Co-Design of Augmented Reality Book for Collaborative Learning Experience in Primary Education

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***Abstract*—Through co-design of Augmented Reality (AR) based teaching material, this research aims to enhance collaborative learning experience in primary school education. It will introduce an interactive AR Book based on primary school textbook using tablets as the real time interface. The development of this AR Book employs co-design methods to involve children, teachers, educators and HCI experts from the early stages of the design process. Research insights from the co-design phase will be implemented in the AR Book design. The final outcome of the AR Book will be evaluated in the classroom to explore its effect on the collaborative experience of primary school students. The research aims to answer the question - Can Augmented Books be designed for primary school students in order to support collaboration? This main research question is divided into two sub-questions as follows - How can co-design methods be applied in designing Augmented Book with and for primary school children? And what is the effect of the proposed Augmented Book on primary school students' collaboration? This research will not only present a practical application of co-designing AR Book for and with primary school children, it will also clarify the benefit of AR for education in terms of collaborative experience.**

Keywords—Augmented reality; augmented book; co-design; cooperative inquiry; child-computer-interaction; collaborative learning

I. INTRODUCTION

Augmented Reality (AR) has gained much research attention in recent years. Several research projects have been done for the use of AR in different fields, and education is an area where this technology could be especially valuable [1]. The advancement of AR technology has matured to the point where it can be applied to formal education [2]. However, AR has not been fully adopted into academic settings, and the lack of awareness of AR's wider benefits for education is one of the reasons [3].

Compared to traditional technologies, AR creates an environment where the learners can interact and collaborate in groups. Using AR, it is possible to augment the text book so as to enrich the whole classroom learning experience by adding multimedia and three dimensional objects to the printed material. Although AR is acknowledged for supporting the learning experience in many aspects, very little research work has been carried out to substantiate these claims [4]. This research will further explore the benefit of AR Book in education focusing on collaboration as one of the most important aspects in the learning experience [5].

Different considerations of the design process are required to meet the intended users' needs, especially when these users are children [6]. Therefore, co-design is considered for the practical part of this study as an efficient way to engage children in developing their AR Book [7]. This research will contribute a theoretical foundation for the educational researcher in the field of collaborative learning, as well as a practical framework for the designer in both contexts of AR design and co-design with children.

This paper will explain the research questions, present related work in the field, followed by an explanation of the research methods and procedure. After that, the contributions of the research will be highlighted.

II. RESEARCH QUESTIONS

Can Augmented Books be designed for primary school students in order to support collaboration?

This main research question has been clarified into two sub-questions:

- How can co-design methods be applied in designing Augmented Book with and for primary school children?
- What is the effect of the proposed Augmented Book on primary school students' collaboration?

Beginning with the design process of the AR Book, using co-design methods, the research study will proceed to the evaluation of the final outcome in the classroom. This research will contribute a practical application of AR through co-deign with children. It will also examine the benefit of AR in terms of collaborative experience in primary education.

III. RELATED WORK

Billinghurst, Kato, and Poupyrev pioneered the concept of AR Books by presenting the "Magic Book" [8]. It was the first attempt at creating a transitional AR interface using a normal book as the main interface. Since the first commercial AR Book became available in 2000, a growing number of AR

Sponsor: Saudi Arabian Cultural Bureau in London.

978-1-4673-7606-8/15/$31.00 ©2015 IEEE

Books entered the market [9]. Several research projects have been steered towards the technological development of AR Books [10], [11], [12], [13]. Although some researchers have started to explore the potential of AR Books in education, they have limited the evaluation on preliminary usability tests such as [14], and [15]. Moreover, AR Books should be developed focusing on a specific aspect of education or specific educational subjects [16]. An example of AR Book for children education is an interactive coloring book [17]. Another one for an educational subject is Live Solar System (LSS) which was developed to help children learn Astronomy [18]. Thirsty Crow is also an AR play book for learning numbers [19]. Despite the few numbers of studies that focus on specific areas of education, AR Books should be developed for all kinds of subjects, and explored in different educational aspects in order to fully understand the potential of AR in education. The AR Book of this study will be designed based on an English school book for foreign speakers.

An example of educational AR book is (miBook). It was tested on adults, not children [20]. That study has not identified the target group for its AR Book. Although different studies argue that AR Book can enhance learning experience, there was no evidence of how that conclusion was found. Moreover, most researchers were focusing on the implementation and technological development of their proposed AR Books, rather than focusing on design consideration, or evaluating the effects on education.

Unlike other educational technologies, AR applications are user-friendly, open-access, and can be used by teachers to create daily teaching activities [21]. It can also be cost effective by using off-the-shelf tablets. In addition, AR Book values the traditional paper, and offers a medium that bridges the gap between the physical and the digital. A comparative study between a book supported with a CD and a book augmented with digital media found that the ergonomics in the AR Book provide a flexible interface which supports collaboration between children in educational settings [22]. Furthermore, Dunleavy wrote, "AR is well aligned with situated and constructivist learning theory as cognitive tool or pedagogical approach. As the field matures and more research teams explore the potential of AR to enhance teaching and learning, it will be critical to determine the design techniques that optimize the unique affordances of AR" [23]. Despite the wide argument of AR supporting collaboration, there is a huge lack of studies evaluating this aspect on students in the classroom. Design considerations of AR Book for collaborative learning environment have been identified by [24]. This study will build on these considerations to develop and then evaluate an AR Book. According to Azuma, "The major trend of interaction research is the development of collaborative AR interfaces" [25]. Within this research trend, the question of the impact of these collaborative AR interfaces on collaborative learning is still unanswered.

Looking at the development of this collaborative AR interfaces in the context of child education raises the need for co-designing with children. The methods of co-design are important to understand the children's perspectives, and inform the design process based on their needs. Druin argued that involving children in the design of a technology that supports learning can impact the technologies that are created, and can offer a better understanding of how children learn, which can lead to new theories for education and new teaching practices with technology [26]. Bruckman, Bandlow, and Forte make a similar point of the need of involving children in the design process:

To design for kids, we must have a model of what kids are and what we would like them to become. Adults were once kids. Many are parents. Some are teachers. We tend to think that we know kids—who they are, what they are interested in, and what they like. However, we do not have as much access to our former selves as many would like to believe. Furthermore, it is worth noting that our fundamental notions of childhood are in fact culturally constructed and change over time. In designing for kids, it is crucial to become aware of one's own assumptions about the nature of childhood. Designers should be able to articulate their assumptions, and be ready to revise them based on empirical evidence [27].

The authors' research will build on previous work to explore new perspectives of developing AR Books for children in education using co-design methods. After that, the collaborative aspect of AR Books will be examined on primary school students.

IV. Research Methods

The interdisciplinary nature of this study requires mixing a range of methods at the technique level of the research. The research question involves different fields such as AR, education, and user experience. These multiple concepts suggested taking an eclectic approach of method selection for answering the research questions. Therefore, a combination of qualitative and quantitative methods is selected from the field of user experience research which encompasses several design perspectives, including human-computer interaction (HCI) [28], interaction design, and user-centered design (UCD). Research has shown that user experience is the key to the success of a product [29]. Co-design, which is a form of UCD, will be adapted to inform the process of designing the interactive AR book experience. To answer the first research question, cooperative inquiry will be used to involve children, teachers, HCI experts, and educators as design partners in the design process. It is a co-design approach suitable for use with children aged 7-11 when designing new technology for children [30]. For the second portion of the study, a questionnaire developed from Fun Toolkit, followed by a focus group interview will be carried out in the classroom to evaluate the collaborative learning experience. The questionnaire data will be analyzed quantitatively, and the following focus group data will be analyzed qualitatively for the purpose of triangulation. A description of each method is illustrated below.

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A. Low-tech Prototyping

The research will start with low-tech prototyping which is a brainstorming technique, sometimes referred to as Bags of Stuff [31]. This co-design session will involve groups of children, educators, teachers and HCI experts. The session will produce models and low-tech prototypes, which represent the key concepts and directions for designing the AR book. The children participants (with an average age of 8-10) will be placed in three groups of three with one adult. Three adult participants (a teacher, HCI expert, and an educator) will join each group of children. Firstly, the idea and the aim of the AR book will be explained. Each group will be given a bag of art supplies, and asked to generate a model (low-tech prototype) for the AR book. After that, each group will present their work and discuss it with the whole group, while the researcher will be taking notes of the key ideas of each prototype on a white board. The models will then be given to a different group to build on and create another prototype, and present, with the researcher taking notes again. Finally the ideas on the white board will be discussed with the adult members. The adult participants will use thematic analysis based on the research questions to form key concepts for the design of the AR Book.

B. Usability Evaluation with Affinity Diagramming

After the development of the AR Book based on the data collected from the previous method, usability evaluation will be conducted with sticky note critiquing, which is another co-operative inquiry technique. This formative evaluation session will involve the same previous groups but with new participants to ensure variation of data. A model will be given to each member to experiment with. The participants will be asked to write their likes, dislikes, and any suggested design ideas on separate sticky notes. The researcher will collect the sticky notes and place them on a white board, and then use affinity diagramming to help guide the next iteration of design.

C. VAS Questionnarie

Final evaluation will take place in the primary school classroom to examine the AR Book's effect on students' collaboration. The questionnaire will be based on Fun Toolkit [32] which is a visual analogue scale (VAS), suggested by child-computer interaction (CCI) studies to be useful for collecting opinions from children [33]. It uses a smilyometer to allow children to select an answer based on the visual scale which can be measured as a 5-point Likert scale. The students will experience the AR Book in their classroom during the school day. After that, they will be asked to answer the questionnaire that covers aspect of collaborative experience.

D. Focus-group Discussion

Based on the scores of the questionnaire, students with the highest and the lowest scores will be selected for the focus groups. This conversation will allow students to express more about their experience, and easily give their opinions in their own simple language. It will be useful for gathering information-rich qualitative data in order to supplement the result from the previous questionnaire. Fig. 1 shows a diagram of the research procedures.

Using this set of proposed methods, the research study can provide a clear understanding of different aspects of the research questions. On the other hand, it raises possible challenges concerning the involvement of children in each stage of the research. Revealing these challenges will help design researchers to reflect on co-design methods and techniques for further adjustment to be used with children.

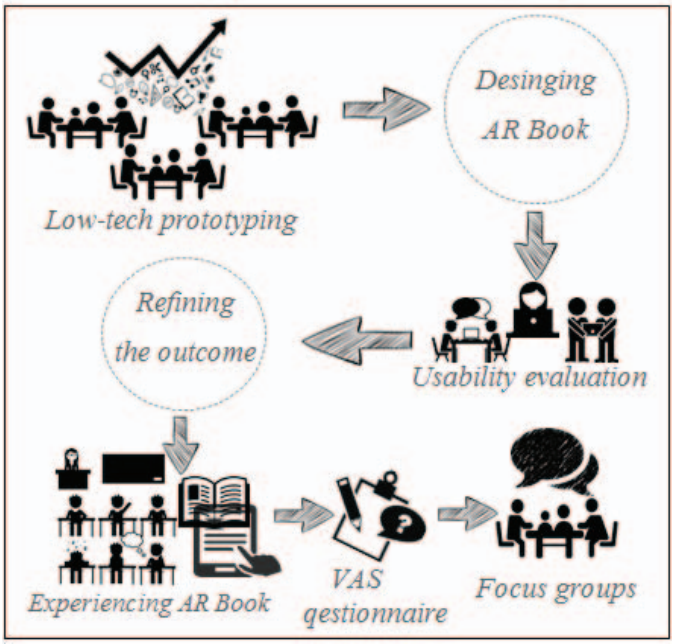

Fig. 1. Research procedures

V. Contributions

There is a growing optimism of AR in education for the future. It is expected that with time, the use and influence of AR in education delivery is likely to become more significant. While there has been some progress in this direction, there is still a dearth of research, and unanswered questions on how AR can be embedded in the educational curriculum for different learning stages, and how it affects different aspects of learning such as collaboration. In this respect, this research fills the gap and it aims to explore the collaborative experience of primary school students when they interact with the AR book. It also seeks to present practical implementation of how AR can be designed for these specific users, suggesting new perspectives of AR books' development through a co-design approach for and with children.

This practice-based research will make a contribution by proposing an interactive co-designed AR Book based on a primary school book. It will also contribute in the novel implication of co-design with children within the context of AR in education. Finally, it will provide a greater clarity of the effectiveness of AR Books on primary school students' collaboration, in which it will advance the knowledge in the field of AR in education in general.

Acknowledgment

The funding source of this research study is Saudi Arabian Cultural Bureau. The authors would like to express gratitude to Al Rowad International School and Ibn Khaldoon School for their participation in this study.

978-1-4673-7606-8/15/$31.00 ©2015 IEEE

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