Supporting low ability readers with interactive augmented reality

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Abstract: Augmented Reality (AR) is a technology which allows the overlay of 3D virtual images onto the real world, and which has been used to develop various educational applications. By actively involving the learner, AR offers interesting possibilities for creating engaging educational media. To study how interactive AR affects different kinds of learners we used an AR based storybook designed for early literacy education. We found that good readers re-told significantly more events from text passages than low ability readers. However, for the AR interactive sequences, there was no difference between the two groups in retell and recall performance. These results indicate that AR books that allow children to interactively engage with the content may be a good learning medium to support low ability readers.

Introduction

Augmented Reality (AR) allows the user to view and interact with virtual content in a real environment. Computer generated content is embedded into the real world and registered in 3D space. This technology has been used to develop various kinds of educational applications many of which were realized as augmented books. The notion of augmenting a traditional medium with virtual content was introduced with the MagicBook (Billinghurst, Kato, & Poupyrev, 2001). This is an AR book containing 3D virtual and animated content registered on real pages, mimicking a traditional “pop-up” book. Augmented books combine the advantages of physical books with new interaction possibilities offered by digital media.

Books can be enhanced with interactive visualizations, animations, 3D graphics and simulations (Shelton, 2002). Various implementations of the MagicBook paradigm range from computerized “pop-up books” that allow the user to see animated 3D content and associated sound (e.g. the eyeMagic book (McKenzie & Darnell, 2004) and books that allow users to interact with the virtual content (e.g. the AR Volcano (Woods et al., 2004), to books in which the user can seamlessly move inside the book, being fully immersed in a virtual environment (Billinghurst et al., 2001). These books and the possibilities they offer have caught the attention of researchers who are interested in studying their use in education and potential benefits they offer in this area.

Figure 1. Examples of MagicBook implementations; left: ARVolcano (Woods et al., 2004); right: eyeMagicBook (McKenzie & Darnell, 2004)
Learning with interactive augmented reality books

Learning and comprehension can be supported by interaction, self-directed learning, exploration and collaboration (Mantovani, 2001). According to Loftin et al. (1993), educators generally agree that experience is the best teacher. However, in reality students are seldom given the opportunity for direct experience of what is to be learned. To a certain extent this could be due to the media that are used in traditional educational.

One advantage of using novel technologies is that they may engage students to work and learn with new these new learning materials (Byrne, Holland, Moffit, Hodas, & Thomas A. Furness, 1994). Regian et al. (1992) argue that if learning can be made more interesting and fun, students may remain engaged for longer periods of time. Incorporating new media in education can augment the reading and learning experience (Loftin et al., 1993), motivating learners and enhancing engagement. There may be unique benefits to having students experientially engaged in the learning context. According to Roussos et al. (1999) there is reason to believe that the ability of Virtual Reality (VR) to situate users in an alternative cognitive frame of reference may be the most valuable contribution to learning. Winn et al. (2002) found that immersion in a virtual environment can help students construct understanding of dynamic three-dimensional processes.

Ucelli 2005 et al. (2005) argue that we can build up knowledge by interacting with others and with materials in an environment that stimulates the learners personal learning style. We learn better when educational content is presented to us through different means and through different channels. Traditional educational methods, which rely on textbook and basic practical lessons, have certain limitations in supporting learners to develop understanding and their intellectual skills (Chen, 2006), and limitations in supporting learners with different cognitive abilities and different learning styles. Students learn through a variety of different mechanisms, many of which are not provided in traditional educational methods (Bell & Fogler, 1995).

Interactive AR can overcome some of these limitations by providing innovative presentation and interaction capabilities, and concrete experience and active experimentation. Integrating text, audio, 2D illustrations, 3D virtual content, and animation allows students to learn according to their preferred learning style. New methods and media cannot only add various educational delivery mechanisms, but “specifically address those areas where traditional methods are weakest” (Bell & Fogler, 1995, p.3).

AR enables the user to experience the real world augmented with computer generated content, and facilitates intuitive interaction with virtual content in real time. Interactive AR can provide a better understanding of complex content that can be actively manipulated and explored (Dünser, Kaufmann, Steinbügl, & Glück, 2006). The physical aspects of an augmented book enable quite intuitive and easy to use interaction methods. For example, different virtual scenes can be introduced simply by turning the book pages, or additional tangible elements can provide other ways to interact with and actively manipulate story elements (Kato, Billinghurst, Poupyrev, Imamoto, & Tachibana, 2000). Tangible interaction can provide innovative ways for children to play and learn, bring playfulness back into learning and support collaborative learning (O’Malley & Fraser, 2005; Price, Rogers, Scaife, Stanton, & Neale, 2003; Tallyn, Frohlich, Linektscher, Signer, & Adams, 2005).

Interactive augmented books do not solely rely on text and static 2D illustrations, so these learning environments could be valuable for learners who have problems with traditional text based materials such as students with low reading skills or dyslexic students. However, there is little known about the effectiveness of augmented books as instructional tools (Shelton, 2002). In our research we have been investigating how young children interact with augmented books and the tangible interaction devices, and how the design of the system, the interactive sequences, and the story impact on interactive behavior (Dünser & Hornecker, 2007a2007b).

In this paper we provide a first investigation of how an interactive AR book that conveys information through multiple channels may support learners with different reading abilities. We examine what good readers and low ability readers are able to remember after interacting with an interactive AR story book.

In the remainder of this paper we first present the system and story book we used for this experi-
ment and then discuss our findings and their implications. Finally we present our conclusions and discuss directions for future work.

**Study**

The AR system and story books. We used a desktop based AR system with a web camera mounted on top of a computer screen which showed the augmented view. The AR story book consists of paper pages and cardboard paddles containing black square ARToolKit markers (Kato & Billinghurst, 1999).

Once the markers are within camera view the augmented book content becomes visible on the screen (overlaid onto the markers). This setup allows the user to see real and virtual content in a combined view in front of them as well as themselves interacting with the story (see Figure 2). An advantage of this setup is that it can be used on standard computer equipment. Hence it can be used in most modern classrooms or homes without requiring expensive additional hardware. However, it does not provide an integrated view of real and virtual objects like other AR setups using head mounted displays.

The book we use is “Big Feet and Little Feet” which tells the story of two little baby chickens who have been left behind and have to overcome several obstacles to find their mother. This story and other AR books have been created by the BBC for their AR-Jam project and are aimed at early literacy education (Dünser & Hornecker, 2007a; 2007b; Smith et al., 2007). The story-book consists of text pages and AR sequences. The text pages are shown on the computer screen and the children use the mouse for interaction (next page, back, close page). By clicking on a listen button the text is read to the children.

![Figure 2](image_url)
In the interactive AR sequences the paddles (and paper pages) are used for interaction. The children have to solve different interactive tasks in the AR sequences. Each interactive sequence is represented on a separate book page. Therefore the children have to turn the paper pages before starting with a sequence. The pages usually have ‘hot spots’ next to the markers, indicated by a grey outline or other drawings. Placing paddles on a hot spot usually triggers certain events. For example, in one task the chickens have to sneak past the sleeping fox without waking him up. For this the children have to move their paddles (augmented with 3D models of a chicken) along a certain path from the start to the finish sign. If the chicken come too close to the fox he wakes up, growling, and the children have to start again (see Figure 3).

**Participants**

Twenty-one six and seven year olds (10 male, 11 female) from two primary schools read and interacted with the AR book.

The study was conducted at a Library and Learning Centre that collaborates with local schools and offers various literacy programs. The participants were recruited from two nearby schools. The children were chosen by their teachers according to their reading skills. One group of nine children was identified by their teacher as being good and avid readers. For the other group, twelve children with low reading skills were chosen who were less curious about or interested in books. Most children from this school lived in a socioeconomic neighborhood with lower income levels.

**Method**

All children read and interacted with the book in a controlled experimental setting either in pairs (9 pairs) or individually (3 children). The experimental sessions lasted for approximately 40 minutes. Two researchers were present during the sessions to support the children if problems arose or they got stuck with the story. With some initial help, most children were able to interact with the system without much prompting. After the children finished the story-book they were interviewed individually. The child’s ability to recall and retell the story was scored using a list of story events. Retell performance was scored as the number of events correctly retold by the children without any hints. If, after the children finished retelling the story, some events were not retold the interviewer gave some hints (e.g. “What happened after…?”). Recall was scored as the overall number of events recalled. We were interested in studying which children could retell or recall more events from either the text parts or interactive sequences. Hence we scored eight events that were mentioned in the text parts and another six events that related to interactive sequences.

For completion time analysis we measured times spent for text passages and times spent for interactive sequences. In a final semi-structured interview we asked the children several questions such as ‘What did you like best?’ or ‘Would you like other books like this?’.

**Results**

Figure 4 shows the average recall and retell scores for the text and interactive sequences, from both the good readers and the low ability readers.
We found that the good readers retold significantly more events from text passages ($t(19) = 3.36, p < .01$) compared to low ability readers. Good readers retold on average 44.44% ($SD = 14.13$) of events, whereas low ability readers only retold 20.83% ($SD = 17.13$) (see Figure 4). However, there were no significant differences in retell performance of interactive sequence events between the two groups. Thus good readers remembered significantly more events from text passages than low ability readers but not significantly more events from interactive sequences. No significant differences could be found for recall performances. Therefore, with some hints from the experimenters, the two groups scored similarly for both the text and interactive sequences.

The analysis of completion times showed that good readers finished significantly faster with both the text passages ($t (19) = -3.37, p < .01$) and the interactive sequences ($t (19) = -2.94, p = .01$). Good readers spent on average 6.85 minutes ($SD = 1.60$) with text passages and 8.42 ($SD = 4.50$) with interactive sequences, for low ability readers these times were 8.84 ($SD = 1.11$) and 12.89 ($SD = 2.42$) respectively. Overall the time spent with the augmented books was on average six and a half minutes longer for low ability readers. They interacted with the book approximately four and a half minutes longer and spent around two minutes longer with the text passages. As most children choose to listen to the story, and thus listened to the same pre-recorded voice, the time differences for text passages are smaller. Although both groups were able to interact with the stories on their own after some initial scaffolding, low ability readers tended to get stuck more often and needed a little bit more support which explains the longer interaction times.

Analyzing the children’s interview answers we found no systematic differences between the two groups. When asked what they liked best, almost all children referred to events of interactive sequences with ‘cracking the eggs’ (the first sequence where the children had to bang their paddles to crack virtual eggs) being the most favourite. Two children mentioned that they liked using the paddles.
When asked if they would 'like other books like this', four of the low ability readers answered with no, while all good readers answered yes. This might be because we asked if they liked other 'books' like this. Most children referred to the AR book as a 'computer game' rather than a 'book'. In future studies we might have to rephrase this question to see if this is based on misunderstanding or if we can find a tendency that low ability readers are in fact less keen about such books.

Discussion

In this pilot study we found that the good readers retold significantly more events from text passages than the low ability readers. However, for the AR interactive sequences, there was no significant difference between the two groups. These results give a first indication that interactive AR books may be a means to help low ability readers to perform on similar levels as good readers in terms of being able to retell information. In further studies we plan to study this with bigger sample sizes and more rigorous testing methods.

Our study suggest that AR educational media could be a valuable and engaging addition to the predominantly text based materials that are used in schools today. Chen (Chen, 2006) argues that the current textbook based methods pose various limitations in assisting learners in recalling knowledge. Interactive AR allows designers of educational materials to integrate different media and delivery mechanisms, and allows students to take in knowledge according to their preferred learning style. While conveying information through different channels can be helpful especially for learners with certain difficulties, we all can benefit from multisensory learning (Bell & Fogler, 1995).

Apart form just presenting knowledge, augmented books enable readers to interact with the content. Therefore learners not only passively take in information but actively engage with the content. Being able to interact with the story seems to be an important factor for engagement and might also facilitate retention of story events. Winn (Winn, 2003) for example found that bodily activity in virtual environments can support enhanced understanding. Further indication of how interacting with virtual environments can engage students is given by Byrne et al. (1994), who report that at "risk students" showed up to class more often and with more enthusiasm during a program where they could create their own virtual world. However, we cannot preclude that some of this engagement caused by experiencing and interacting with these technologies is due to a novelty effect. This issue should be addressed in future longitudinal studies.

Children in our study enjoyed interacting with the augmented books and 'moving around' the paddles. They referred to the books as games, some asked how it worked, and one child even said "It's magic". When asked what they liked best the story remained dominant in their subjective experience. In earlier research (Dünser & Hornecker, 2007b) we discussed how story design and the design of interactive sequences influence engagement and enjoyment of the overall experience.
Conclusion

We presented a study to investigate how interactive AR books can support children with different reading abilities. We found that these can be very engaging educational media that can overcome some of the limitations of predominantly text-based materials. By addressing multiple learning modalities and offering interaction with the content AR books can support students who have problems with traditional textbooks.

In future work we want to study the exact mechanism how interactive AR can influence learning. We have to better understand the benefits that such novel learning media have for education.

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