Collaborative Augmented Reality in Schools

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Abstract: Augmented Reality as an interactive real-time technology combining real and virtual objects in a real 3D space carries enormous educational potential. We describe a project (ARISE: Augmented Reality in School Environments) that aims to realise this potential by developing a collaborative, robust and affordable Augmented Reality learning platform for schools. The learning affordances of Augmented Reality are discussed, and an educational application is described that supports remote collaboration between students in a shared 3D workspace, where students from different countries present, discuss and manipulate virtual objects relating to their local culture. The evaluation of the application is based on a distributed summer school project involving students from two European countries. In addition to more conventional evaluation approaches, special requirements for evaluating remote collaboration in a shared Augmented Reality workspace have been met with a customised approach involving synchronised video observations in both locations with subsequent editing of the material into and a single screen giving a comprehensive overview of the collaboration from both ends. The results of the evaluation study are currently being analysed, but preliminary findings suggest that the Augmented Reality learning platform has been well received by students and teachers, and is well suited for remote collaborative learning.

Overview
Augmented Reality (AR) has a range of affordances that resonate with learning theory. Reflecting the early stage of the technology however, much of the research into AR focuses on technical issues while only little research has been carried out to explore its educational potential. One reason for this has been the lack of robust, reliable and affordable AR displays and applications that allow the technology to be evaluated in an authentic educational context. The ARISE (Augmented Reality in School Environments) project tries to fill this gap by developing an affordable AR learning platform suitable for deployment in schools, and creating educational applications that leverage the specific learning affordances of the technology. The main objective of the project is to test the pedagogical effectiveness of AR in the classroom and to facilitate remote collaboration between school students. The resulting AR display Spinnstube is based on off-the-shelf hardware components and open source software, thus keeping costs to a minimum while offering a reliable and high quality AR experience. Up to four Spinnstube devices can be arranged around a table for co-located collaboration, as the system keeps the desktop free from construction parts that might impede natural communication or restrict the movement of hands when sharing real or virtual objects. In a remote collaboration scenario, Spinnstube devices are networked to provide a shared workspace where collaborating students can view and manipulate virtual objects and communicate over an additional audio channel. In order to evaluate the learning platform, from both usability and pedagogical perspectives, three successive educational applications were developed between 2006 and 2008 and evaluated in summer school projects with students from Malta, Romania, Lithuania and Germany.

Learning Affordances
As an interactive real-time display technology that combines and registers real and virtual objects in a real 3D space (Azuma, 1997), AR has enormous educational potential. The presentation of objects in 3D lends itself to the exploration of spatial problems that are difficult to grasp in 2D media (Woods et al., 2004) and supports the development of spatial abilities (Seichter, 2007) as an important component of human intelligence (Gardner, 1983). The combination of real and virtual objects in a real 3D space gives rise to new kinds of tangible user interfaces that eliminate the artificial seam between the real world and the shared digital task space (Ishii et al., 1994) and may be more suitable for younger children (Billinghurst, 2002), a quality that resonates with Piaget’s (1970) view that learning materials and activities should involve the appropriate level of motor and mental operations for a child of given age. The ability of AR to offer different views on the same object or situation can be used to facilitate extrapolation by helping learners to go beyond the information given (Bruner, 1973) and to aid cognitive development through adaptation by giving alternative views on already familiar objects or situations (Piaget, 1970). Collaborative AR systems support learning through communication and social interaction (Bandura, 1977; Vygotsky, 1978) where learners develop a deeper understanding of concepts by exchanging ideas with peers engaged in the same activity (Salomon 1993) and reflecting on their experiences (Kolb, 1984). Finally, AR engages and motivates learners (e.g., Hornecker and Dunser, 2007; Lamanauskas et al., 2006, 2008) and can provide a bridge from instruction to construction: the dynamic control of augmentation.
levels enables a smooth transitions from the presentation of information to active exploration and experimentation.

Remote Collaboration around Virtual Objects
With the aim of leveraging these affordances in educational applications, the project consortium has developed three successive prototypes, each reflecting the evolving technological capabilities of the AR learning platform and addressing different pedagogical approaches. The first two applications, process visualisation in human biology based on behaviourist and cognitive learning theories, and guided construction of chemical elements based on constructivist learning theories, were originally planned to include local collaboration implemented as individual activities due to practical issues. These applications are described elsewhere (e.g. Balog et al. 2007; Lamanauskas et al., 2006, 2008; Priebeau et al., 2008). The third application, focusing on cultural exchange, involves both local and remote collaboration around cultural heritage objects and is based on social learning theories. The application was evaluated in a summer school project held over two days in Lithuania and Germany, involving twelve pairs of 13 to 14 year old students.

Preparation of Artefacts
Students prepared for the summer school by discussing suitable topics of interest, making local excursions, and creating meaningful 3D objects relating to their local history and culture. The process was supported by a novel 3D sculpting tool for the Spinnstube, and a desktop-based tool to create 3D box objects from photographs. Thus, the preparation involved local collaboration between students preparing and discussing the artefacts used to anchor remote discussions in the summer school, and in addition students had an opportunity to familiarize themselves with the Spinnstube AR display.

Introduction by Video Link
Before starting their Spinnstube session, students had the opportunity to get to know each other and discuss organisational issues relating to their collaborative Spinnstube session through a live video link using the VoIP software Skype. Students took up the opportunity enthusiastically and despite some language problems (the project language was English) most students used up all their allocated time to talk to their counterparts, exchange contact details, and in some cases even arrange further Skype meetings outside summer school.

Spinnstube Remote Collaboration
Following the Skype session, students moved on to their Spinnstube collaborative session with the same partner. Two Spinnstube AR displays were in operation at each location, making it possible for two pairs of students to take part at a time. Due to the specific requirements of the visualisation software, the room was semi-dark. One technician was present in the room on stand-by for technical problems, and the students’ teacher was available for operational and organisational questions. No language support was given.

After taking their seat in the Spinnstube, students put on a pair of shutter glasses to gain stereoscopic 3D vision, and a headset for communication via the audio link. Once the partner’s presence was confirmed via the audio link, each student could either start their own presentation by loading artefacts into the AR display and talking about them, or follow their remote partner’s presentation, inspecting the displayed artefacts and listening to their counterpart, occasionally asking questions.

The presenting student then continued by asking their counterpart questions about the presented content, both to test the partner’s understanding and to discuss similarities or equivalents in their own local culture. This part also included the presenting student erasing part of the artefact on display in the shared workspace and asking their counterpart to reconstruct it. As both students were able to observe the reconstruction process, they could discuss the progress and result. The Spinnstube sessions took approximately one hour each with students switching roles at half time so that each side had a chance to present their content.

Evaluation
The evaluation of the application takes into account pedagogical, usability and social interaction aspects, and involves different researcher teams using both quantitative and qualitative approaches to increase validity and reliability. Of special interest in the context of evaluating remote collaboration in a shared AR workspace is the synchronised video observation of summer school sessions involving two high-quality video cameras in each location audio-recording the spoken communication and video-recording participants’ gestures and facial expressions (front-view) as well as the 2D double image from the projection surface (rear-view). The resulting material can be edited into a 4-in-1 overview that comprehensively documents the remote collaboration from both ends and thereby gives a more detailed picture of the remote collaboration than possible with traditional techniques. A thorough analysis of the material is currently under way.

Conclusions
Evaluation results for the first and second applications have confirmed that many of the specific learning affordances of AR can be leveraged in a school context to create effective and enjoyable learning activities. Diverse representations of related issues offered in the human biology application proved effective in conveying complex content. Spatial 3D representations of atoms and molecules, together with a haptic user interface in the chemistry application, were well received and led to a deeper understanding of the matter among students. Finally, the AR display dramatically improved students’ motivation and engagement, confirming similar reports in the literature (e.g., Hornecker and Dunser, 2007).

Regarding the suitability of the Spinnstube AR display as a collaborative learning platform, the picture is less clear. Due to fundamental design issues, co-located collaboration is only possible when each participant uses their own AR display, which proved impractical in the first two summer schools. As for remote collaboration, the evaluation results from the last summer school are still pending. Anecdotal evidence however suggests that the system is very well suited for remote collaboration as it enables students to view and manipulate virtual objects in a shared 3D workspace in real-time and simultaneously communicate over an audio link.

References

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