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 studies have reported that the electronic feature may negatively affect children. Briefly, as children are attracted by the games or sounds in electronic books, this study intends to fill the gap with Augmented Reality (AR) technology. 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 study aims to present a picture e-book based on Augmented reality (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 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, 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 [3–5]. Although past research of picture e-books regard them as successful and effective for children, some studies have still reported that the electronic feature may negatively affect children, such as the distracting multimedia element [6]. 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 [7–9]. 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 [10–12]. 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 [13–16]. 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 [17], which can make people exceed their past experience and create meaningful and
complete possibilities from organizing fragmented situations. White [18] 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 [19, 20]. Several researches have shown that imaginative capability is an important factor of learning [21-23]. 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 [24, 25], enhances imaginative capability [26], and designs learning strategies into learning activities [27]. 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 [28].

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 [3]. Cochran and Bull [29] 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. [30] suggested a framework for considering the effects of the interactive features in picture e-books and K-6 student’s comprehension. Yokota and Teale [28] 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 [31] 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. [32] 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. [33] 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 [6].

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. IMAGINATIVE CAPABILITY

Imaginative capability, which is a kind of creativity faculty and power of the mind [17], can make people exceed their past experience, and create meaningful and complete concept possibilities from organizing fragmented situations. Heath [34] 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 [18] 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 [19, 20]. Several researches have shown that imaginative capability is an important factor of learning [21-23]. Yeh, et al. [35] found that, though the mediator effect is imagination, student’s self-efficacy had high influence on learning performance. Lin, et al. [36] examined the
relationship between personal traits and imaginative capability according to curvilinear effects. Clarkin–Phillips, et al. [37] 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. [38] 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 [39-41]. Actually, several studies have indicated that motivation can be enhanced by create knowledge with web technologies [42, 43]. 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 [44-47]. 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 [45]. The effect of learning on the changes of student learning motivation, as based on the ARCS model, has been widely discussed in recent years [39, 48-51]. Chang, et al. [39] 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 [52] 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 [53]. 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, engineering, art, and mathematics (STEAM) education. Yakman [54] indicated that the STEAM framework, which combines science, technology, engineering, art, and mathematics with interdisciplinary teaching methods, allows students to engage in hands-on work to construct projects, and present the art according to the foundations of mathematics and science. 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.

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.

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 for evaluate student’s imagination capability and learning motivation. The questionnaire contains 54 questions, using a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). It consists of two aspects: 28 items about imagination capability and 26 items about learning motivation. Table 1 showed the Cronbach’s α value of each dimension.

The imagination capability scale was adopted in this study was developed on the basis of scale designed by Liang and Chia [55]. Imagination capability can be divided into three main dimensions: (1) Initiating imagination that included items have the relationship with novelty, productivity, and exploration, (2) Conceiving imagination that included items have the relationship with sensibility, intuition, concentration, effectiveness, and dialectics, and (3) Transforming imagination that included items have the relationship with crystallization and transformation[55, 56]. There are nine items of initiating imagination (e.g. “Compare to others, I...
have different ideas during the learning activity,” and “I have learned that I can use different way to express same idea”). Cronbach’s α was 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 was 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 everyone as examples to express unknown ideas”). Cronbach’s α was 0.858. The learning motivation scale was adopted in this study was developed on the basis of scale designed by Keller [57]. 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 activity must have “Relevance” with the student’s learning goal and need, (3) through the amount of effort learners invest to complete the activities and feeling of control can build student’s “Confidence”, and (4) after the learning activity, student will get the knowledge, ability and skill, those led to their level of “Satisfaction”[44, 45, 47]. There are seven items of attention (e.g. “The learning activity held my attention,” and “The presentation way of the learning activity was really various to helped me concentrate”). Cronbach’s α was 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 interest”). Cronbach’s α was 0.930. There are six items of confidence (e.g. “I’m confident that the degree of difficulty is just good for me,” and “I’m confident that I know what I suppose to learn from this learning activity”). Cronbach’s α was 0.980. There are six items of satisfaction (e.g. “I enjoy this learning activity,” and “”). Cronbach’s α was 0.987.

In this study, fifteen students from experiment group (those who used picture e-book) were be interviewed. The interview questions designed based on the Technology acceptance model (TAM) model by Davis [58].

### IV. Data analysis and results

#### A. Analysis of imaginative capability

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

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Cronbach’s α</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiating imagination</td>
<td>0.900</td>
<td>Liang and Chia [55]</td>
</tr>
<tr>
<td>Conceiving imagination</td>
<td>0.907</td>
<td>Liang and Chia [55]</td>
</tr>
<tr>
<td>Transforming imagination</td>
<td>0.858</td>
<td>Liang and Chia [55]</td>
</tr>
<tr>
<td>Attention</td>
<td>0.955</td>
<td>Keller [57]</td>
</tr>
<tr>
<td>Relevance</td>
<td>0.930</td>
<td>Keller [57]</td>
</tr>
<tr>
<td>Confidence</td>
<td>0.980</td>
<td>Keller [57]</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>0.987</td>
<td>Keller [57]</td>
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</table>
TABLE II
RESULT OF ANOVA OF THE IMAGINATION CAPABILITY OF THE EXPERIMENTAL GROUP, AND CONTROL GROUPS A AND B

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

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

TABLE III
RESULT OF POST HOC TEST OF THE IMAGINATION CAPABILITY OF THE EXPERIMENTAL GROUP, AND CONTROL GROUPS A AND B

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Group</th>
<th>Mean Difference</th>
<th>Standard Error</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiating imagination</td>
<td>Experimental</td>
<td>Control A</td>
<td>.57833</td>
<td>.15811</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>1.31714</td>
<td>.18687</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control A</td>
<td>-.57833</td>
<td>.15811</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>.73881</td>
<td>.19416</td>
<td>.002</td>
</tr>
<tr>
<td>Conceiving imagination</td>
<td>Experimental</td>
<td>Control A</td>
<td>.51767</td>
<td>.19516</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>.57457</td>
<td>.23966</td>
<td>.047</td>
</tr>
<tr>
<td></td>
<td>Control A</td>
<td>-.51767</td>
<td>.19516</td>
<td>.033</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>.05690</td>
<td>.23966</td>
<td>.969</td>
</tr>
<tr>
<td>Transforming imagination</td>
<td>Experimental</td>
<td>Control A</td>
<td>.000417</td>
<td>.22581</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>1.13810</td>
<td>.26688</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>Control A</td>
<td>1.00417</td>
<td>.22581</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>.13393</td>
<td>.27729</td>
<td>.880</td>
</tr>
<tr>
<td></td>
<td>Control B</td>
<td>-.13393</td>
<td>.27729</td>
<td>.880</td>
</tr>
</tbody>
</table>

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

For knowing the difference between three groups, the post hoc test was used for analysis. Table III showed the post hoc test results for imaginative capability. To initiating imagination, the result showed that the experimental group students were 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 the control group A was also significantly better than control group B (Mean difference = 0.73881, p<0.01). To conceiving imagination, the result showed that the experimental group students were 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), whereas no significant difference was revealed between the students in the two control groups. To transforming imagination, the result showed 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), whereas no significant difference was 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 IV showed the ANOVA results for learning motivation. The mean value and standard deviation for attention were 4.85 and 0.303 for the experimental group, 3.97 and 0.335 for the control group A, and 2.49 and 0.514 for the control group B, respectively. The result of attention (F=100.791, p<0.05) showed a significant difference between the three groups. The mean value and standard deviation for relevancy were 4.88 and 0.338 for the experimental group, 3.89 and 0.480 for the control group A, and 3.06 and 0.297 for the control group B, respectively. The result of relevancy (F=56.403, p<0.05) showed a significant difference between the three groups. The mean value and standard deviation for confidence were 4.93 and 0.258 for the experimental group, 3.89 and 0.480 for the control group A, and 1.74 and 0.383 for the control group B, respectively. The result of satisfaction (F=171.683,
A was also significantly better than control group (Mean difference = 3.00476, \( p < 0.001 \)). To confidence, the result showed that the experimental group students were 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 the control group A was also significantly better than control group B (Mean difference = 0.83048, \( p < 0.001 \)). To satisfaction, the result showed that the experimental group students were significantly better 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 the control group A was also significantly better than control group B (Mean difference = 1.47643, \( p < 0.001 \)).

For knowing the difference between three groups, the post hoc test was used for analysis. Table V showed the post hoc test results for learning motivation. To attention, the result showed that the experimental group students were 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 the control group A was also significantly better than control group B (Mean difference = 1.90476, \( p < 0.001 \)). To relevance, the result showed that the experimental group students were significantly better than those of the students in control group A (Mean difference = 3.83048, \( p < 0.001 \)) and control group B (Mean difference = 1.93048, \( p < 0.001 \)), and the control group A was also significantly better than control group B (Mean difference = 1.04417, \( p < 0.001 \)). To satisfaction, the result showed that the picture book can enhance student’s learning motivation in comparison with the picture book approach and traditional text reading approach.
C. INTERVIEW RESULTS

All the students in experiment group have participate the interview after learning activity, designed interview questions on the basis of the TAM model. 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’, ‘construction the knowledge faster’ and ‘feeling more relax in learning process’. For example, the learning activity can provide students to understand the caterpillar life cycle by hand-on to operate the picture e-book based on AR technology, not just recited the learning content in the memory.

In the dimension of perceived ease of use, all the students indicated that picture e-book was ‘easy to operate’ and ‘with clearly and easily user interface’. For example, students using the picture e-book by their instinct, have 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 learning activity’ and ‘having confidence to learn’ by using picture e-book. For example, students were excited for using the picture e-book and feel pleased and satisfactory when they complete the leaning activity of caterpillars into butterflies.

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

V. Discussion

This study integrated the picture e-book, AR technology, STEAM education and u-learning into the teaching insect life cycle in science class of elementary school. The picture e-book enables students to construct the knowledge by hand-on process in u-learning environment. To evaluate the effect of this learning approach, an experiment was designed to compared the imagination capability and learning motivation of the students who learned with the picture e-book and those who learned with text book and picture book. The experimental result showed that learned with picture e-book, the imagination capability of students was significantly better than those who learned with the other approaches.

Further, the dimension of initiating imagination, the students learned with picture book was significantly better than those who learned text book. To both dimension of conceiving imagination and transforming imagination, there is no significant difference was revealed between the students learned by picture book or text book.

Among the three learning approaches, the picture e-book had significantly enhanced student’s ability of novelty, productivity, and exploration, and picture book was also significantly better that text book. That is, through the picture based leaning approach could help student to the first step of imagination capability. On the other hand, the picture e-book had also significantly enhanced student’s ability of sensibility, intuition, concentration and transforming imagination, whereas no significant difference was revealed between picture book and text book. That is, only through picture e-books can inspire students’ complete imagination.

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

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

VI. Conclusion and future studies

In this study, students learned through the picture e-book based on AR technology different from text book and picture book. This way of learning improved students’ understanding of insect growth and metamorphosis process knowledge. The obtainment of knowledge was transformed from the passive instillation by teachers into proactive operate through picture e-book. With U-learning and AR technology rather than aimless conception, students were able to understand the knowledge and inspire their imagination capability, which further improved their learning motivation. Through the picture e-book based on AR technology, students can interaction with caterpillar in real learning environment. They can reach all the caterpillar turn butterfly process in real learning environment. Though this learning way that could get and keep students’ attention, confidence and have better satisfaction.

The present study can be as a start point for further studies on this topic. This study was designed with the elementary school students of four grade as the research subjects; The future studies could be conducted on students of different genders, grades, and learning performance. In addition, this study was conducted on insect life cycle of elementary
school science class; The future studies could conduct on different subject.

REFERENCES


