An Integrated Design Flow in Developing An Augmented Reality Game for Enhancing Children Chinese Learning Experience

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Abstract

With advanced information technologies were widely embedded into children's learning environment, the learning experience were augmented. Augmented Reality (AR) is an assistive technology in such innovative computing technologies trends that can better introduce narrative content and support the impressive fusion of boundaries between real and virtual worlds, has unveils the potential on creating rich and fantasy learning environments. Benefits from the novel environment which AR can provide, lots of educational AR applications were also being notable. This study introduces a children participated design flow for developing AR game on enhancing Chinese alphabet learning. Young children from kindergarten were recruited in the design flow and practical user study. The learning performance and enjoyment were also evaluated after learning exercise. The positive outcome reveals that the children-involved design flow generated a playful interface which encourages young children in an augmented game-play environment.

Keywords: Human-Computer Interface, Media In Education, Multimedia Systems

1. Introduction

Considering Piaget's constructivism, the development of a child's capacity to learn is based on stimulating interest, initiative, discovery, play, and imagination [1]. Information technology today serves as a critical part of children's daily lives, stimulating interest, discovery and imagination whilst being a successful catalyst to meet the requirements of knowledge development. In language learning for example, the investigation on the use of multimedia supported materials including images, animations and hyper-texts concluded that learning through web would provide flexible and effective learning in foreign languages [2]. Multimedia also brings positive influence on children’s learning, especially on the ability of inference and memory related tasks [3-8]. Further, the growth of educational applications for children, multimedia has been an important bridge for children to grasp knowledge within rich interactive environments.

Virtual Reality (VR) has been a successful multimedia medium for learning [9], attributing to its unique and attractive characteristics to support long-distance learning and information visualization [10]. In VR environments, children tend to perform better in memory terms if they can have the sense of presence in that particular environment rather than simply viewing pictures of it [11]. It does not even matter whether the environment is real or virtual, as long as the participant feels immersed in it as children will be given a better memory structure for understanding the environment [12]. The benefits in such attractive interactions are a contributing factor as to why VR is widely used on learning for children. As VR begins to be widely accepted, important trends of multimedia applications on education are revealed. Rich visualizations of interactive, participatory and multi-sensory environments that mix the physical with the virtual have been a popular solution for more exciting user experiences and bring influences on learning [13]. Facilitating the understanding of key concepts to be as easy as the interaction of children with physical or tangible objects is the main concern in this trend setter. Adopting from several benefits VR offers on education, Augmented Reality (AR) however would pose to be a more effective solution as it represents an intimate relationship between virtual and reality. In AR, physical objects are embedded and overlaid with virtual information and their respective coordinates are translated based on the corresponding visual angles, enabling people to sense virtual information in a closer proximity and relevance to the real world. AR also provides a seamless method
in interaction and collaboration between users by natural manipulations [14,15] while having the characteristics of VR with better interactivity [16]. These traits therefore collectively make AR an ideal solution for educational purposes.

2. The Chinese Learning Strategy

The learning of the Chinese language in Taiwan starts in kindergarten, beginning with basic pronunciation and aiming to train the students to read the characters through the pronunciation of the phonetic alphabets that would reinforce the memorization of the Chinese words. This pronunciation-learning skill that is mentioned comprises of a system of phonetic symbols that is used to indicate how the characters are actually pronounced and is known as Zhu-Yin-Fu-Hao. Zhu-Yin-Fu-Hao is the official system that is used in Taiwan before children are taught to read any characters of the Chinese language [17]. In a study of the effectiveness of Chinese learning, the pronunciation structure of the text enhances the learning of Chinese and has a better learning effect on children without pronunciation skills. There are 37 pronunciation phonetics listed as elements to substitute the phoneme of the language structure. These not connected to what the words literally mean, yet the pronunciation of the language cannot be recognized through the words themselves. The Chinese uses the logographic text system and therefore the familiarization of the Chinese pronunciation system does help with the learning of the language. In more recent times, students must undergo ten weeks of phonetics learning as a tool for learning Chinese before they begin writing the words. Children in the Zhu-Yin-Fu-Hao learning process will use hinted images that are in fact associated to physical objects that children will find familiar to enhance their memory retention. The multimedia materials that are used are mainly pictorial books that serve as the principle teaching tool in a classroom environment to motivate and assist learning activity in children.

It may however still be a challenge for students to memorize abstract phonetics. In the learning of the Chinese language, the phonetics (Zhu-Yin-Fu-Hao) is a better learning method and the memorization of it along with its pronunciation is the foundation of the whole learning process. By referencing, one is able to comprehend or express the abstract meanings of symbols through their corresponding associated mediums. Real-time interactions can enhance their learning effects and memorization processes. Hence if this concept is applied to the learning of the pronunciation of Chinese, it can create a better connection and memorization on the phonetics.

AR technology can be a powerful solution for the learning of Chinese phonetic alphabets. There have been at least six areas of potential AR applications that have been explored: medical visualization, maintenance and repair, annotation, robot path planning, entertainment, and military aircraft navigation and targeting. Although the research in AR has grown in the past few years, it is still relatively new in the field of education [18]. Recent works in this area that include the Magic Book [19] which uses a book metaphor to perform small-scale and close-up constructions in collaborative configurations, science education [20], chemistry education [21], art education [22], an AR based storytelling system [23], and mathematical spatial geometry learning [24], all exhibited great potential of AR in education.

Aimed at incorporating AR technology to develop classroom-based teaching tools to engage learning for students and promote collaboration with teachers, the AR Chinese learning system is designed for kindergarten children (5-6 years old) for supplementing traditional teaching methods. This is to help students grasp related knowledge more easily and increase their motivation and ability to memory the Zhu-Yin-Fu-Hao. About 30 children were enrolled into the learning activity for the study. This small number of students could only represent regional and bore few generic trends on the whole. We will then discuss AR’s potential as a tool to support children’s Zhu-Yin-Fu-Hao learning from recorded achievements and observations.

3. System Overview

In order to make the Chinese learning more interesting and intuitive, we conceptualized and developed an AR-based education application and a children participated design flow was
introduced. Firstly, we selected the immediate relevant Zhu-Yin-Fu-Hao learning chapter from generic pictorial book materials and conducted discussions with teachers to identify the visual characters to be digitized as the 3D content. To motivate students, several popular comic characters are intentionally included in the selection as well. Secondly, to create the ideal classroom environment and to address ergonomic concerns, the setup is kept appealing to participating students with a shareable and open space constructed for them. In addition, a big projected display decorated as a magic mirror is used instead of a Head-Mounted Display (HMD) system. Thirdly, for the interaction and manipulation of virtual objects by students, a series of paper markers printed with Zhu-Yin-Fu-Hao alphabets are used in the system instead of the conventional keyboard or mouse interfaces. Finally, although AR technology in the education domain may bring many benefits, issues on the performance on learning through the AR system still remains as a vital concern. A learning evaluation on the system is then conducted to establish the influences of AR and to provide data for system analysis.

Apart from the main motivation of investigating the possible influences of AR during the study, we are also looking for a collaboration approach on AR-based interface design so as to determine the form learning materials should appear in order to appeal to children. Through design methods and brain-storming exercises, the learning environment is defined as an adventure game in a board game format. The system features animations to introduce learning content and to provide instant media feedback. Students would just need to throw a dice with an overlaid magic mirror agent and then assign tasks for picking up paper markers. If they do manage to complete all the tasks successfully, the treasure box would open.

3.1 System Design

In the design of formal teaching materials, one key problem during the process is the selection of an adequate form for representing learning content in an AR environment. We are hoping that the AR materials could bring not only to children interesting experiences, but also to serve as a well-designed platform that could seamlessly fit children’s requirements. To deal with this problem, we started to explore from various perspectives that included observation, analysis and execution phases. Firstly, five children were recruited for observation. We conducted an exercise to derive the user profiles containing their current opinions and the factors of games that would attract them. Secondly, from the analysis of the collected data, two designers and two teachers (each with more than five years of teaching experience) underwent a brain-storming exercise using these user profiles and a concept design was proposed. During the execution phase, a prototype based on the concept design was developed for the five children and their feedback and responses were observed and recorded for advancing the AR system.

The collaboration design model was extended from Druin’s onion model [25], which presents how children serve as different roles in interactive product development. In our design flow, children serve as user, informing designers of their experience and requirements. The teachers serve as design partners, works as equal members of the designers, helping designers to manage essential conditions for the AR system.

![Figure 1. The collaboration framework with designers, students and teachers.](image)

From the design process, the children’s favorite activities were determined through observation and interview processes with storytelling, pretend play and stuffed toys amongst
their favorite activities and props in their daily lives. It was noted that the appealing stories that garnered their interests would usually feature interesting character(s) in an adventure scenario. Designers and teachers conducted a discussion over the collated data from the brain-storming session to propose a possible solution. After the exercise, an adventure scenario is adopted in the form of a board game and the characters presenting Zhu-Yin-Fu-Hao symbols are then created by designers.

For the AR system, designers collaborated with the teachers to create the scenario and to identify the most appropriate characters in the system. The learning environment is designed as a storytelling environment with a scenario to guide the children to understand the pronunciation of the phonetics and to go on an adventure through the embedded lessons. The adventure board game would lead children to process learning while they simply need to throw the dice to trigger agents that would assign different tasks to them. Students have to pick markers with accompanying phonetic symbols to meet the magic mirror’s request for releasing the characters. During the course of the adventure, it would involve the pronunciations of the phonetics and the associated characters. In addressing the issue on sensory conflict from the time lag experienced in the user’s environmental tracking by the HMD [26], we arranged for a projector to be used instead. It is decorated as a magic mirror to display the image and to provide an open environment in order to lighten the physical burden of the children and also to create a storytelling learning scenario for them.

**Figure 2.** Rules of the adventure games: (a) The dice is thrown in order to trigger the allocation of an agent based on the landing face of the dice which will assign tasks to children. (b) The agent requires children to pick the right marker from the marker set to pass the task. (c) The agent will then show corresponding animations to dictate if the input answer is right or not (visually) and will also feature the symbol’s pronunciation. After that, the agent provides a briefing for the next task for the adventure. (d) After all the 7 markers have been collected and the agents released, an adventure map reveals to children a treasure box containing randomly located treasures.

The AR system offers students several interesting interaction methods to communicate with peers and system:

1. **Grasp and move information:** The AR system is able to translate the markers’ coordinates and orientations to real-time overlaid virtual objects. It is therefore easy for students to manipulate the information without conventional mouse clicks in extended activity spaces.

2. **Media response:** As the original 3D images representing the phonetics’ symbols are shown on the markers. The virtual character would display corresponding animations and sounds in accordance to an agent’s response(s).

3. **Magic Mirror:** Magic Mirror would almost always play a familiar role in stories. We assigned this role with an interesting visual image from a comic character that children are familiar with, which would be a stimulus to trigger media responses and attention spans of children to the story.

3.2 **Structure of AR system**

The AR system consists of two primary components: tangible interactive interface and processing component. The custom tangible interface mimics a board game interface for interaction. A dice, a map and a set of paper makers are given as the props for children to interact with stage (Figure 3.a). The map, dice and paper markers were imprinted with Zhu-Yin-Fu-Hao symbols and game character icons to allow system to recognize its respective characters.
and spatial information, necessary for real-time AR renderings. The processing component comprises of FLARToolkit library, audio and 3D animation library, FBX 3D model loader, and interactive model, which recognize symbols and response animation in AR environment (Figure 3.2).

![Figure 3. (a) Tangible interface of AR application. (b) Architecture of processing component.](image)

3.3 Participants

30 young children from a kindergarten were recruited in groups and interviewed. The participants aged 5-6 years consisted of 16 males and 14 females. They were separated into two groups; AR material group and pictorial book group. Both learning groups were given the paper materials, where the Zhu-Yin-Fu-Hao symbol and images of the spiritual characters that represented the pronunciations were shown on the cover. The difference was that the AR group was given a board game version. The pictorial book group was given a book version with the same learning content as the AR group without accompanying 3D real-time overlaid images on the book. All the participants were new to learn Zhu-Yin-Fu-Hao, and were introduced by teachers with regard of how to use the system. The teacher introduced the purpose and process of this experiment, and then conducted a demonstration on the usage of the system. A learning evaluation on pronunciation, writing, and correct memory association between phonetics and the animation characters is conducted for each of the two learning groups after a fixed learning interval.

4. Application to education environment and evaluation

For both groups, the teaching was conducted by the teachers and it starts with the following introduction of a story of a magic mirror to lead children into the story. In the AR group especially, students would be given more flexible interaction. They were required to throw a dice to call agents and then pick up the paper markers to meet the agent’s requirements based on the hint and the pronunciation. As the students pick up the required markers, the agent would display different animations on the screen which was decorated as a magic mirror. On the magic mirror, the characters would be ‘released’ and presented using animation and sound media. Omitting the rich interaction environment, the photo book group was just assigned the basic pronunciation and learning tasks using the story. The duration for both groups was kept to the same normal class time of a kindergarten of 30-40 minutes.

The evaluation took place after the learning activities, “ㄅ, ㄆ, ㄇ, ㄈ, ㄉ, ㄊ, ㄋ”, where the 7 phonetics were evaluated through the three tasks that would normally be regarded as the typical criteria in Taiwan for an assessment of the class. As standard evaluation tasks, the first two would usually involve the arrangement of further pronunciation and writing activities in the classroom in order to evaluate the children’s learning achievement after the class learning. The third evaluation task looks at the design of the linked connotation between the phonetics and the story character to determine if the material difference would be a main factor on children’s learning performance in these two groups. Through the
evaluation items, we hope to prove that an AR environment would provide as a better solution for Chinese learning in some perspectives.

1. Pronunciation: This test aimed to evaluate the pronunciation ability of the children with reference to their memories of the phonetics’ shapes. The examination method involved the teacher pronouncing the phonetics and the children circling the correct answer on the test sheet. The goal was to assess whether they could pick the correct phonetic through the pronunciations given by the teacher.

2. Connotation between the phonetics and the story character: The seven phonetics and respective images of the story characters were shown in a random mix altogether. The children were asked to line the images up in the correct order of connotations. This determined if the 2D and AR groups would have the same outcome as the preliminary findings of the first experiment that resulted in AR media being successfully able to create a better environment for the memorization task of the phonetics.

3. Writing: This was a more difficult assessment. During a normal 30-40min class, the children were required to memorize the pronunciations and shapes of the phonetics so that they could write the correct answers (alphabets) on the test sheet from the pronunciations made by the teacher.

5. Results

The aim of the study was to evaluate the respective performances under the three learning criteria using different media. This identified and revealed which learning group would gain better performance for each evaluation task. Further, to clarify if the learning influence would be affected by different learning materials, the independent t-test was applied to examine learners’ performances on the different learning materials used, namely the AR and the pictorial book. The tested criterion range was writing, pronunciation and memorization of phonetics. Every criterion contained seven questions and one point was allocated to each correctly answered question.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Experimental Group</th>
<th>Number of Subjects</th>
<th>Mean</th>
<th>SD</th>
<th>t-value</th>
<th>df</th>
<th>sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronunciation</td>
<td>AR</td>
<td>15</td>
<td>2.7333</td>
<td>1.5337</td>
<td>1.079</td>
<td>28</td>
<td>0.291</td>
</tr>
<tr>
<td></td>
<td>Photo Book</td>
<td>15</td>
<td>2.2000</td>
<td>1.1464</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory test</td>
<td>AR</td>
<td>15</td>
<td>5.0000</td>
<td>1.1339</td>
<td>3.851</td>
<td>28</td>
<td>0.001</td>
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<tr>
<td></td>
<td>Photo Book</td>
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<td>3.0667</td>
<td>1.5796</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>AR</td>
<td>15</td>
<td>1.1333</td>
<td>0.8338</td>
<td>1.203</td>
<td>28</td>
<td>0.240</td>
</tr>
<tr>
<td></td>
<td>Photo Book</td>
<td>15</td>
<td>0.8000</td>
<td>0.6761</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*significance level p<.05

The first evaluation task revealed that the unique environments created through various media forms had no significant differences (p>0.05) in the pronunciation learning results of the two groups, with mean scores of 2.7333 (SD=1.5337) and 2.2000 (SD=1.1464), respectively. This indicates that the media has no clear connotation on the learning performance of the children. On the second evaluation task concerning memory, there is a significant influence (p<0.05) on the connotative learning between the phonetics and the story characters, with mean scores of 5.0000 (SD=1.1339) and 3.0667 (SD=1.5796), this shows that the virtual information created through AR’s real-time overlay formulates a better connotation between the abstract phonetics and the story characters. The third category which assessed on the ability to write; the performance shows no influence (p>0.05) on the different medias, with mean scores of 1.1333 (SD=0.8338) and 0.8000 (SD=0.6761).

The independent t-test reveals no significant differences in the experimental group with respect to writing and pronunciation. This suggests that on those two tasks, the different media environments do not constitute as the main factor to influence the learning achievement. The characteristics of AR did not make any significant influence as compared to the photo book. For the memory task, it is noted that different performances were observed with the media.
differences and AR performed better, addressing the capability of memory enhancement by AR. For the mean average between the two learning groups, the averaged score for each evaluation and it is obvious that the AR group shows a better result than the pictorial book group out of the three evaluation tasks.

6. Participant observations

This session was held during and after the participants had used the system. Students commented of what they liked and disliked in the AR environment and a comparison of the two learning groups was performed. During the comparison, distinct differences appeared between the learners’ motivations and oral interactions. It was found that for the students in the two groups, the AR environment had increased oral communication between the children and their peers. They also gave increased feedback to the teacher by asking more questions. In contrast, the pictorial book group had less interactions and conversations between the students. In addition, AR media established flexibility for the interaction with information. Children tended to take the AR cards and describe the story characters to their peers. The AR markers serve as a social communication bridge that creates a richer interactive environment to capture children’s attention in class.

In concluding the observations, we found some notable points;
1. Bigger collaborative learning spaces: the visual feedback of children should not be limited to books. Through tangible operations, information can be mobile. Learning environments through books or VR are limited to the input devices of conventional mouse and keyboard. An AR system can be used by more than one active user at the same time through the use of supplementary markers that are mapped to physical environments.
2. Ideal for gaming: The media provides both 3D animation and sound feedback. Fiducial markers can be designed in a combination of game and educational context by teachers to bring to students an enriched interactive environment for learning.
3. A visual and auditory experience for better learning motivation: The interaction flow in AR can be planned by designers to create event specific triggers for animation and sound presentations. Since the images are integrated with physical environments, the coordinates of the virtual objects will visually correspond to any perspective changes of the cards, presenting the objects as though they are in the same space as the environment. This creates a more immersive atmosphere for the children. With reference to the prior literature review in addition, this provides a better environment for the children to concentrate on the learning content with increased memory retention efficiency.
4. Learning efficiency: During our observation process, participants in the AR group could recognize what the vocabulary meant quickly and the virtual objects that were embedded in physical reality attracted the participants and motivated them to learn. The AR group achieved better learning experiences as they were subsequently able to provide richer descriptions of the animation and sound feedback. The trial inspires us to apply AR to Chinese learning in the classroom and its learning exercises.

7. Conclusion and Future Works

Physical interaction and information visualization bridge the gap between the children and their peers in class. AR as a supporting tool in teaching usually intrigues learning interests through various channels of interaction. There are various developments in AR technology such as Magic Book and Kanji [27] that also aim to address the needs of these learning characteristics by having them as their main design objectives.

The AR system presented in the study has obtained positive feedback from students and teachers collectively. In this study, we take advantage of AR, where real-time information visualization and tangible interaction are seamlessly integrated into a virtual and shareable learning environment. The evaluations and observations in the classroom unveil its potential for the short learning span. AR media has a significant learning effect through children’s learning content and the corresponding
memorization of the virtual information presented with better results over traditional books. Although the effects of media differences were not significant on the pronunciation and writing, however, this cooperative communication between children in shareable AR learning environment does be a notable feature on the future of related AR application. Furthermore, in the design and teaching of the course, how to design different interaction methods with reference to the needs of the course and children is something more important and need to be discussed in further based on the children participated design flow. In future studies, the learning performance in actual teaching situations and the influence on memory that AR brings will be another interesting topic.

8. References


