IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received July 1, 2018, accepted September 24, 2018, date of publication October 22, 2018, date of current version November 19, 2018.

Digital Object Identifier 10.1109/ACCESS.2018.2875675

Exploring Imaginative Capability and Learning Motivation Difference Through Picture E-Book

PEI-HSUAN LIN[1], YUEH-MIN HUANG[1], AND CHIA-CHEN CHEN[2]
[1]Department of Engineering Science, National Cheng Kung University, Tainan 701, Taiwan
[2]Department of Information Management, National Chung Hsing University, Taichung 402, Taiwan

Corresponding author: Yueh-Min Huang (huang@mail.ncku.edu.tw)

This work was supported by the Ministry of Science and Technology, Taiwan, China, under Grant MOST 106-2511-S-006 -006 -MY3 and Grant MOST 105-2511-S-005-001-MY3.

ABSTRACT As advanced technology emerges into learning, learning behavior has changed from printed books to e-books with diversified teaching plans, such as picture E-books. Although past research regards picture E-books as successful and effective for children, some studied have reported that the electronic feature may negatively affect children. Briefly, as children are attracted by the games or sounds in electronic books, this paper intends to fill the gap with the augmented reality (AR) technology. The imaginative capability is an important factor to stimulate potential and inspire creativity. The research field of imaginative capability is a critical element of the effect student creativity development in the future; however, to the best of our knowledge, little attention has been focused on imaginative capability with technology, to say nothing of learning in ubiquitous learning environments. To cope with this problem, this paper aims to present a picture E-book based on the AR technology and learning theories to build a learner-centered u-learning environment, and examines how to inspire students' imaginative capability in three ways: text-based traditional learning, picture-based traditional learning, and picture E-books with the AR technology–in order to determine the differences of students' learning motivations and imaginative capabilities.

INDEX TERMS U-learning, imaginative capability, learning motivation, picture e-book, AR technology.

I. INTRODUCTION

Picture books are a combination of pictures and simple story texts, which are mainly based on pictures and supplemented by text through information technology. Researchers results have shown that, compared with pure text reading, picture book reading is more attractive to children, and is a promising learning activity for young students [1], [2]. As advanced technology emerges into learning, leaning behaviors have changed from printed books to e-books with diversified teaching plans [3]–[6], such as digital picture books. To date, many investigators have discussed the effect of picture e-books on the changes of students' learning behaviors and experiences [7]–[9]. Although past research of picture e-books regard them as successful and effective for children, some studied have still reported that the electronic feature may negatively affect children, such as the distracting multimedia element [10]. Briefly, children are attracted by the games or sounds in electronic books, and this study intends to fill that gap by AR technology. AR has advanced considerably, and has been used in a wide range of applications in learning environments. AR technology not only provides seamless awareness between physical and virtual worlds, it also controls the users' point of view and interactions [11]–[13]. However, little research has been conducted in either in the classroom or in a u-learning environment on the educational benefits of integrating AR technology, as based on picture e-books [14]–[16]. In light of this, AR picture e-books, which combine the virtues of printed books with digital technology content, may be worth exploring further.

Many investigators have mentioned that changing student's learning methods can improve their creativity and imaginative capability [17]–[20]. Even though both of types of capabilities have been mentioned, most research focused on the capability of creativity, while few focused on imaginative capability. Imaginative capability is a kind of creativity faculty and power of the mind [21], which can make people exceed their past experience and create meaningful and complete possibilities from organizing fragmented situations. White [22] considered that imaginative capability is an important factor to stimulate potential and inspire creativity; hence, imaginative capability is regarded as the foundation for cultivating creative thinking, as well as a driver for

innovation [23], [24]. Several researches have shown that imaginative capability is an important factor of learning [25]–[27]. The research field of imaginative capability is a critical element of the effect of student creativity development in the future; however, to the best of our knowledge, little attention has been focused on imaginative capability with technology, to say nothing of learning in ubiquitous learning (U-learning) environments.

To cope with this problem, this study aims to present a picture e-book, as based on AR technology and learning theories, to build a learner-centered u-learning environment, and examines the inspirations for students' imaginative capability in three ways: text based traditional learning, picture based traditional learning, and picture e-books with AR technology - to know the differences of students' learning motivations and imaginative capabilities. It is hypothesized that students would feel the full imagination experience and concentration in u-learning environments. The main aims of this study are, as follows:

1. Are there differences in learning motivations between students who learn by text based traditional learning, picture based traditional learning, and picture e-book with AR technology?

2. Are there differences in students' imaginative capabilities according to the learning approach, which depend on whether students are learning by text based traditional learning, picture based traditional learning, or picture e-book with AR technology?

II. RELEVANT RESEARCH

A. PICTURE E-BOOK IN EDUCATION

Picture books are a combination of pictures and simple story texts, where the pictures are the main presentation, with text as a presentation aid. Compared with text based books, picture e-books are better able to attract younger students. Many studies have been conducted regarding teaching that applies picture books, and the results show that teacher guidance for students reading picture books improves literacy ability [28], [29], enhances imaginative capability [30], and designs learning strategies into learning activities [31]. As applied technology, the development of picture books can be categorized into four types: (1) scanning the physical picture book to digital, (2) filming the picture books content as a movie story, (3) combining the unique feature of digital technology with picture books, and (4) adding interactive features, such as games [32].

Nowadays, picture books combine mobile devices and information technology into picture e-book. Based on the benefits of picture books, digital pictures can simultaneously achieve visual and aural satisfaction, and learning behaviors and processes also become more interesting through interaction [7]. Cochran and Bull [33] mentioned that digital picture books could provide multiple ways for sense stimulation, which can enhance student learning motivation, keep student attention, improve student learning achievements, provide individualized teaching, and real-time feedback. Schugar *et al*. [34] suggested a framework for considering the effects of the interactive features in picture e-books and K-6 student's comprehension. Yokota and Teale [32] also focused on teachers, and how to choose a print or digital version for particular learning situations, where the main factors should be considered in assessing digital picture books for class. Verhallen and Bus [35] found that, no matter whether the learning method is a digital storybook or a nonverbal computer game, both benefited students learning receptive and expressive vocabularies. Some recent studies have also discussed the picture e-book, Zhao *et al*. [36] designed an interactive picture e-book for Chinese short stories by 3D technology, and the result showed that they make education more interesting and facilitate interactions between parents and children. Yilmaz *et al*. [37] found that AR picture e-books were attractive and enjoyable for children, and could be an effective educational tool for preschool children's cognition and listening abilities. Although past research suggested picture e-books are regarded as successful and effective for children, some studied have reported that the electronic feature of may negatively affect children, such as the distracting multimedia element [10].

This study intends to fill the research gap of AR technology and overcome the limitations of picture book reading in the classroom, where the purpose is to use picture e-books to inspire student's imaginative capabilities and learning motivations, as based on picture e-book AR technology, to result in interactive play for children in the u-learning environment.

B. IMAGINETIVE CAPABILITY

Imaginative capability, which is a kind of creativity faculty and power of the mind [21], can make people exceed their past experience, and create meaningful and complete concept possibilities from organizing fragmented situations. Heath [38] pointed out that imagination capability is a highly valuable cognitive ability, which is suited to be an enabler of active activity and make people to think beyond the actual experience. White [22] considered that imaginative capability is an important factor to stimulate potential and inspire creativity; hence, imaginative capability is regarded as the foundation for cultivating creative thinking and the driver of innovation[23], [24]. Several researches have shown that imaginative capability is an important factor of learning [25]–[27]. Yeh *et al*. [39] found that, though the mediator effect is imagination, student's self-efficacy had high influence on learning performance. Lin *et al*. [40] examined the relationship between personal traits and imaginative capability according to curvilinear effects. Clarkin–Phillips *et al*. [41] showed that museums are potentiating learning environments, and dialogue between adults and peers to co-construct knowledge can enhance children's artistic and imaginative capabilities. Hsu *et al*. [42] reported the relationship between imaginative capability and creativity among agriculture college students, and the results showed that (1) originality is influenced by initiating imagination and conceiving imagination,

(2) transforming imagination has light negative influence on originality, and (3) usefulness is mainly influenced by conceiving imagination and is lightly influenced by initiating imagination. Even though both types of capabilities were mentioned, most research focused on the capability of creativity, while few focused on imaginative capability. The purpose of this study is to inspire student's imagination capabilities through picture e-books in interactive u-learning environments.

C. LEARNING MOTIVATION

To inspire student's learning motivation is the primary mission of this study, and also the most important factor to improve student's learning performance during the learning process [43]–[45]. Actually, several studies have indicated that motivation can be enhanced by create knowledge with web technologies[46], [47]. The most commonly used motivation model is the attention, relevance, confidence, and satisfaction (ARCS) model, which provides a guiding strategy for teachers to enhance student's motivation, as it is well-developed and has been used for more than 30 years [48]–[51]. Based on the ARCS model, the instructional materials to motivate and encourage students require: (1) catch and keep student's attention, (2) explain the reason why students need to learn the learning content, (3) make students believe that they are able to succeed if they put in the effort, and (4) help student to feel rewarded and proud of themselves [49]. The effect of learning on the changes of student learning motivation, as based on the ARCS model, has been widely discussed in recent years[43], [52]–[55]. Chang *et al*. [43] examined mobile inquiry-based learning (M-IBL) combined with the ARCS motivational theory, and students received higher grades in the dimension of relevance, confidence, and satisfaction by M-IBL. Toussaint and Brown [56] described game based learning combined with the ARCS model to increase student's motivation and engagement for a math course. ARCS is a convincing model to design and explain student's learning processes; with the advances in e-learning, AR technology is useful for leaning [57]. However, to the best of our knowledge, little research has been devoted to investigate the effect of AR technology on the changes of student learning motivation. In this study, the ARCS model is used to evaluate the impact of student's motivation for picture e-book learning, as based on AR technology.

D. PICTURE e-BOOK WITH AR TECHNOLOGY

Description of the picture e-book:

In Taiwan, students learn the insect life cycle in the fourth grade of elementary school. Currently, insect life cycle education is taught with text books in the classroom, and consists of materials supplemented by multimedia. This study applies a picture e-book as supplementary material for a science course for elementary students with an iPad application called My Very Hungry Caterpillar AR, which was developed by StoryToys Entertainment Limited. The story content is based on the picture book-The Very Hungry Caterpillar, as written by Eric Carle. This picture e-book allows children to play in the digital world, while connected to the real world, and contains science, technology, art, and mathematics education. In this study, the dimension of science is the life cycle of caterpillars, the dimension of technology uses a mobile device and AR technology, the dimension of engineering allows students to sequence and build the interactive learning environment, the dimension of art allows students to arbitrarily paint and create the learning environment, and the dimension of mathematics is to count the days and the foods. This picture e-book presents the story contents in light of the student's actual environment. Figure 1 shows screenshots of the picture e-book, which helps students to understand the insect life cycle, and offers wide range of interactive activities.

FIGURE 1. Snapshot of learning activity.

III. METHOD

To measure the effect of this innovative learning approach, an experiment was conducted to compared the imagination capabilities and learning motivations of students who participated in the learning activity with different learning strategies.

A. PARTICIPANTS

The participants are 34 elementary school students in South Taiwan, who were randomly divided into an experimental group and two control groups; that is, 15 students in the experimental group, 12 students in control group A, and 7 students in control group B. This study uses a convenience sampling method, the mean age is 10 years, and all of the students were taught the same course by the same teacher.

B. LEARNING ACTIVITY DESIGN

The class materials and methods are based on the insect life cycle unit of the fourth-grade Natural Science and Technology textbook, and were designed in consultation with experts and teachers. Figure 2 shows the learning scenario. In Phase 1, the experimental group and two control groups were given two week classes on the basics of insect knowledge as part of their regular course learning in science for insect life cycle. Thus, they had basic knowledge of the insect metamorphosis process.

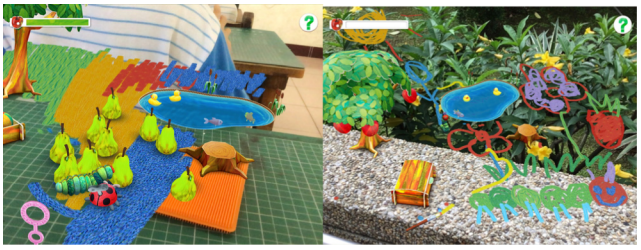

FIGURE 2. Snapshot of screen during learning activity.

In Phase 2 of the learning activity, the students in the experimental group were taught how to operate the application- My Very Hungry Caterpillar AR, on the iPad, where the teacher read the digital pictures to the student, and showed them how to operate the touchscreen with gestures. All students in the experimental group used the mobile device with AR technology for telling the story and observing in the U-learning environment. At the beginning of the learning activity, students had to find a suitable place for the caterpillar grow up. After finding a suitable place, the egg was hatched into a caterpillar. Students had to feed the caterpillar different quantities and types of fruit, be interactive with the caterpillar, and count the days and times to make caterpillar sleep and grow up. During the activity, student could arbitrarily paint and create the environment for the caterpillar at any time. Finally, the caterpillar entered pupation and emerged as a butterfly.

The students in control group A received the picture book - The Very Hungry Caterpillar, and they were asked to create their initial idea of a caterpillar using the traditional paper and pencil approach.

The students in control group B used neither a picture e-book based on AR technology nor a picture book during the learning process; instead, they were guided by a text book and listened to the story content of The Very Hungry Caterpillar, as read by the teacher.

In phase 3, after the learning activity, all the students completed a questionnaire to evaluate the effect of inspiring their imaginative capability and learning motivation. Interviews were conducted with the students in the experimental group.

C. MEASURING TOOL

The purpose of questionnaire was administered after the learning activity in order to evaluate student's imagination capability and learning motivation. The questionnaire contains 54 questions, and uses a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree), and consists of two aspects: 28 items about imagination capability and 26 items about learning motivation. Table 1 shows the Cronbach's α value of each dimension.

The imagination capability scale adopted in this study was developed on the basis of the scale designed by. Liang and Chia [58]. Imagination capability can be divided into three main dimensions: (1) Initiating imagination includes items that have a relationship with novelty, productivity, and exploration; (2) Conceiving imagination includes items have a relationship with sensibility, intuition, concentration, effectiveness, and dialectics; (3) Transforming imagination includes items have a relationship with crystallization and transformation[58], [59]. There are nine items of initiating imagination (e.g. "Compared to others, I had different ideas during the learning activity," and "I have learned that I can use different way to express the same idea"). Cronbach's α is 0.900. There are eleven items of conceiving imagination (e.g. "I can quickly grasp what I should do in learning activities," and "I can think over and over again and put forward different ideas for learning activities."). Cronbach's α is 0.907. There are eight items of transforming imagination (e.g. "I can use the daily examples to express abstract ideas," and "I can use something familiar with detail to show everyone as examples to express unknown ideas"). Cronbach's α is 0.858.

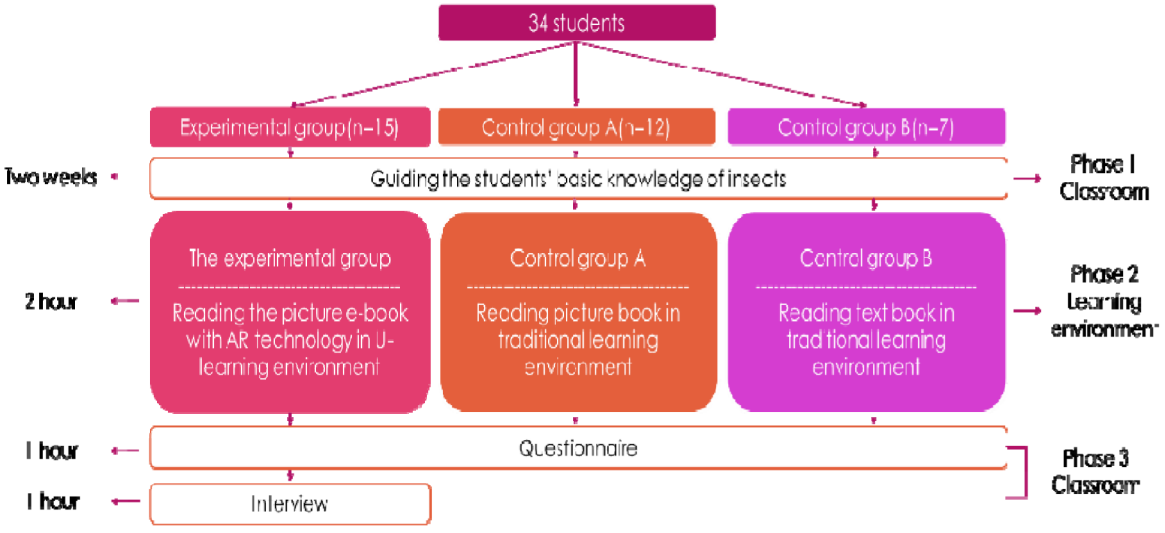

FIGURE 3. Learning scenario.

TABLE 1. The Cronbach's α value for each dimension.

Dimensions	Cronbach's α	Developer
Initiating imagination	0.900	Liang and Chia [55]
Conceiving imagination	0.907	Liang and Chia [55]
Transforming imagination	0.858	Liang and Chia [55]
Attention	0.955	Keller [57]
Relevance	0.930	Keller [57]
Confidence	0.980	Keller [57]
Satisfaction	0.987	Keller [57]

TABLE 2. Results of ANOVA FOR the imagination capability of the experimental group, and control groups A and B.

Dimension	Group	N	Mean	SD	F	p
Initiating imagination	Experimental	15	4.46	.359	25.431	.000
	Control A	12	3.88	.475		
	Control B	7	3.14	.643		
Conceiving imagination	Experimental	15	3.91	.567	4.817	.015
	Control A	12	3.39	.300		
	Control B	7	3.33	.629		
Transforming imagination	Experimental	15	3.61	.559	13.800	.000
	Control A	12	3.82	.610		
	Control B	7	2.81	.616		

Notes: *p<0.05; **p<0.01; ***p<0.001

The learning motivation scale was adopted in this study was developed on the basis of the scale designed by. Keller [60]. The learning motivation model can be divided into four main dimensions: (1) to attract and keep student's ''Attention'' and arouse their curiosity; (2) all the learning activities must have ''Relevance'' with the student's learning goal and need; (3) the amount of effort learners invest to complete the activities, and the feeling of control can build student's ''Confidence''; (4) through the learning activity, students will obtain knowledge, ability, and skill, which leads to their level of ''Satisfaction''[48], [49], [51]. There are seven items of attention (e.g. ''The learning activity held my attention,'' and ''The presentation methods of the learning activity were varied, which helped me concentrate''). Cronbach's α is 0.955. There are seven items of relevance (e.g. ''The content of this learning activity is consistent with the knowledge I have learned before,'' and ''The learning activity is related to my interests''). Cronbach's α is 0.930. There are six items of confidence (e.g. ''I'm confident that the degree of difficulty is just right for me,'' and ''I'm confident that I know what I was supposed to learn from this learning activity''). Cronbach's α is 0.980. There are six items of satisfaction (e.g. ''I enjoy this learning activity,''). Cronbach's α is 0.987.

In this study, fifteen students from the experimental group (those who used the picture e-book) were interviewed. The interview questions were designed based on the Technology acceptance model (TAM) by. Davis [61].

IV. DATA ANALYSIS AND RESULTS

A. ANALYSIS OF IMAGINATIVE CAPABILITY

To evaluate imagination capability and learning motivation, one-way ANOVA was conducted to analyze the data of imagination capability and learning motivation. In this study, SPSS is used to analyze the data, and a p-value of less than 0.05 is considered significant. Table 2 shows the ANOVA results for imagination capability. The mean value and standard deviation for initiating imagination are 4.46 and 0.359, respectively, for the experimental group, and 3.88 and 0.475, for control group A, and 3.14 and 0.643 for control group B, respectively. The results of initiating imagination (F=25.431, p<0.001) show a significant difference between the three groups. The mean value and standard deviation for conceiving imagination are 3.91 and 0.567 for the experimental group, 3.39 and 0.300 for control group A, and 3.33 and 0.629 for control group B, respectively. The results of conceiving imagination (F=4.817, p<0.05) show a significant difference between the three groups. The mean value and standard deviation for transforming imagination are 3.61 and 0.559 for the experimental group, 3.82 and 0.610 for control group A, and 2.81 and 0.616 for control group B, respectively. The results of transforming imagination (F=13.800, p<0.001) show a significant difference between the three groups.

To determine the differences between the three groups, post hoc testing was used for analysis. Table 3 shows the post hoc test results for imaginative capability. Regarding initiating imagination, the results show that the experimental group students are significantly better than those of the students in control group A (Mean difference = 0.57833, p<0.01) and control group B (Mean difference = 1.31714, p<0.001), and control group A is significantly better that control group B (Mean difference = 0.73881, p<0.01). Regarding conceiving imagination, the results show that the experimental group students are significantly better than those of the students in control group A (Mean difference =0.51767, p<0.05) and control group B (Mean difference =0.57457, p<0.05), and no significant difference is revealed between the students in the two control groups. Regarding transforming imagination,

TABLE 3. Results of Post Hoc test of the imagination capability of the experimental group, and control groups A and B.

Dimension	Group		Mean Difference	Standard Error	*p*
Initiating imagination	Experimental	Control A	.57833	.15811	.003
		Control B	1.31714	.18687	.000
	Control A	Experimental	-.57833	.15811	.003
		Control B	.73881	.19416	.002
	Control B	Experimental	-1.31714	.18687	.000
		Control A	-.73881	.19416	.002
Conceiving imagination	Experimental	Control A	.51767	.19516	.033
		Control B	.57457	.23066	.047
	Control A	Experimental	-.51767	.19516	.033
		Control B	.05690	.23966	.969
	Control B	Experimental	-.57457	.23066	.047
		Control A	-.05690	.23966	.969
Transforming imagination	Experimental	Control A	1.00417	.22581	.000
		Control B	1.13810	.26688	.000
	Control A	Experimental	-1.00417	.22581	.000
		Control B	.13393	.27729	.880
	Control B	Experimental	-1.13810	.26688	.000
		Control A	-.13393	.27729	.880

Notes: *p<0.05; **p<0.01; ***p<0.001

TABLE 4. Result of ANOVA of the learning motivation of the experimental group, and control groups A and B.

Dimension	Group	N	Mean	SD	F	*p*
Attention	Experimental	15	4.85	.303	100.791	.000
	Control A	12	3.97	.335		
	Control B	7	2.49	.514		
Relevance	Experimental	15	4.88	.338	56.403	.000
	Control A	12	3.89	.480		
	Control B	7	3.06	.297		
Confidence	Experimental	15	4.93	.258	187.092	.000
	Control A	12	3.83	.419		
	Control B	7	1.93	.346		
Satisfaction	Experimental	15	4.93	.258	171.683	.000
	Control A	12	3.89	.485		
	Control B	7	1.74	.383		

Notes: *p<0.05; **p<0.01; ***p<0.001

the results show that the experimental group students were significantly better than those of the students in control group A (Mean difference = 1.00417, p<0.001) and control group B (Mean difference = 1.13810, p<0.001), and no significant difference is revealed between the students in the two control groups. Accordingly, it was found that the picture e-book was helpful to the students in inspiring their imagination capability in comparison with the picture book approach and traditional text reading approach.

B. ANALYSIS OF LEARNING MOTIVATION

Table 4 shows the ANOVA results of learning motivation. The mean value and standard deviation for attention are 4.85 and 0.303 for the experimental group, 3.97 and 0.335 for control group A, and 2.49 and 0.514 for control group B, respectively. The results of attention (F=100.791, p<0.05) show significant difference between the three groups. The mean value and standard deviation for relevance are 4.88 and 0.338 for the experimental group, 3.89 and 0.480 for control group A, and 3.06 and 0.297 for control group B, respectively. The results of relevance (F=56.403, p<0.05) show significant difference between the three groups. The mean value and standard deviation of confidence were 4.93 and 0.258 for the experimental group, 3.83 and 0.419 for control group A, and 1.93 and 0.346 for control group B, respectively. The result of confidence (F=187.092, p<0.05) show significant difference between the three groups. The mean value and standard deviation of satisfaction are 4.93 and 0.258 for the experimental group, 3.89 and 0.485 for control group A, and 1.74 and 0.383 for control group B, respectively. The results of satisfaction (F=171.683, p<0.001) show significant difference between the three groups.

To determine the differences between the three groups, post hoc testing is used for analysis. Table 5 shows the post hoc test results of learning motivation. Regarding attention, the results show that the experimental group students are significantly better than those of the students in control group A (Mean difference = 0.88167, p<0.001) and control group B (Mean difference = 2.35810, p<0.001), and control group A is significantly better than control group B (Mean difference = 1.47643, p<0.001). Regarding relevance, the results show that the experimental group students are significantly better

TABLE 5. Results of Post Hoc test of the motivation of the experimental group, and control groups A and B.

Dimension	Group		Average Difference	Standard Error	p
Attention	Experimental	Control A	.88167	.14088	.000
		Control B	2.35810	.16651	.000
	Control A	Experimental	-.88167	.14088	.000
		Control B	1.47643	.17300	.000
	Control B	Experimental	-2.35810	.16651	.000
		Control A	-1.47643	.17300	.000
Relevance	Experimental	Control A	.98200	.15015	.000
		Control B	1.81248	.17746	.000
	Control A	Experimental	-.98200	.15015	.000
		Control B	.83048	.18438	.000
	Control B	Experimental	-1.81248	.17746	.000
		Control A	-.83048	.18438	.000
Confidence	Experimental	Control A	1.10000	.13168	.000
		Control B	3.00476	.15562	.000
	Control A	Experimental	-1.10000	.13168	.000
		Control B	1.90476	.16170	.000
	Control B	Experimental	-3.00476	.15562	.000
		Control A	-1.90476	.16170	.000
Satisfaction	Experimental	Control A	1.04417	.14595	.000
		Control B	3.19619	.17250	.000
	Control A	Experimental	-1.04417	.14595	.000
		Control B	2.15202	.17923	.000
	Control B	Experimental	-3.19619	.17250	.000
		Control A	-2.15202	.17923	.000

Notes: *p<0.05; **p<0.01; ***p<0.001

than those of the students in control group A (Mean difference =0.98200, p<0.001) and control group B (Mean difference =1.81248, p<0.001), and control group A is significantly better than control group B (Mean difference = 0.83048, p<0.001). Regarding confidence, the results show that the experimental group students are significantly better than those of the students in control group A (Mean difference = 1.10000, p<0.001) and control group B (Mean difference = 3.00476, p<0.001), and control group A is significantly better than control group B (Mean difference = 1.90476, p<0.001). Regarding satisfaction, the results show that the experimental group students are significantly better than those of the students in control group A (Mean difference = 1.04417, p<0.001) and control group B (Mean difference = 3.19619, p<0.001), and control group A is significantly better than control group B (Mean difference = 2.15202, p<0.001). Accordingly, it is found that the picture e-book can enhance student's learning motivation in comparison with the picture book approach and the traditional text reading approach.

C. INTERVIEW RESULTS

The designed interview questions are based on the TAM model, and all the students in the experimental group participated in the interviews after the learning activity. There are four perspectives of TAM, (1) perceived usefulness, (2) perceived ease of use, (3) attitude toward using, and (4) behavioral intention to use.

In the dimension of perceived usefulness, all the students indicated that the picture e-book helped to 'improve their learning performance', 'construct the knowledge faster', and 'feeling more relax in the learning process'. For example, the learning activity can enable students to understand the caterpillar life cycle by hands-on operation the picture e-book based on AR technology, and not just recite the learning content from memory.

In the dimension of perceived ease of use, all the students indicated that the picture e-book was 'easy to operate' and 'with a clear and easily used user interface'. For example, students used the picture e-book by their instinct, and had no questions about the operation of the e-book.

In the dimension of attitude toward using, all the students indicated that 'feeling pleasure', 'making more fun during the learning activity' and 'having confidence to learn' when using the picture e-book. For example, the students were excited to use the picture e-book and felt pleased and satisfied when they completed the learning activity of caterpillars turning into butterflies.

In the dimension of behavioral intention to use, all the students indicated that they would like to 'use learning materials like the caterpillar picture e-book to learn' and 'will make good use of the caterpillar picture e-book to assist learning'. Some of the students had different opinions regarding 'sharing the review about using the caterpillar picture e-book with peers'.

V. DISCUSSION

This study integrated a picture e-book, AR technology, and u-learning into teaching the insect life-cycle in the science class of an elementary school. The picture e-book enables

students to construct knowledge by the hands-on process in a u-learning environment. To evaluate the effect of this learning approach, an experiment was designed to compare the imagination capability and learning motivation of the students who learned with the picture e-book and those who learned with a text book and a picture book. The experimental results show that, when learning with the picture e-book, the imagination capabilities of students were significantly better than those who learned with the other approaches.

Furthermore, regarding the dimension of initiating imagination, the students that learned with the picture book were significantly better than those who learned from the text book. Regarding both dimensions of conceiving imagination and transforming imagination, no significant differences were revealed between the students learning by picture book or text book.

Among the three learning approaches, the picture e-book significantly enhanced student's abilities in of novelty, productivity, and exploration, and the picture book was also significantly better than the text book. That is, the picture based learning approach could help students in their first step of imagination capability. The picture e-book also significantly enhanced student's abilities in sensibility, intuition, concentration and transforming imagination; whereas, no significant difference was revealed between the picture book and the text book. That is, only picture e-books can inspire students' complete imagination.

Moreover, it was found that the students who used the picture e-book to learn were significantly improved in learning motivation after participating in the learning activity. That is, the picture e-book not only inspired the imagination capabilities of the students, it also enhanced their learning motivation.

The results of qualitative interviews show that most learners had positive intentions toward the integration of picture e-book, as based on AR technology, into the insect life-cycle in the u-learning environment. In addition, the learners believed that, with various advantages, such as improving their learning performance, faster knowledge construction, feeling more relax in the learning process, and clearly and easily using the user interface, picture e-books could drive them to use such devices in the long-term, in particular, the feature of creating and drawing the caterpillar's live environment by a touch screen. The learning method of summarizing helped to inspire students' imagination, effectively associate knowledge with the context, and clarify the information.

VI. CONCLUSION AND FUTURE STUDIES

In this study, students learned through a picture e-book based on AR technology, which is different from text books and picture books. This learning method improved students' knowledge and understanding of insect growth and the metamorphosis process. The obtainment of knowledge was transformed from passive instillation by teachers into proactive learning through the picture e-book. With U-learning and AR technology, rather than aimless concepts, the students were able to understand the knowledge, which inspired their imagination capability and further improved their learning motivation. Through the picture e-book based on AR technology, students can interact with caterpillars in a real learning environment, and see the process of a caterpillar turning into a butterfly, which can capture and keep students' attention, thus, improving their confidence and satisfaction.

This study can act as a starting point for further studies on this topic. This study was designed with the elementary school students of the fourth grade as the research subjects, thus, future studies could be conducted on students of different genders, grades, and learning performance. In addition, this study was conducted based on the insect life-cycle for an elementary school science class, thus, future studies could be conduct on different subjects.

REFERENCES

[1] R. Lever and M. Sénéchal, "Discussing stories: On how a dialogic reading intervention improves kindergartners' oral narrative construction," *J. Exp. Child Psychol.*, vol. 108, pp. 1–24, Jan. 2011.

[2] A. G. Bus, M. H. van Ijzendoorn, and A. D. Pellegrini, "Joint book reading makes for success in learning to read: A meta-analysis on intergenerational transmission of literacy," *Rev. Educ. Res.*, vol. 65, no. 1, pp. 1–21, 1995.

[3] Y.-M. Huang and T.-H. Liang, "A technique for tracking the reading rate to identify the e-book reading behaviors and comprehension outcomes of elementary school students," *Brit. J. Educ. Technol.*, vol. 46, pp. 864–876, Jul. 2015.

[4] Y.-M. Huang, T.-H. Liang, Y.-N. Su, and N.-S. Chen, "Empowering personalized learning with an interactive e-book learning system for elementary school students," *Educ. Technol. Res. Develop.*, vol. 60, pp. 703–722, Aug. 2012.

[5] Y.-M. Huang, T.-H. Liang, and C.-H. Chiu, "Gender differences in the reading of e-books: Investigating children's attitudes, reading behaviors and outcomes," *J. Educ. Technol. Soc.*, vol. 16, pp. 97–110, Oct. 2013.

[6] P.-S. Chiu, I.-C. Chao, C.-C. Kao, Y.-H. Pu, and Y.-M. Huang, "Implementation and evaluation of mobile e-books in a cloud bookcase using the information system success model," *Library Hi Tech*, vol. 34, pp. 207–223, Nov. 2016.

[7] R. Henry and C. Simpson, "A match made in heaven," *Teacher Librarian*, vol. 28, pp. 23–27, Feb. 2001.

[8] F. Serafini, D. Kachorsky, and E. Aguilera, "Picture books in the digital age," *Reading Teacher*, vol. 69, pp. 509–512, Mar./Apr. 2016.

[9] C. McGeehan, S. Chambers, and J. Nowakowski, "Just because it's digital, doesn't mean it's good: Evaluating digital picture books," *J. Digit. Learn. Teacher Educ.*, vol. 34, no. 2, pp. 58–70, 2018.

[10] J. Parish-Morris, N. Mahajan, K. Hirsh-Pasek, R. M. Golinkoff, and M. F. Collins, "Once upon a time: Parent–child dialogue and storybook reading in the electronic era," *Mind, Brain, Edu.*, vol. 7, pp. 200–211, Sep. 2013.

[11] K.-H. Cheng and C.-C. Tsai, "Affordances of augmented reality in science learning: Suggestions for future research," *J. Sci. Educ. Technol.*, vol. 22, pp. 449–462, Aug. 2013.

[12] M. Billinghurst, H. Kato, and I. Poupyrev, "The MagicBook: A transitional AR interface," *Comput. Graph.*, vol. 25, pp. 745–753, Oct. 2001.

[13] A. Dünser, "Supporting low ability readers with interactive augmented reality," *Annu. Rev. CyberTherapy Telemed.*, vol. 6, no. 1, pp. 39–46, 2008.

[14] C.-C. Chen and P.-H. Lin, "Development and evaluation of a context-aware ubiquitous learning environment for astronomy education," *Interact. Learn. Environ.*, vol. 24, no. 3, pp. 644–661, 2016.

[15] T.-C. Huang, C.-C. Chen, and Y.-W. Chou, "Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment," *Comput. Educ.*, vol. 96, pp. 72–82, May 2016.

[16] Y.-M. Huang and P. H. Lin, "Evaluating students' learning achievement and flow experience with tablet PCs based on AR and tangible technology in u-learning," *Library Hi Tech*, vol. 35, no. 4, pp. 609–621, 2017.

[17] D. Wyse and A. Ferrari, "Creativity and education: Comparing the national curricula of the states of the European Union and the United Kingdom," *Brit. Educ. Res. J.*, vol. 41, pp. 30–47, Feb. 2015.

[18] S. Ucus and I. H. Acar, "Exploring the perceptions of student teachers about 'creative school' in early childhood education," *Early Child Develop. Care*, pp. 1–16, 2017.
[19] H.-C. Kuo, P. Burnard, R. McLellan, Y.-Y. Cheng, and J.-J. Wu, "The development of indicators for creativity education and a questionnaire to evaluate its delivery and practice," *Thinking Skills Creativity*, vol. 24, pp. 186–198, Jun. 2017.
[20] J.-J. Wu and D. Albanese, "Asian creativity, chapter one: Creativity across three Chinese societies," *Thinking Skills Creativity*, vol. 5, pp. 150–154, Dec. 2010.
[21] K. Perdue. (2003). *Imagination*. [Online]. Available: https://lucian.uchicago.edu/blogs/mediatheory/keywords/imagination/
[22] A. R. White, *The Language of Imagination*, 1990.
[23] F.-C. Chiu, "Improving your creative potential without awareness: Over-inclusive thinking training," *Thinking Skills Creativity*, vol. 15, pp. 1–12, Mar. 2015.
[24] R. A. Finke, "Imagery, creativity, and emergent structure," *Consciousness Cognition*, vol. 5, pp. 381–393, Sep. 1996.
[25] K.-H. Liao, C.-C. Chang, J.-S. Lin, and C. Liang, "Discovering the imaginative capability of technology writers: Its indicators, roots, and cultivation," *Thinking Skills Creativity*, vol. 14, pp. 76–86, Dec. 2014.
[26] K. H. Janes, *Using the Visual Arts for Cross-Curricular Teaching and Learning: Imaginative Ideas for the Primary School*. Evanston, IL, USA: Routledge, 2014.
[27] P. J. Scales, "Developing movement skills in performing arts: An investigation to stimulate a more creative, imaginative and sensitive movement skill engagement through a democratically orientated approach," Tech. Rep., 2017.
[28] J. L. DesJardin, S. E. Ambrose, and L. S. Eisenberg, "Literacy skills in children with cochlear implants: The importance of early oral language and joint storybook reading," *J. Deaf Stud. Deaf Educ.*, vol. 14, pp. 22–43, Jan. 2009.
[29] N. Masataka, "Development of reading ability is facilitated by intensive exposure to a digital children's picture book," *Frontiers Psychol.*, vol. 5, p. 396, May 2014.
[30] P. C. Rabidoux and J. D. MacDonald, "An interactive taxonomy of mothers and children during storybook interactions," *Amer. J. Speech-Lang. Pathol.*, vol. 9, pp. 331–344, Nov. 2000.
[31] L. E. Skibbe, A. J. Moody, L. M. Justice, and A. S. McGinty, "Socio-emotional climate of storybook reading interactions for mothers and preschoolers with language impairment," *Reading Writing*, vol. 23, pp. 53–71, Jan. 2010.
[32] J. Yokota and W. H. Teale, "Picture books and the digital world," *Reading Teacher*, vol. 67, pp. 577–585, May 2014.
[33] P. S. Cochran and G. L. Bull, "Integrating word processing into language intervention," *Topics Lang. Disorders*, vol. 11, no. 2, pp. 31–49, 1991.
[34] H. R. Schugar, C. A. Smith, and J. T. Schugar, "Teaching with interactive picture e-books in grades K–6," *Reading Teacher*, vol. 66, pp. 615–624, May 2013.
[35] M. J. A. J. Verhallen and A. G. Bus, "Low-income immigrant pupils learning vocabulary through digital picture storybooks," *J. Educ. Psychol.*, vol. 102, no. 1, pp. 54–61, 2010.
[36] J. Zhao, L. Guo, S. Zheng, S. Li, and J. Zhu, "Design and development of mobile interactive picture books," in *Applied Sciences in Graphic Communication and Packaging*. Singapore: Springer, 2018, pp. 353–360.
[37] R. M. Yilmaz, S. Kucuk, and Y. Goktas, "Are augmented reality picture books magic or real for preschool children aged five to six?" *Brit. J. Educ. Technol.*, vol. 48, pp. 824–841, May 2017.
[38] G. Heath, "Exploring the imagination to establish frameworks for learning," *Stud. Philosophy Educ.*, vol. 27, pp. 115–123, Apr. 2008.
[39] H.-T. Yeh, W.-S. Lin, and C. Liang, "The effects of imagination between psychological factors and academic performance: The differences between science and engineering majors," *Int. J. Eng. Educ.*, vol. 30, pp. 746–755, Jun. 2014.
[40] J.-S. Lin, C.-T. Liang, W.-S. Chang, and C. Liang, "Relation between personality traits and imaginative capability of engineering students," *Int. J. Eng. Educ.*, vol. 31, pp. 23–36, Jan. 2015.
[41] J. Clarkin-Phillips, M. Carr, R. Thomas, A. Tinning, and M. Waitai, "Fostering the artistic and imaginative capacities of young children: Case study report from a visit to a museum," *Int. J. Early Childhood*, vol. 50, pp. 33–46, Apr. 2018.
[42] Y. Hsu, L.-P. Peng, J.-H. Wang, and C. Liang, "Revising the imaginative capability and creative capability scales: Testing the relationship between imagination and creativity among agriculture students," *Int. J. Learn., Teach. Educ. Res.*, vol. 6, pp. 57–70, Jun. 2014.
[43] C. Chang, C.-K. Chang, and J.-L. Shih, "Motivational strategies in a mobile inquiry-based language learning setting," *System*, vol. 59, pp. 100–115, Jul. 2016.
[44] P. R. Pintrich, "A motivational science perspective on the role of student motivation in learning and teaching contexts," *J. Educ. Psychol.*, vol. 95, pp. 667–686, Dec. 2003.
[45] F. Paas, J. E. Tuovinen, J. J. van Merrienboer, and A. A. Darabi, "A motivational perspective on the relation between mental effort and performance: Optimizing learner involvement in instruction," *Educ. Technol. Res. Develop.*, vol. 53, pp. 25–34, Sep. 2005.
[46] L. A. Annetta, J. Minogue, S. Y. Holmes, and M.-T. Cheng, "Investigating the impact of video games on high school students' engagement and learning about genetics," *Comput. Educ.*, vol. 53, pp. 74–85, Aug. 2009.
[47] D. U. Bolliger, S. Supanakorn, and C. Boggs, "Impact of podcasting on student motivation in the online learning environment," *Comput. Educ.*, vol. 55, pp. 714–722, Sep. 2010.
[48] J. M. Keller, "The use of the ARCS model of motivation in teacher training," *Aspects Educ. Technol.*, vol. 17, pp. 140–145, 1984.
[49] J. M. Keller, "Development and use of the ARCS model of instructional design," *J. Instruct. Develop.*, vol. 10, p. 2, Sep. 1987.
[50] K. Li and J. M. Keller, "Use of the ARCS model in education: A literature review," *Comput. Educ.*, vol. 122, pp. 54–62, Jul. 2018.
[51] J. M. Keller, "Motivational design of instruction," in *Instructional Design Theories Models: An Overview Their Current Status*, vol. 1. 1983, pp. 383–434.
[52] S. Annamalai, "Implementing ARCS model to design a motivating multimedia e-book for polytechnic ESL classroom," *J. Telecommun., Electron. Comput. Eng.*, vol. 8, no. 8, pp. 57–60, 2016.
[53] W. Zhang, "Design a civil engineering micro-lecture platform based on the ARCS model perspective," *Int. J. Emerg. Technol. Learn.*, vol. 12, no. 1, pp. 107–118, 2017.
[54] P. Y. Kurt and İ. Keçik, "The effects of arcs motivational model on student motivation to learn English," *Eur. J. Foreign Lang. Teach.*, vol. 2, no. 1, pp. 22–44, 2017.
[55] H. Karakis, A. Karamete, and A. Okçu, "The effects of a computer-assisted teaching material, designed according to the ASSURE instructional design and the ARCS model of motivation, on students' achievement levels in a mathematics lesson and their resulting attitudes," *Eur. J. Contemp. Educ.*, vol. 15, no. 1, pp. 105–113, 2016.
[56] M. J. Toussaint and V. Brown, "Connecting the arcs motivational model to game design for mathematics learning," *Transformations*, vol. 4, no. 1, pp. 19–28, 2018.
[57] M. Specht, S. Ternier, and W. Greller, "Dimensions of mobile augmented reality for learning: A first inventory," *J. Res. Educ. Technol.*, vol. 7, no. 1, pp. 117–127, 2011.
[58] C. Liang and T.-L. Chia, "Reliability, validity, and factor structure of the imaginative capability scale," *Creativity Res. J.*, vol. 26, no. 1, pp. 106–114, 2014.
[59] C. Liang, Y. Hsu, C.-C. Chang, and L.-J. Lin, "In search of an index of imagination for virtual experience designers," *Int. J. Technol. Des. Educ.*, vol. 23, pp. 1037–1046, Nov. 2013.
[60] J. M. Keller, *Motivational Design for Learning and Performance: The ARCS Model Approach*. Springer, 2009.
[61] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quart.*, vol. 13, no. 3, pp. 319–340, 1989.

PEI-HSUAN LIN is currently pursuing the Ph.D. degree with the Department of Engineering Science, National Cheng Kung University, Taiwan. Her research interests include education technology, ubiquitous learning, and augmented reality.

YUEH-MIN HUANG received the M.S. and Ph.D. degrees in electrical engineering from the University of Arizona in 1988 and 1991, respectively. He is currently serving as the Vice President of Kun Shan University, Taiwan, where he is also a Chair Professor with the Department of Engineering Science, National Cheng Kung University. He has co-authored three books and has authored over 250 refereed journal research papers. He has completed over 60 Ph.D. and 250 M.S. thesis students. His research interests include e-Learning, multimedia communications, wireless networks, and artificial intelligence. He has received many research awards, such as the Awards of Acer Long-Term Prize in 1996, 1998, and 1999, respectively, the Best Paper Award of the Computer Society of the Republic of China in 2003, the Excellent Research Awards of National Microcomputer and Communication Contests in 2006, the Best Paper Award of 2007, the IEA/AIE Conference, two times of the National Outstanding Research Award in 2011 and 2014, respectively, given to Taiwan's top 100 scholars. He received many funded research grants from the National Science Council, Ministry of Education, the Industrial Technology of Research Institute, and the Institute of Information Industry. He has been invited to give talks or served frequently in the program committee at national and international conferences.

CHIA-CHEN CHEN is currently an Associate Professor of management information systems at National Chung Hsing University, Taiwan. Her current research interests include RFID, context awareness, e-Learning, and smart living. His research is published in information sciences, information fusion, computers and education, telematics and informatics, electronic commerce research and applications and a number of national and international conference proceedings.