Exploring the Use of Augmented Reality to Support Science Education in Secondary Schools

Mattias Davidsson, David Johansson, Katrin Lindwall
School of Computer Science, Physics and Mathematics; Linnaeus University
Växjö, Sweden
{mattias.davidsson, david.johansson, katrin.lindwall}@lnu.se

Abstract— **During the last 2 years we have conducted several trials exploring how augmented reality and mobile technologies can be used to support learning and teaching in science education. In particular, we present the on-going efforts that are part of the EU funded project Science Center To Go. We provide an overview of the different activities, the lessons learned and what we propose as ways to forward making the technology, mobile, affordable and in the long term – ubiquitous available.**

Keywords: Augmented Reality; mobile learning; inquiry-based learning

I. Introduction

The latest advances in mobile computing and sensing technologies allow for experimenting with Augmented Reality (AR) in ways that go far beyond of what could be done only with expensive military applications a few years ago. Uses of AR can now be found in many domains including medicine, urban planning and marketing, just to mention a few of them. In the field of education, AR has been used in laboratory settings and more recently various tested in real classrooms [1-3]. Novel uses of AR make it possible to combine educational and entertainment activities in new ways, thus creating new opportunities to support learning and teaching in formal and informal settings [4]. Research efforts regarding earlier uses of AR in education indicate that in classroom settings, students tend to work more effective together if they can share a common workspace that combines physical and computer generated visualizations, something that can be difficult in traditional desktop applications [5]. By using AR applications that rely on a tangible interface metaphor, physical objects can be enhanced by having virtual information tied to them, allowing students to control it in an intuitive way and collaborate and communicate in a more natural way within the physical environment.

In the EU Science Center To Go (SCeTGo) project a series of miniature exhibits that are enhanced by augmented reality have been developed to provide new ways to visualize complex physical and natural phenomena. The particular solutions that have been designed and developed in this project to allow learners to interact dynamically with the augmented exhibit has been tried out and tested. In addition to making it possible to visualize invisible physical quantities, the proposed software solution allows to control the variables of importance for the phenomenon under exploration.

The preliminary findings of the trials carried out with teachers and students using the AR technology provide some indications that the students perceived the learning activities as exciting and joyful, thus increasing motivation among participant learners. In the rest of the paper, we will first present some background information regarding the use of AR for learning, and some related work in this field. We further proceed by describing the SCeTGo project, followed by description of our findings. The paper concludes with a brief presentation of, and a discussion about our on-going and future efforts.

II. RELATED WORK

Augmented Reality is a term describing technologies that allow a real-time mixture between computer-generated digital content and the real world [6]. AR can also be defined as being an overlay or superimposing of digital data visualised on top of the real view of the surrounding environment. From a technological perspective, AR is often related to wearable computers and overhead monitors [3]. People usually associate AR with expensive hardware that requires significant processing capability, which can be found only in research and specialist environments, as fighter pilots cabins. Nevertheless, nowadays we can witness a wide variety of AR alternatives that can be implemented by much simpler solutions, such as a laptop and a web camera or even with the use of a PDA or a mobile phone.

Previous research efforts in the field, show that AR can provide some benefits for education. Construct3D is a tool for exploring and learning about geometry. It takes aspects of computer-aided-design (CAD) and combines it with AR technology to create a learning tool aimed to promote social interaction in the shared space, allowing its users to communicate with each other in a natural way [7]. Construct3D was mostly used in an experimental setting, requiring personnel doing maintenance and technical support to run. One key finding from the project was that in order for the AR application to be used for learning, it needed to be seamless and transparent; allowing the user to focus on the actual task rather than the application itself. In

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line with the constructivist theory of learning, it is good for students to have the opportunity to explore on their own or in collaboration with others, however some guidance might be required or the task at hand might be too hard to understand. In the EU funded Connect Project [8], learners have been using special head-mounted displays and wearable computer backpacks to visualize different complex scientific phenomena both in schools and museums. This project showed some of the potentials and benefits of using AR, but at the same time turned out to be to complicated and hard to implement in everyday school practices schools.

III. The Science Center to Go Project

The aim of the SCeTGo project is to integrate AR technology into both formal & informal science teaching.. By offering learners the opportunity to gain exposure to everyday science, the hope is to facilitate lifelong learning. Science Centers (SC) adopt the philosophy of [9-10] by offering first hand interactive science experiences in the form of exhibits, offering natural ways of active playful learning. AR and other modern visualization techniques are often used to enrich the experience and to display hidden phenomena, but the SCeTGo approach goes one step further and aims to bring the mixed reality experience of a SC into a school's classroom and/or everyone's home. The miniature exhibits (see example in fig. 1) are portable and can be used with off the shelves technology to be used anywhere at anytime, combining the powerful capabilities offered by tailor-made exhibits and AR.

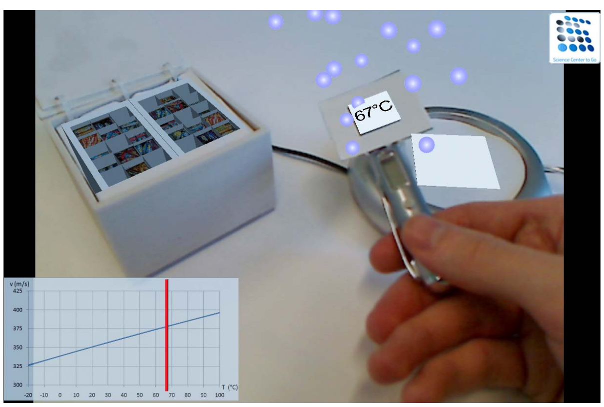

Figure 1. One of the SCeTGo miniatures illustrating heat as the motion of molecules: moving slower or faster if put on top of the fridge (left) or heater (right). An augmented thermometer shows the "virtual" temperature.

IV. ONGOING EFFORTS AND FINDINGS

In the last 3 years we have been conducting different activities exploring novel uses of AR in education. In one of these projects, students collected and gathered geometrical data outside of the school using mobile devices and a customized application developed for this purpose. Using these data sets, students designed a model of a building in 3D, to be displayed using AR. It was that shown that these activities in an outdoor setting, supported collaboration, discussion, and reflection about the math problems involved. The students reported that the aspect of exploring the physical world outside of the classroom combined with this data using new visualization techniques was a novel and good way to experience math [11].

SCeTGo further develops the line of thinking described in [12], as well as the thoughts behind multimodal learning [13] by including sound, touch, and manipulation of the virtual overlay of visual representations on top of the real objects. During the testing phase of the SCeTGo project, we noticed quite a large interest in the technology and its application both from teachers, students (see fig. 2). Almost none of the people involved in the trials had any prior experience with using AR.. The trials took place during the spring 2012 with several local secondary schools involving a total of 19 teachers and 73 students. After the trials, all these people were surveyed. Out of these, 3 teachers and 8 students were also interviewed more in depth putting an emphasis on expectations, affordance, usability, ease of use and understanding. A common denominator among the students was that they found the technology exciting, easy to use, and above all it was experienced as something very different to normal lessons. Hence, there was a clear element of novelty that might have acted to our advantage when presenting the project. One negative point of view from the students was that the theory behind some of the miniatures was hard to understand. The reaction from the teachers was also generally positive. Typical questions concerned when the product would be available to them, and potential costs. One opinion especially worth mentioning was that, for the teachers to take the step and use this kind of technology in class it would have to be more or less 100% likely to work – 100% of the time.

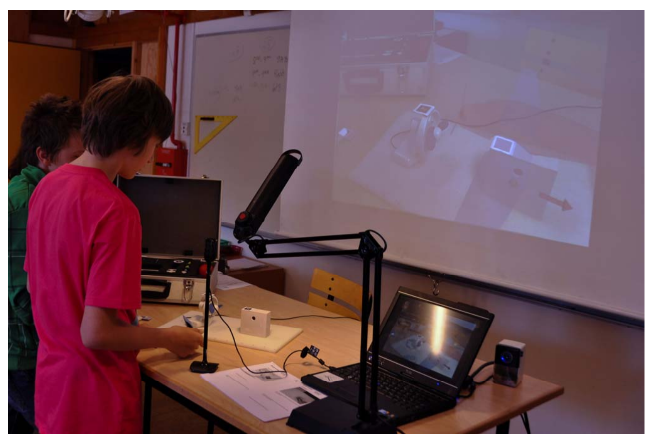

Figure 2. Students manipulating the physical miniature of an airplane, thereby changing the lifting force as illustrated in the augmented picture shown on the screen.

Another aspect was commented by one of the teachers in the following way: "The only problem I see in the way this particular phenomenon is visualized is that it can produce misconceptions of the students' scientific thinking". The teacher has to explain to the students that this is a model and it might not the totally accurate representation". Thus, as in any learning setting, especially including aspects of personal inquiry, the teacher needs to have a clear and deep understanding of the topic and he/she need to discuss the content with the learners to clear out misconceptions.

V. DISCUSSION AND FUTURE EFFORTS

In order for AR applications to be widely adopted in education, it would be fair to assume that the technology needs to be easy to use for the average teacher/educator. Early designs like those tested in the Connect Project [8] that heavily rely on experimental/complex technological solutions will be hard to implement in schools mainly because the need for special education and training. This is likely to change in the very near future, as wearable computers, mobile devices, and AR applications are becoming ubiquitous. One major benefit of combining physical and computational media is to provide different ways of thinking about the world if compared to interacting solely with digital representations or solely with the physical world. The purpose of providing this kind of multiple representations is to provide a link between the abstract data and the physical activity of collecting it, in a way that enables learners to reflect on how the different combinations of the variables they have been measuring or aspects they are investigating, affects these processes. The visualizations of these phenomenon also provide a sense of personal relationship with the data that can facilitate learners' ability to recall what happened for the various projected data points connected to what they experimented and saw. Having a more intimate relationship with the abstract data, in the sense of knowing how they were physically created, it may trigger strong associated concepts related to complex learning [14].

At the present stage, new versions of the SCeTGo miniatures are under development and the ubiquity of touch based technology such as tablet computers, smart-phones and interactive whiteboards are becoming a reality in Swedish schools. With this as a backdrop, we are currently investigating the affordance of these technologies and how they, together with AR and also Kinect type of motion tracking hardware and software, can be combined to help students understand and see the connections between the mathematical representations of the physic in everyday phenomenon. Special efforts under current exploration include: 1. Investigating the possibilities mentioned earlier in this section by using off the shelf technologies, and: 2. Making the students and their bodies more involved in the creation of the representations of the studied phenomena [12]. Furthermore, we propose to develop a system for collaborative manipulation of the AR virtual objects disconnected from the tangible physical objects, making it possible to "touch" and move the objects as seen by the collaborators using either personal hardware such as tablets, smart-phones or computers. It would also be interesting to investigate if the effects of the increased interest in the learning activities and hence the curriculum will survive the novelty factor once the AR-technology is no longer to be considered news for the student. Finally - how will teachers make clear and discuss the fact that what is studied are models that are only possible by using mobile and interactive visualization technologies with given limitations and not replications of reality?

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