adopt AR 3-D touch interaction can achieve a better learning effect, which indicates that such an approach possesses application value.

Keywords: Augmented Reality (AR) · Touch interaction · Children's cognition
Plant education

1 Introduction

Under the general circumstance that information exchange modes and information transmission routes rapidly make progress, people are paying increasingly more attention to and attaching greater importance to knowledge acquisition. Education is aimed at spreading scientific knowledge, research methods, theoretical thoughts and exploring spirit, etc. discovered in the process of research to the society in a proper way, so that they can be cognized and understood by students and even the masses. Resultantly, overall quality of the public is improved. Regarding traditional educational methods, especially children education modes, reading materials in paper are usually used as carriers, for which it has become more and more difficult to satisfy children's actual demands in a new media environment of diversified information content and multi-dimensional spreading forms at present. However, a great variety of digital readings based on personal computer and smart mobile terminals, etc. not only provides novel

A. Marcus and W. Wang (Eds.): DUXU 2018, LNCS 10920, pp. 170–184, 2018.
https://doi.org/10.1007/978-3-319-91806-8_14

and rich learning and entertainment patterns for children, but gives them fresh and interesting interactive experience. Comparing with vivid and interesting digital readings, a combination of characters and pictures in traditional education readings seems to be monotonous. How to design an education mode conforming to children's present demands and develop their interests in knowledge learning is an important subject of the current children education research.

With development and popularization of information technology, forms of children education readings become increasingly varied. Figueiredo and Bidarra [1] propose gamified interactive readings where knowledge is incorporated into games and readers can learn through lively activities. In his opinion, manifestations of AR technology are rich and interesting; therefore, it can be deemed as a preferable carrier of gamified education and dynamic interaction between emerging and heatedly discussed AR technology and children education readings is a beneficial exploration and investigation of children education modes.

AR technology has been applied in the field of children education, such as universe science popularization [2], e-learning [3] and word retention [4], etc. In addition, there exist many outstanding cases.

Chen and Tsai [5] probe into practicality of AR technology in books for children. As demonstrated by relevant results, children hold the positive attitude towards such books and AR can improve their spatial cognitive abilities to a certain degree. According to IRadu [6], AR plays a positive role in book teaching activities, because it is beneficial to enhance knowledge understanding, facilitate long-term memory and elevate children's initiative in learning. Rambli et al. [7] investigate AR based alphabet learning effects of children. Through much experimentation, it has been proven that children are keenly interested in such a learning style. Nevertheless, hardware equipment limitations and a single interactive mode affect their learning effects to a certain extent.

To sum up, previous studies indicate that AR technology plays a certain role in children education field and is conducive to deepening their understanding of cognitive level knowledge. However, existing research on application of AR in children education places emphasis on vision performance in most cases and reveals visual augmented presentation of traditional knowledge information. Besides, interactive modes involved are rather limited.

Specific to above problems, an AR interactive mode based on 3-D touch was proposed. In terms of application, users can perform touch interaction simulation similar to the real 3-D space for AR technology-based models on the screen of a hardware device (e.g., smartphone). If such an approach is applied into children education, more vivid and more interesting interactive experience can be provided to them effectively promoting their cognition and memory of knowledge. Hence, learning effects of them are improved ultimately. To verify application validity and reasonability of AR 3-D touch interaction in children education, a contrast experiment was designed combining characteristics of children's cognition and AR technology with an aim to explore knowledge learning differences subjected to diverse interactive modes and conduct experimental data analysis and conclusion.

In this paper, children's plant education readings independently developed by the author was taken for example to analyze AR technology application status in children

education readings at present. Hopefully, shortcomings of its application in children education can be pointed out and an AR based knowledge learning mode in consistency with children's cognitive characteristics be raised. In this way, children are able to learn and memorize knowledge on the premise of remaining highly interesting in them, so as to improve their learning effects in the process of edutainment.

2 Cognitive Characteristics of Children and AR 3-D Touch Interaction

2.1 Cognitive Characteristics of Children

3 to 6 years old children in physiologically and psychologically developmental stages gradually get rid of the way to acquiring information from the outside world by behavior acts and begins to understand and learn the outer world by virtue of their perception. Children are vivacious and restless and love playing. They are good at simulating languages and behaviors surrounding them to establish their own psychological cognition. Moreover, they are also particularly curious about everything in the external world. As they grow up little by little, their sensory functions turn to perfection visually, auditorily and tactilely, etc. Under the dual influence of their exposure to the outer world and their mental and physical maturation, psychological demand patterns with distinctive features take form.

Keen to Simulation. For children in developmental stages, simulation is one of their major learning approaches. At the phase of immature self-cognition, language and behavior contents perceived by simulation are most direct and most effective learning style and their thirst to cognize the outer world makes their simulation psychology more intense.

Strong Curiosity. Children begin to acquaint themselves with outside objects through their own perceptions. In this course, their cognitive competence makes progress and can be built up so as to promote their longing for cognition of new things. Such a promoting effect is directly embodied in the emergence of their curiosity. Meanwhile, their curiosity pushes them to cognize more abundant external information so that their cognitive competence is further fostered. Through such a cyclic and superimposed effect, a psychological demand of intense curiosity is finally generated in children.

Memory Simplification. Memory ability of children is still at a developmental stage. They frequently simplify contents that they have memorized by themselves. In other words, those that they are interested in are maintained, while those nothing special and boring are forgotten. Such psychology of memory simplification leads to children's weak ability to stay dedicated. Consequently, presentation forms should be constantly changed to stimulate their interest points in a manner similar to playing games and extend the time of being engaged.

2.2 AR Technology

According to AR technology, computer graphics and visualization are utilized to make virtual images generated by computer arithmetics superimposed in a real image to combine virtual images and the real image together finally so that scenarios of the actual world can be enhanced or unpacked by virtue of additional information produced by the computer. It is featured with virtual-real synthesis, real-time interaction and 3-D registration. Display equipment based on AR technology presents a visual effect of "virtuality in reality" for users. Not only can dummy objects be displayed in a real 3-D environment, but non-geometrical information about the actual object is presented.

In line with technological features described above, AR technology covers static images, dynamic images and written messages, etc. in terms of visual display. Furthermore, sound effects can be inserted at the time of visual display to further improve its multi-media presentation ability. Interactive mode combining AR technology commonly takes advantage of screen multi-touch, i.e., users conduct single-finger or multi-finger clicks and gesture interaction on equipment screen to move, rotate and zoom 3-D images presented by this technology, etc.

According to preliminary analysis, multi-media presentation ability and virtual-real synthesis effect of AR technology have the capability to meet children's psychological demands and conform to their cognitive characteristics. Regarding children who are observing and reading AR books, virtual information embedded in them cannot be directly perceived by naked eyes; however, if they adopt the camera of a smart mobile device to scan a particular picture in the book, 3-D model hidden can be vividly revealed on the paper. Such sudden senses of freshness and surprise give children rather intense sensory stimuli to simulate their interests in cognitive learning. Meanwhile, behavior acts of using a camera to scan a book and perform screen touch interaction are easy to learn. Children are able to simulate and learn them in a very short time. In this case, their psychological demands are satisfied and their enthusiasm for study retained.

2.3 3-D Touch Interaction

Dependent on IBSE rule [8], objectives of learning investigation, understanding operation, building knowledge framework and changing misunderstanding, etc. should be achieved in the process of reading books for learning. As proposed by Vosniadou [9] in conceptual change theory, psychological model construction consists of three stages, namely, initial model construction, synthetic model construction and scientific model construction. Education mode of AR technology based 3-D touch interaction investigated in this paper is geared to the needs of preschool children 3 to 6 years old. While their most fundamental cognitive competence has been just formed, such children are at a behavioral stage of initial model construction. Therefore, they learn under guidance and education. Considering this, visual, accurate and understandable interactive mode built between knowledge information presentation and contents learnt by children is the core attracting attention.

3-D touch is an interactive mode simulating perspective and occlusion relationship in the real world based on AR technology. Interaction triggered components should be

grouped and bound to a 3-D model according to objective circumstances; in addition, grouping cooperation and IK resolving should be carried out for triggering conditions of such components. Interactive components change in consistency with relevant perspective rules and corresponding to variations in scanning and shooting angles and distances of the hardware equipment, so as to guarantee users' interactive experience similar to objective reality. Taking Mimosa pudica as example, its leaves immediately close after it is touched. In a conventional AR interaction solution, the entire plane of a device screen is bound to an interactive trigger. As a result, leaf closure animation of Mimosa pudica can be triggered whenever a user touches the Mimosa pudica model with any part surrounding it on the screen. In line with a 3-D touch based interaction scheme, stems, leaves and flowers of Mimosa pudica are respectively bound to interaction triggers according their biobehavioral characteristics (Fig. 1); besides, effective touch range of a 2-D plane that an interactive component in 3-D space has been projected onto is also figured out. In this way, when the user touches different sections of the Mimosa pudica model on the screen, different behaviors of the model responding to the user's acts can be observed. For example, it the user touches its leaf, the leaf closes; when he/she touches its flower, the flower sways, which share much resemblance with real Mimosa pudica's responding behaviors. In this case, comprehensible and lifelike interactive experience can be incurred in users, not only possessing game enjoyment in terms of interactive mode, but guaranteeing truth-seeking and rigorous requirements for education.

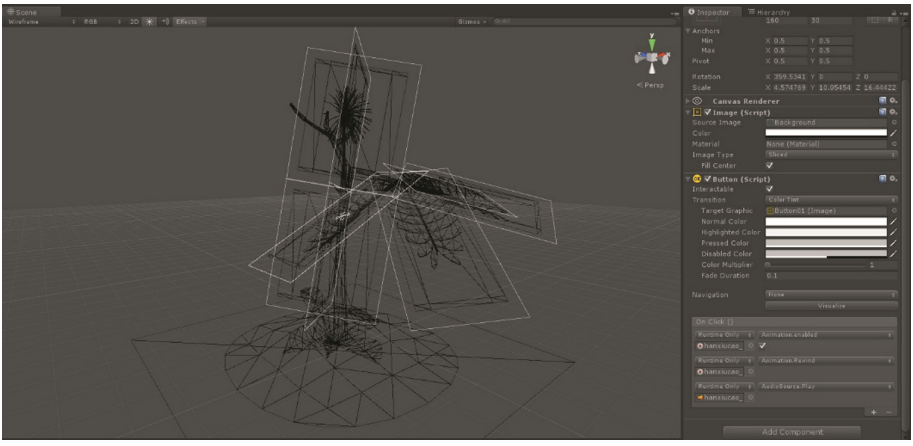


Fig. 1. An interactive trigger in 3-D touch interaction solution.

3 Materials and Methods

3.1 Experimental Design

A knowledge learning style contrast experiment was designed to verify potential defects of AR application in children education and probe into application validity and

reasonability of AR 3-D touch interaction proposed in this paper. During the experiment, control variables are testees who have the same educational content, the same learning time and the same learning environment without significant differences, while independent variables are diverse education modes and learning styles.

Educational content adopted by 4 groups of experiments designed is knowledge relevant with Mimosa pudica, Phyllanthus niruri and Aeschynomene indica (Fig. 2), primarily involving their names, flowers biological structural characteristics, stem and leaf structures and habit characteristics. With a similar morphological structure, they are all herbaceous plants featured with alternate growth of plume like compound leaves and are green in terms of the complete stool. Differences of such 3 kinds of plants mainly lie in morphological characteristics of the complete stool, characteristics of flowers and biobehavioral characteristics (petiole of Mimosa pudica's leaf touched becomes pendent and its small lamina closes; but, another two types of plants present no such behaviors). Participants should be questioned after the experiment and the question contained 3 terms with a major aim to investigate their memories about such 3 plants. Then, differences in different learning styles were estimated according to accuracy of their answers. In addition, application validity and reasonability of AR technology based interactive modes in Children's knowledge learning process were thoroughly analyzed.

Fig. 2. Three kinds of plants learned.

3.2 Questions After Experiment

(1) Which plant foliage closes after being touched? The correct answer is "Mimosa pudica". As biological behavior of leaf closure after being touched is particularly unique among plants, it falls into the category of knowledge of strong features and can be memorized easily. Such a question aims to investigate strongly featured content memorization ability of children tested, effects of different education modes and learning styles during memorization of strong features, and preliminarily explore diverse effects of different AR interaction models on knowledge learning.

(2) Which plant has the largest leaf? The correct answer is "Phyllanthus niruri". Knowledge involved with such a question is poorly featured. As Mimosa pudica, Phyllanthus niruri and Aeschynomene indica share long leaves of pinniform alternate growth; although sizes of individual leaves are different from each other, such

differences are insignificant. Consequently, it is much likely for people to get confused. This question aims to investigate tested children's abilities to memorize details with slight differences, explore detail memorization promoting degrees of different education modes and learning styles, analyze potential problems incurred by application of AR interaction modes in knowledge learning, and compare validity of diverse interaction modes utilized in knowledge learning.

(3) Photos of Mimosa pudica, Phyllanthus niruri and Aeschynomene indica each were presented to children tested (plant display angles in these photos are slightly different from those adopted during their study), they are randomly selected by these children twice without replacement. After each selection, children tested are required to name the corresponding plant in the photo. If correct answers have been given for twice selection, it is noted to be correct; otherwise, it should be noted as being wrong. Such a question comprehensively investigates children's mastery of knowledge they have learned. Due to a high difficulty degree, children who have accurately cognized characteristics unique to different plants have the ability to answer it correctly. On this basis, application validity and reasonability of AR 3-D touch interaction in children education and learning are further explored.

3.3 Experiment Participants

The research implemented by Fleck and Simon [10] addresses that no direct correlation exists between children's understanding of AR space and their genders. No significant differences have been found in the process of learning by children of diverse genders. From perspectives of experimental requirements and humanity, children 3 to 5 years old are featured with poor expression logicality and weak physical fitness; for this reason, 40 6-year-old children were selected as experimental objects with a male-female ratio of 1:1. In addition, academic records of these participants are similar to each other. In-depth learning of plant knowledge is absent in all of them and they are interested in natural plant knowledge without exception. All participants without exposure to any content of AR technology have received qualified training of touchscreen phone usage. Moreover, all participants are willing to join the experiment voluntarily.

3.4 Experiment Content

40 participants were equally divided into 4 groups numbered from 1 to 4. Each group consisted of 5 male and 5 female children. According to the serial number of the experiment, 4 groups of experiments were conducted correspondingly. Considering that participants were rather young and their self-learning and cognitive competencies were still immature, a professional kindergarten teacher was assigned to each experimental group to assist children in their learning, guarantee that they could securely and effectively use AR hardware devices, and perform subjective evaluation and recording of their degrees of concentration on learning. Dependent on key points analyzed and investigated, 4 groups of contrast experiments were designed and presented as follows in details.

Experimental Group 1
As a contrast experimental group, participants under the guidance of a laboratory technician read traditional plant books for children to acquire knowledge about 3 kinds of plants without help of AR technology.

Experimental Group 2
Based on book reading, participants of this group under the guidance of a laboratory technician took advantage of 3-D models and corresponding animation effects of such 3 kinds of plants presented by AR technology to assist their learning and memorization without interactive operations; that is, they only observed visual effects displayed by AR technology.

Experimental Group 3
Based on book reading, participants of this group under the guidance of a laboratory technician took advantage of 3-D models established for such 3 kinds of plants and presented by AR technology to assist their learning and memorization; and, they can not only rotate and zoom such models in an interactive mode by virtue of the touchscreen, but trigger animations corresponding to the relevant plants by touching and clicking the animation play button on the screen.

Experimental Group 4
Based on book reading, participants of this group under the guidance of a laboratory technician studied in an AR 3-D touch interactive mode. Participants were allowed to perform touch interaction for all parts of plants. Different structures of their 3-D models gave diverse types of feedback after screen touch signal reception and their feedback behaviors were rather similar to those of real plants. If a participant repeatedly clicked a construction of the plant, special animation also appears accordingly. For example, if he/she clicks a flower over and over again, an animation effect of petals falling down can be incurred.

3.5 Experimental Procedure

Participants in 4 experimental groups accepted the test at the same time in the uniform learning environment. Experimental period of each group was controlled below 20 min and experiments of different groups did not interfere with each other. After experiments, 3 questions mentioned above were raised to participants to make statistics about correct and wrong answers. Moreover, participants were also required to subjectively evaluate their own experimental processes, that is satisfaction measurement of different learning styles.

3.6 Experimental Data

Experimental data collected were constituted by two parts. First is the statistics about participants' answers to above questions after experiment; second is participants' subjective satisfaction rating about their own experimental forms, which has been classified into Very Dislike, Dislike, Prefer, Like and Very Like. Scores corresponding to such 5 ratings are 1, 2, 3, 4 and 5 respectively.

3.7 Interview

Participants who have completed all experimental contents were interviewed. The interviewing mainly centered on their feelings of participation into the experiment and during the experiment; moreover, reasons for their judgments and answers were briefly inquired targeted at concrete situations of these questions for the purpose of analyzing the relationship between AR technology based interactive modes and the knowledge learning and memorizing.

4 Results and Discussion

4.1 Qualitative Analysis

According to interview results, children making use of AR technology were generally surprised and excited. They were willing to utilize AR technology for their studies continuously. Such emotions have not been found among children reading books and even some of them felt bored. Subjective evaluations made by a laboratory technician of each group on children's learning concentration degrees indicated that children reading ordinary books began to have their attention diverted after 15 min of learning and a small number of them hoped to stop learning. In comparison, those who studied by virtue of AR technology based visual presentation were rather excited when they saw 3-D plant models on the screen; after about 10 min of observation and learning, their attention, however, also began to be diverted. In addition, children who learned by means of AR multi-touch interaction were especially interested in such an interactive mode, repeatedly touched buttons on the interactive interface and observed plant animations after clicked the button. Although they maintained high degrees of excitement in the entire process of experiment, those buttons made their attention diverted to a certain extent. As for children utilizing AR 3-D touch interaction, they were also particularly interested in structures of the 3-D plant model and focused on repeated observation and touch interaction of different plant structures during the experiment.

Participants also evaluated their subjective satisfaction about experimental procedures that they accepted (Fig. 3). Considering that participants in each group only went through education mode and learning style of its own group, statistical graphs of satisfaction could not be compared horizontally and they only played a role in elaborating and describing facts. In line with information expressed in these graphs, participants in Group 1 generally dislike book reading so that their satisfaction about such education mode and learning style is low. Regarding Group 4, participants have been highly satisfied with AR 3-D touch interaction and they are fond of this education mode and learning style.

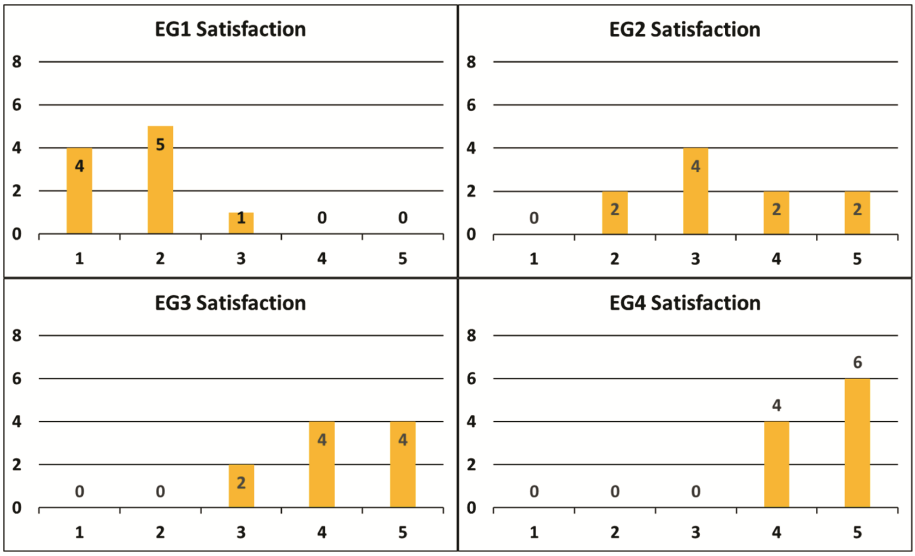


Fig. 3. Satisfaction statistics of experimental groups.

As specified, score assigned to correct answers is 1, while that to wrong answers is 0. Question answering situations of all groups have been presented in Fig. 4. By referring to graphics of each group's statistics, the number of correct answers given by Group 1 is significantly smaller than other groups; and, correct answer counts of Group 4 are higher than those of other groups.

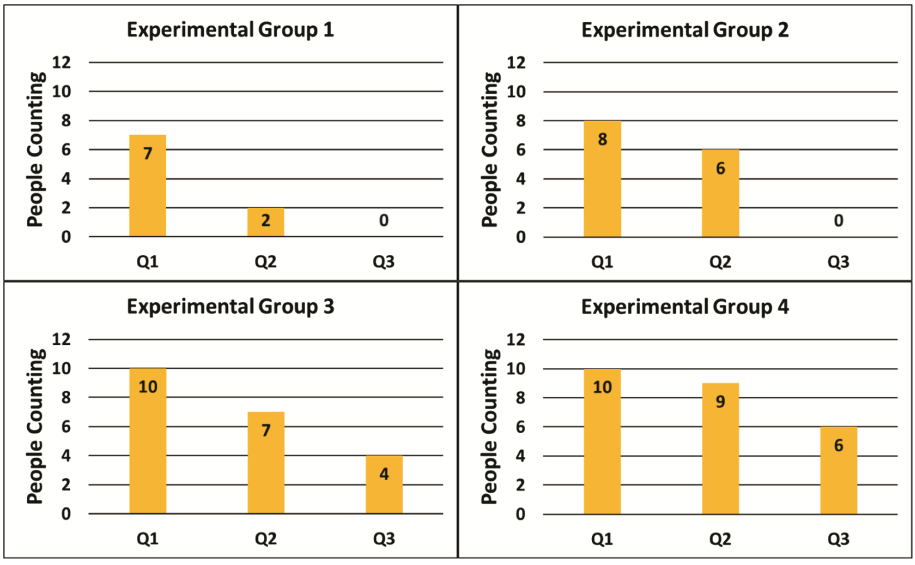
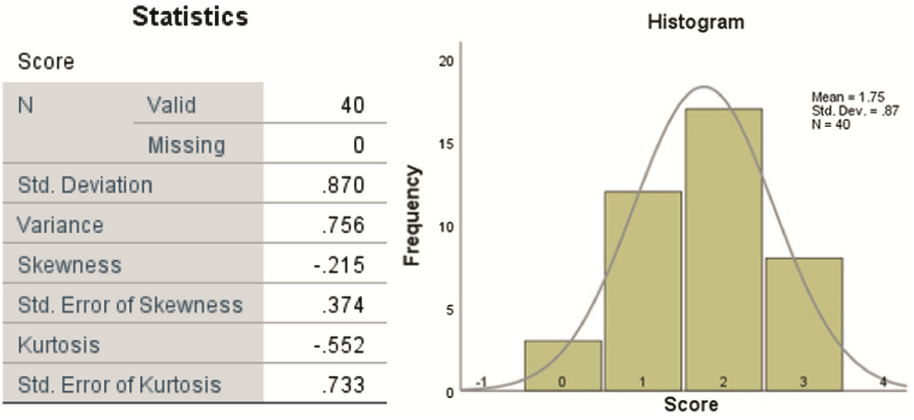


Fig. 4. Answer statistics of experimental groups.

To sum up, it can be preliminarily inferred as follows. As regards children's education and learning, those adopting AR technology gains a learning effect better than those independent of such a technology; furthermore, learning by means of AR 3-D touch interaction achieves is more efficient. To verify such an inference, data analysis should be further performed.

4.2 Quantitative Analysis

SPSS software was utilized to process experimental data and carry out statistical analysis on data about 3 questions answered by 4 groups. As shown in Fig. 5, normal distribution test has proven that scores gained by children participating the experiment are distributed in a approximately normal manner, which further demonstrates reasonability of questions designed and data acquired through such experiments. In addition, independent sample T-test can be also conducted according to data of all experimental groups to analyze correlation and reliability of experimental data.



Statistics

Score

N	Valid	40
	Missing	0
Std. Deviation		.870
Variance		.756
Skewness		-.215
Std. Error of Skewness		.374
Kurtosis		-.552
Std. Error of Kurtosis		.733

Fig. 5. Normal distribution test.

As for Question 1, answers of groups 3 and 4 are all correct; that is, standard deviation of the data is denoted as 0. Under this circumstance, independent sample T-test is only carried out targeted at experimental groups 1 and 2. As indicated in Table 1, data about groups 1 and 2 are tested and proven to conform to homoscedasticity. Considering that $P = 0.628 > 0.05$, the original hypothesis can be accepted and it is deemed that no significant difference exists between Group 1 and Group 2. In other words, no significant difference lies in strongly featured knowledge learning processes of book reading and AR based visual content display. As all answers of groups 3 and 4 to Question 1 are correct, it is preliminarily believed that interactive modes of AR multi-touch and AR 3-D touch promote children's learning and memorizing abilities.

Table 1. Independent sample T-test results of Question 1 in Groups 1 & 2

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q1 (EG1; EG2)	Equal variances assumed	.987	.334	-.493	18	.628	-.100	.203	-.526	.326
	Equal variances not assumed			-.493	17.677	.628	-.100	.203	-.527	.327

Specific to data obtained from Question 2, independent sample T-tests have been conducted for groups 1 & 2, groups 1 & 3, and groups 1 & 4 respectively (see Table 2). It turns out that all test results conform to homoscedasticity. Among them, $P = 0.074 > 0.05$ in terms of groups 1 & 2, so that the original hypothesis is accepted and such two groups are deemed to be free of significant differences. Regarding groups 1 & 3 where $P = 0.024 < 0.05$, and groups 1 & 4 where $P = 0.001 < 0.05$, the original hypothesis should be rejected and no significant differences exist in groups 1 & 3 and groups 1 & 4. In the process of learning knowledge details, learning effect achieved by AR based visual content display is not significantly different from that obtained by book reading; however, comparing AR multi-touch and AR 3-D touch interactions, differences are rather significant. Under the circumstance that the number of children who correctly answered Question 2 is compared, data of groups 3 & 4 were apparently higher than those of Group 1, which verifies preliminary conclusion drawn during analysis on data obtained by Question 1.

Table 2. Independent sample T-test results of Question 2 in all Groups.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q2 (EG1; EG2)	Equal variances assumed	3.429	.081	-1.897	18	.074	-.400	.211	-.843	.043
	Equal variances not assumed			-1.897	17.308	.075	-.400	.211	-.844	.044
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q2 (EG1; EG3)	Equal variances assumed	.987	.334	-2.466	18	.024	-.500	.203	-.926	-.074
	Equal variances not assumed			-2.466	17.677	.024	-.500	.203	-.927	-.073
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q2 (EG1; EG4)	Equal variances assumed	1.531	.232	-4.200	18	.001	-.700	.167	-1.050	-.350
	Equal variances not assumed			-4.200	16.691	.001	-.700	.167	-1.052	-.348

Data acquired from Question 2 answered by groups 3 & 4 are further analyzed accompanied with independent sample T-tests. As for relevant results, they have been given in Table 3 and confirmed to be in consistency with homoscedasticity. As $P = 0.288 > 0.05$, the original hypothesis can be accepted and groups 3 & 4 are deemed

to have no significant difference. It signifies that AR multi-touch interaction and AR 3-D touch interaction are not significantly different from each other as far as detailed knowledge learning is concerned.

Table 3. Independent sample T-test results of Question 2 in Groups 3 & 4.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q2 (EG3, EG4)	Equal variances assumed	5.684	.028	-1.095	18	.288	-.200	.183	-.584	.184
	Equal variances not assumed			-1.095	15.517	.290	-.200	.183	-.588	.188

Question 3 is designed to comprehensively investigate children's mastery of knowledge that they have learnt. In this case, children who have accurately perceived the plant learned have the ability to answer it correctly, which is rather difficult. Practical knowledge learning puts more emphases on cognition and memorization of integrated knowledge. Therefore, data obtained through Question 3 are of practical meaning. According to preliminary analysis on related data, it turns out that no correct answers have been achieved from groups 1 & 2. Considering this, independent sample T-test should be conducted for groups 3 & 4 (see Table 4). Test results obtained are in conformity with homoscedasticity, in which case, $P = 0.018 < 0.05$. As a result, the original hypothesis should be rejected and groups 3 & 4 are deemed to significantly differ from each other. As indicated by graphical data above, the number of people giving correct answers in Group 4 is greater than Group 3. It demonstrates that AR 3-D touch interaction is superior to multi-touch interaction in terms of integrated knowledge learning. The possible cause to such an outcome is that buttons on the interactive interface adopted by multi-touch interaction in Group 3 play a role in making children distracted, which further results in learning effect reduction.

Table 4. Independent sample T-test results of Question 3 in Groups 3 & 4.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q3 (EG3, EG4)	Equal variances assumed	12.054	.003	-2.611	18	.018	-.500	.191	-.902	-.098
	Equal variances not assumed			-2.611	14.918	.020	-.500	.191	-.908	-.092

To sum up, learning efficiency and learning effects acquired by AR based visual presentation and book reading are similar, while AR multi-touch interaction is superior to AR based visual presentation despite that buttons on the interactive interface of the former can distract children from learning; however, AR 3-D touch interaction gives rise to higher learning efficiency and better learning effects. It has the capacity to facilitate children's learning and memorization abilities.

5 Conclusion

Dependent on laboratory findings, children participating the experiment show excitement and surprise of different degrees when they get in touch with AR technology for the first time. Nevertheless, pure AR based visual presentation fails to effectively make children concentrated continuously so that the purpose of learning and memorization ability promoting cannot be achieved in the real sense. When AR multi-touch interaction is adopted, children are able to rapidly learn and simulate touch operations and their interests in learning be stimulated; in this case, excitatory state can be maintained during learning. Nonetheless, conventional buttons on its interactive screen lead to decline of their concentration degrees, reduction of learning efficiency and adverse influence on learning effects. In the case that AR 3-D touch interaction has been utilized by children, they can be excited and engaged in the entire learning process. Thanks to the fact that interaction triggered components of such an interactive mode are integrated into THE plant's 3-D model, only a few buttons are required to guarantee that children concentrate more on cognitive learning and memorization.

Combining children's cognitive characteristics described above, learning and memorization by virtue of watching photos and characters have many defects. Not only does flat image information fail to bring a full range of visual presentation to children, but complicated written messages may incur understanding difficulties in them. Consequently, these children may lose their interests in further cognition and exploration. AR technology can be used to achieve an effect of visual experience enhancement. But, it cannot ensure that children are able to stay focused for a long time in the entire learning process and reasonable interactive modes should be set up to attract children. Although multi-touch interaction has the ability to improve children's learning and memorization concentration degree to a certain extent, they need to rotate and zoom the relevant plant's 3-D model, which is insignificantly correlated to biological characteristics of plants. As a consequence, it is much likely for it to incur memory omission of detailed knowledge. Comparatively, AR 3-D touch interaction makes learning more efficient. Children are able to touch all parts of the plant's 3-D model and observe corresponding interactive feedback animations. With a high skeuomorphism degree and a strong surprised feeling, such an interactive mode guarantees that children can keep interested in learning for a long time and their understanding and memorization of integrated knowledge be effectively strengthened.

In this paper, it has been demonstrated through experiments that AR based visual presentation and multi-touch interaction have certain shortcomings in the course of children education and learning; and, children who adopt AR 3-D touch interaction acquire higher learning efficiency and better learning effects. Children participating the experiment positively respond to gamified interactive mode based on AR and they are especially and strongly interested in 3-D touch interaction featured with skeuomorphism and attractiveness. 3-D touch interaction is a new attempt of AR based interactive modes. In this paper, only its application in children education was discussed. It is believed that such an interactive mode also has certain application values in other domains, which requires further exploring and investigating.

Acknowledgments. This work is supported by the Fundamental Research Funds for the Central Universities (2015ZCQ-YS-02) and Beijing Higher Education Young Elite Teacher Project (YETP0785).

References

1. Figueiredo, M., Bidarra, J.: The development of a gamebook for education. Procedia Comput. Sci. **67**, 322–331 (2015)
2. Sin, A.K., Zaman, H.B.: Live solar system (LSS): evaluation of an augmented reality book based educational tool. In: IEEE Information Technology (2010)
3. Jawad, S., Habib, A., Ali, B.: Enhanced interactive learning using augmented reality. In: IEEE Multi Topic Conference (2014)
4. Barreira, J., Bessa, M., Pereira, L.C., et al.: MOW: augmented reality game to learn words in different languages: case study: learning english names of animals in elementary school. **52**(11), 1–6 (2012)
5. Cheng, K.H., Tsai, C.: Children and parents' reading of an augmented reality picture book: analyses of behavioral patterns and cognitive attainment. Comput. Educ. **72**, 302–312 (2014)
6. Radu, I.: Why should my students use AR? A comparative review of the educational impacts of augmented reality. In: IEEE International Symposium on Mixed and Augmented Reality (2012)
7. Rambli, D.R.A., Matcha, W., Sulaiman, S.: Fun learning with AR alphabet book for preschool children. Procedia Comput. Sci. **25**(25), 211–219 (2013)
8. Minner, D., Levy, A.J.: Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. J. Res. Sci. Teach. **47**(4), 474–496 (2010)
9. Vosniadou, S.: Capturing and modeling the process of conceptual change. Learn. Instr. (Special Issue) **4**(1), 45–69 (1994)
10. Fleck, S., Simon, G.: An augmented reality environment for astronomy learning in elementary grades: an exploratory study. In: ACM IEME Conference Francophone on L'interaction Homme Machine (2013)