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Evaluation of a portable and interactive augmented reality learning system by teachers and students

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Abstract

This study investigates the role of teachers' and students' acceptance of a learning approach within the Science Center To Go system. Science Center To Go specifically makes miniaturized Augmented Reality exhibits available out of science centers. In this paper we focus on a qualitative teacher- and student-centered evaluation of the technical acceptance and pedagogical effectiveness of the system. The study indicates that acceptance is high in general and that pedagogical effectiveness is very positive rated. It also shows that a meaningful evaluation of such a system in a real school environment heavily demands prototypes with extraordinary usability and robustness, to be fully reliable for teachers.

Keywords

Mixed and Augmented Reality, Hands on, Technology acceptance, Technology-enhanced learning, Usability evaluation

1. Introduction

In contrast to Virtual Environments that completely immerse users into a virtual world, Augmented Reality (AR) combines the real world with artificial, computer generated elements. The mixture of real and virtual information, as a new kind of user experience conducted in a science centre, has been shown to positively influence students' intrinsic motivation, as well as cognitive learning, especially of low achieving students. It thereby can help to maintain pedagogical effectiveness [1-4].

However, the implementation of AR in school environments as a new way of learning was so far only realized and evaluated in very few cases [5, 6]. The Science Center To Go (SCeTGo) project is offering an innovative approach to the needs of teacher instruction in the classroom, by adapting an existing AR system for science centres and other informal learning settings [3, 7].

In the framework of SCeTGo a series of miniature exhibits were developed, illustrating various physical phenomena which enable learners to visualize the invisible (e.g. electric

or magnetic fields, molecular movements) through AR technology. In this manner learners have the chance to control conditions in order to uncover and visualize physical phenomena.
In so doing they participate in an active learning form that enables students to investigate physical phenomena instead of simply memorizing facts. Pupils enhance their experimental and analytical skills together with an appropriation of knowledge with regard to natural sciences.
In order to improve quality of the miniature exhibits, animations of physical processes in the classroom are accomplished by pedagogical scenarios. A detailed description is presented in the current issue [15]. Scenarios are tangential to the curriculum. An inquiry-based learning scenario is performed as follows:

Phase 1: Question Eliciting Activities
Phase 2: Active Investigation
Phase 3: Creation/ Formation
Phase 4: Discussion
Phase 5: Reflection

This way the SCeTGo setup assures an innovative inquiry-based learning approach that is tailored to students` needs and implements not only "hands-on", but also 'minds-on' experiments. Additionally, it allows teachers a successful application within school curricula without the need to a time consuming preparation of teaching material.
Bringing AR into classrooms seems to be a promising approach in consideration of the referred advantages. However, making AR computer-mediated learning technology attractive to teachers needs to consider teachers requirements: Teachers still act as key players in the use and acceptance of any new educational technology and there remains an enormous gap between developing AR technologies and its implementation in school [4]. Therefore this study is one of the few attempts to investigate the role of teachers' and students` acceptance of AR in school environments. Both user groups (teachers and students) have their own requirement and operate with a new AR technology in a different way. Which conditions have to be considered that AR has an impact on education in long term?
The main objectives of the present study include a validation of (1) the pedagogical approach and educational value as well as of (2) technical issues of the SCeTGo system.
In the following, we will present the suitcase and its first evaluation results. After describing the SCeTGo suitcase in section 2, we will illustrate the evaluation methodology and results in section 3 and 4. Finally we will discuss our findings in section 5.

2. The Suitcase

The Science Center To Go (SCeTGo) is based on work of the consecutive projects CONNECT [7] and EXPLOAR [10, 11].
The suitcase stores all necessary elements for the existing five exhibits. Also included in the suitcase is a laptop with a touch screen, a webcam and a little stand. The webcam is placed on the stand and connected to the computer. On startup the computer directly starts into the SCeTGo main screen; ready to set up one of the exhibits in front of the webcam. The webcam stream is displayed on the computer screen and augmented with additional content. In the following we will briefly describe the five exhibits currently included in the suitcase. A more detailed description may be found in [11]. Further information to pedagogical intentions pursued by the miniatures is given in [15] [17].

2.1 The Mini Wing Experiment

The Mini Wing consists of a small box that stores the model of an airplane wing. The wing is about 5.5 cm long, 3 cm wide and 1.5 cm high.
The wing is mounted on an axle to change its angle of attack. A USB powered fan generates an air stream. The air stream is visualized in the AR view as shown in Figure 1.

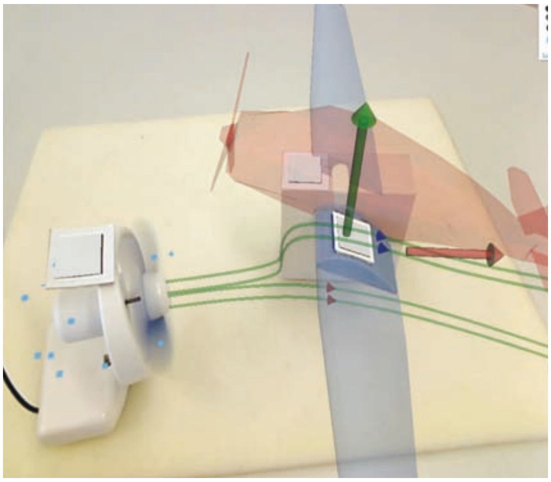

Figure 1. The Mini Wing exhibit augmented through an airflow coming from a USB powered fan. Two arrows are displaying the lift and drag, the movement of air molecules is displayed at the fan.

Forces of lift and drag are indicated through arrows at the wing model. The virtual content of the augmented view is instantly adapted for new angles of attack. Learners might change the airstream by changing the position of the fan as well as trying out differently shaped wing models.

2.2 The Doppler Experiment

The Doppler Experiment consists of a sound emitting fire truck and a virtual microphone representing a listener. The sound of a fire truck siren together with a visualization of its wave propagation is instantly simulated in Augmented Reality (AR). The simulation is chronologically scaled down by a factor of 500. Users are able to move both, the listener and the sound fire truck.

2.3 The Double Slit Experiment

Learners are invited to test the double slit with a virtual cannon shooting big particles or electrons at a slit. The cannon might also be replaced by a source emitting waves with a certain frequency. In particle mode a virtual cannon fires little "cannon balls" at the slit screen. After numerous balls a pattern analogous to a slit appears at the projection plane (compare Figure 2).

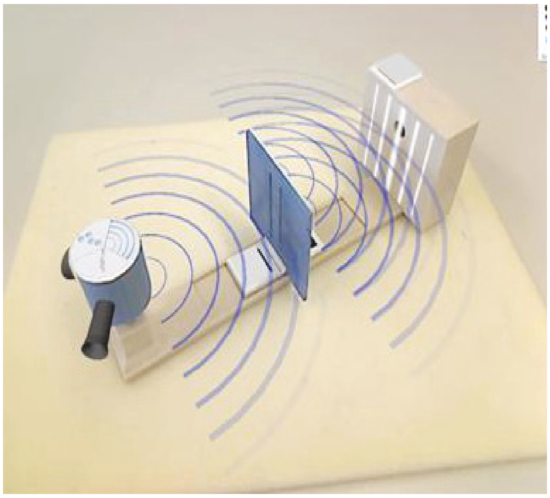

Figure 2. The double slit setup consisting of a floor board (dark), the slit board in the foreground, a box as a projection plane, and a virtual cannon

Users are able to move the slit board, and switch between single and double slit.

2.4 The Double Cone Experiment

The double cone miniature consists of two rails of 12 cm length each. The rails are jointly connected on one side; on the other side each rail rests on a ramp. The ramps provide an inclination of 1.5 cm by 3 cm. Additionally four rolling objects are available to be put on the rails. Three of the rollers are double cones and one is a cylinder. The opening angle measured alongside the double cones differs between 15, 30 and 45 degrees.
Users may change the slope or opening angle of the rails. The AR system tracks the setup and displays the formula describing the current constellation, directly when users make changes.

2.5 The Boltzmann Experiment

The Boltzmann Experiment contains a USB powered freezer, a thermometer, and a USB powered heating surface. Learners are able to feel and measure the temperature at different areas of their setup. Additionally, molecule movement is visualized at the tip of the thermometer. On the AR screen users might observe that molecules in areas of a high energy, near the heating surface, move faster than molecules around areas of low energy, e.g. inside the refrigerator.

3. Evaluation – Material and Methods

During the implementation phase of the SCeTGo system (07/2010 -11/2011) miniatures were introduced to teachers and students.

SCeTGo was presented to 72 Finish pre-service science teachers and 27 Romanian in- service science teachers at schools within a professional development framework. During such courses, participants were offered information about the project, the Augmented Reality (AR) technology and its application in the classrooms.

Learning scenarios were presented and teachers were given an introduction about technological aspects, including an explanation about the handling of the tool. Thereby, teachers could interact with all exhibits and AR features that were developed in the framework of the SCeTGo system.

Scenarios, together with the corresponding miniatures have been shown to be adequate for pupils aged between 15 and 18 years [15] [17].

As part of students' evaluation learning scenarios and miniatures were presented to a total of 512 Romanian pupils aged between 14 and 18 years. Scenarios, together with the corresponding miniatures were divided evenly to appropriate age groups. After the successful implementation workshop leaders consulted teachers as well as students, willing to be interviewed.

Altogether 29 Finnish pre-service science teachers (gender: ♀ 22, ♂ 7; age: Ø 26.8, range: 19-51 years) and 19 Romanian in- service ones (gender: ♀ 16, ♂ 3; age: Ø 45.8 range: 33-55 years) teaching in inferior and upper secondary school, were asked about their attitudes towards SCeTGo and its carrying out in school.

Additionally, individual interviews have been conducted with 32 Romanian students (gender: ♀ 23, ♂ 9; age: Ø 15.4, range: 14-17 years).

Two categories of questions with regard to teachers' and students` motivation to use the system in consideration of usability and pedagogical aspects were addressed. Interviews had an average duration of 20 minutes. To guarantee homogeneity of data, interviewers followed general principles according to descriptions of Lamnek [12]. All questions were adjusted in an open form and interviews were incorporated in a trustful situation.

Interviews were analysed following Mayring`s qualitative content analysis [13]. A category was formed, if not less than two interviewees referred to the same aspect.

4. Evaluation – Results

We present a summarising content analysis, integrating the results of individual interviews that have been conducted with the sample reported above. Selected questions considering (1) pedagogical effectiveness and (2) technical acceptance of the system are presented.

4.1 Students` Evaluation

All students asked if they were satisfied with the lesson answered in the affirmative.

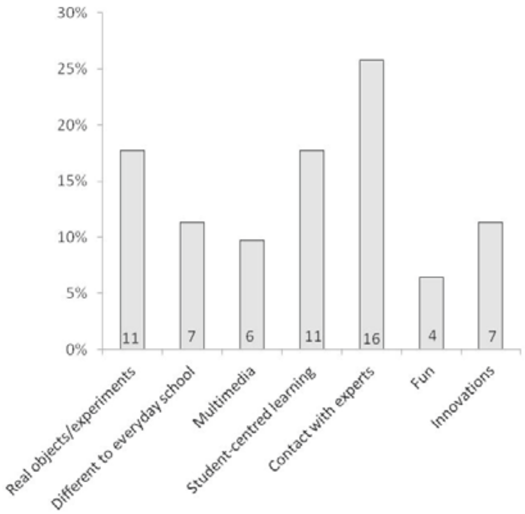

Figure 3. Results of content analysis with reference to the question: "Why did you like the lesson?" (students, n: 32). Percentages (relative frequencies) refer to total number of answers given, numbers in bars relate to absolute frequencies.

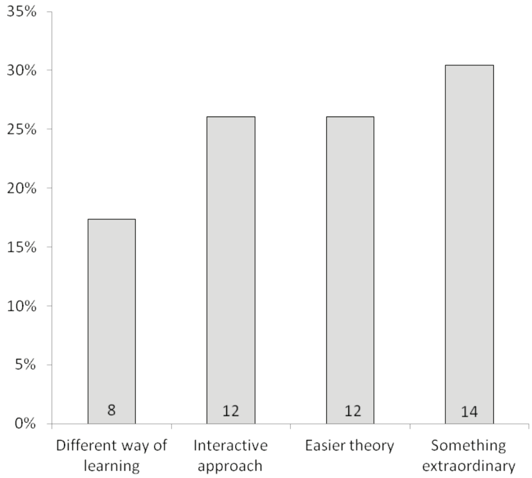

Figure 4. Results of content analysis with reference to the question: "Why did the lesson raise your interest in science?" (students, n: 32). Percentages (relative frequencies) refer to total number of answers given, numbers in bars relate to absolute frequencies.

As shown in Figure 3, students liked most contact with experts (25.8%). Furthermore they favored learning with real objects and real experiments (17.7%), same ratio of interviewees preferred a student-centered learning approach. In addition a lesson, different to everyday, school was looked upon as favorably as the innovative approach (11.3%).

The multimedia aspect was mentioned in 9.7% of cases, to a lesser extend it was stated that learning with miniatures was fun (6.5%).

Additionally, students were asked if the lesson raised their interest in science (no figure shown). Most of students answered positively (87.5%). Nobody negated the question and only a minority of students were unsure about this question (12.5%).

The lesson raised students` interest in science for different reasons (Figure 4). In a majority something extraordinary, different from everyday class (30.4%) was stated as a cause. An interactive approach, as well a simplification of theory, easier in comparison to normal lessons was mentioned to a same amount (26.1%). In addition, a different way of learning provided by the exhibits was pointed out (17.4%).

With regard to usability features students were asked, if they have had any problems concerning the usage. Only a small number of pupils (15.6%) mentioned technical problems, however the majority (84.4%) did not have problems with reference to the usage of the exhibits.

4.2 Teachers` Evaluation

Participants were asked, if they were motivated to use the SCeTGo system in their future lessons (no figure shown): 75% agreed, 18.8% would not integrate the SCeTGo approach in instruction, 6.3% were undecided.

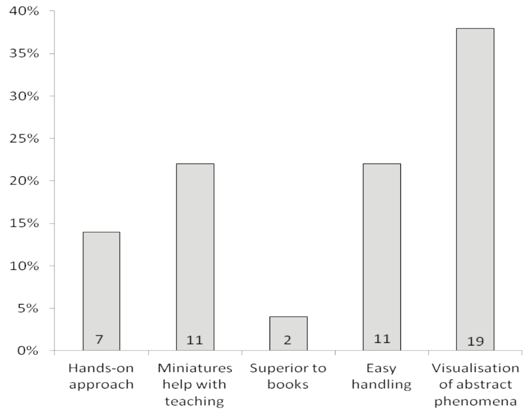

Figure 5. Results of content analysis with reference to the question: "What exactly convinced you, to make use of the SCeTGo approach?" (pre-service science teachers, n: 21; practicing science teachers, n: 15). Percentages (relative frequencies) refer to total number of answers given, numbers in bars relate to absolute frequencies.

Furthermore, in-service teachers and pre-service teachers, who indicated to use the exhibits, pointed out the most convincing features of SCeTGo, (Figure 5): A visualisation of abstract phenomena was mentioned most frequently (38%), followed by an easy handling and a support during teaching (22%). In addition, they emphasized that they liked the hands-on activities (14%). However, only in a minority SCeTGo was estimated superior to books (4%).

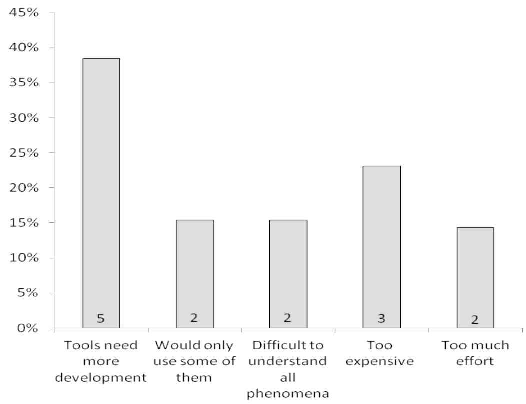

Figure 6. Results of content analysis with reference to the question: "Why don't you want to make use of the SCeTGo approach?" (pre-service science teachers, n: 9; practicing science teachers, n: 4). Percentages (relative frequencies) refer to total number of answers given, numbers in bars relate to absolute frequencies.

All in-service and pre-service science teachers, who were not willing to take use of the SCeTGo exhibits were asked for their motives, (Figure 6): In majority, interviewees referred to the prototype status of the miniatures (38.5%). Furthermore, they predicted miniatures to be to costly for an application in school (23.1%). Also some instructors found it to be difficult to understand all phenomena or would only apply some of the exhibits to practice (15.4%).

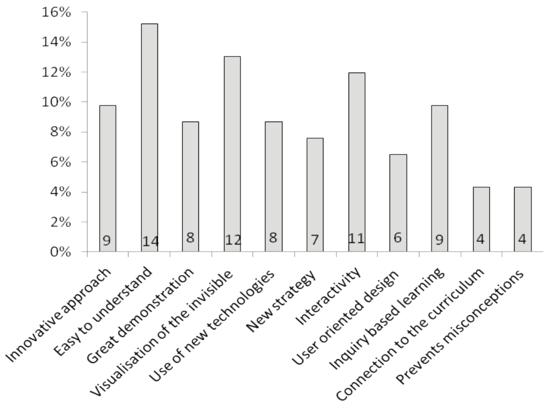

Figure 7. Results of content analysis with reference to the question: "What do you think are the most positive aspects of the SCeTGo?" (pre-service science teachers, n: 29; practicing science teachers, n: 19). Percentages (relative frequencies) refer to total number of answers given, numbers in bars relate to absolute frequencies.

In-service and pre-service science teachers highlighted several reasons, why they were motivated to take use of the SCeTGo exhibits, (Figure 7): A majority of interviewees considered the less demanding theory in context of physical phenomena as a positive feature of SCeTGo (15.2%), followed by the illustrating visualization (13.0%). Interactivity (12.0%) and an innovative approach (9.8%) were positively emphasized. In addition inquiry based learning was stated as a positive aspect (9.8%).

Further features referred to were a use of new technologies (8.7%), together with a great demonstration of physical phenomena (8.7%), a new teaching strategy (7.6%) and a user oriented design (6.5%). A connection to the curriculum, as well as a prevention of misconceptions was only mentioned in 4.3% of cases.

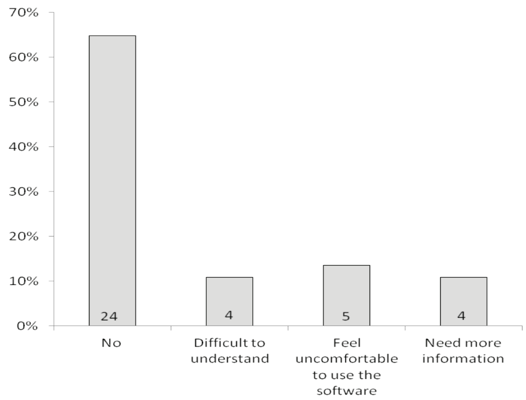

Figure 8. Results of content analysis with reference to the question: "Is there something you didn't understand, concerning the usage of the SCeTGo exhibits?" (pre-service science teachers, n: 29; practicing science teachers, n: 19). Percentages (relative frequencies) refer to total number of answers given, numbers in bars relate to absolute frequencies.

Figure 8 shows that the majority of teachers did not have problems, concerning the usage of the SCeTGo exhibits (64.9%). However, a minority felt uncomfortable to use the software (13.5%).
The same ratio of interviewees found the physical phenomena difficult to understand and need more information (10.8%).

5. Evaluation – Discussion

In the context of SCeTGo AR is used for educational purposes as a computer-mediated learning system that aims at the integration of AR technology in science teaching. Thereby, SCeTGo provides an augmented visualization aid for education.
However, in recent years technology enhanced teaching systems were questioned considering their learning efficiency. Ardito et al. [14] demanded "a synergy between the learning process and a student's interaction with the software." Furthermore "usability features should not only allow people to efficiently manipulate the interactive software, but should also be appropriate for the intended learning task."
As a consequence, the purpose of this study was to get an insight in the (1) educational value and (2) usability of an AR technology for students and teachers in order to ensure utilization in classrooms.

5.1 Pedagogical effectiveness

Pedagogical effectiveness was rated by students with regard to an increase in interest in natural science and enjoyment of the lesson. Teachers evaluated the educational value of SCeTGo and mentioned positive and negative aspects of the approach.
Overall, the feedback given by pupils within the individual interviews was positive. According the data students really liked working and learning with the miniatures. They did not suggest any improvements.
In particular, the hands-on approach of the miniatures, the student-centered lessons and the multimedia aspects was accentuated. The application of the SCeTGo miniatures raised students` interest and activated the majority of participants to get more involved in science contents. The high percentage of fascinated students shows that most of them were inspired by the exhibits and the AR technology. It therefore could engage students to get more interested in science in general.
Teachers evaluated the miniatures in combination with an AR technology as a valuable tool for instruction. They positively emphasized the interactive visualization by placing additional information (e.g. invisible molecules) into real surroundings. It was evaluated positively, as it simplifies learning and allows the learner to interact dynamically with the miniature exhibits. An active participation of the learner during the learning

process is regarded as a basic prerequisite for acquiring knowledge [16]. The qualitative analysis revealed that SCeTGo simplifies instruction, what implies that miniatures have a high value to teachers. SCeTGo proposes an inquiry-based approach with a learner-specific constructivistic idea of learning. It enriches the repertoire of learning offers to more innovative teaching methods due to an AR inclusion with the specific aim to improve quality of learning. Thereby, an AR enhanced learning system, as SCeTGo contributes to a new form of education.

5.2 Technology acceptance

Results indicate that technology' acceptance is high in general and that the usability of the system is rated very positive by pupils and teachers. However requirements with regard to usability differ between these two user groups.
Balog and Pribeanu [4] for instance, had shown the perceived usefulness and the perceived enjoyment as relevant factors for students' acceptance of an AR application, while the perceived ease of use was not a significant precursor for students' acceptance. Still in contrast to students, teachers are standing in front of a class while using an interactive software system.
Therefore, teachers require a user friendly software, they could fully rely on. Consequently Ardito and collegues [14] argued that from the point of view of people, who are applying an interactive software system, usability should be the most important aspect. With regard to usability features (technical demands, user-friendliness and handling) of the SceTGo approach most educators reviewed exhibits to be easy to handle. Especially a rapid prearrangement of the setup was pointed out as a positive feature.With reference to technical acceptance, the system is easy to operate and there are no real obstacles that teachers have to overcome in order to use the system.
Yet, teachers mentioned that a system needs to be extraordinary flawlessly operational, in order to be usable at school – in some cases this was already demanded from the prototypes. Taking this into consideration, the SCeTGo technology still needs improvement to finally convince also critical teachers of its applicability.

5.3 Critical remark with regard to teachers' acceptance of AR

Science teachers play a crucial role for the implementation of AR technologies in school. Results indicate a high interest for new technologies amongst teachers in school environments in general.
Nevertheless participating teachers were not randomly chosen, since they selected the teachers training courses in order to get to know state-of-the-art technologies and to get new ideas for improvement of their instruction. As workshop participation was an optional offer, it could be the case that teachers not interested in new technologies in general decided not to participate.

In summary, all students enjoyed working and learning with the miniatures and most of the teachers assessed pedagogical effectiveness as well as technological aspects throughout positive. Usability features along with software application were rated well.
Validation could show that next to pedagogical effectiveness a user-friendly design is an important pre condition to ensure users `acceptance. Usability plays a central role to meet the requirements of teachers and students and to adapt the AR technology to the specific needs of school environments. Results emphasize that an AR system like SCeTGo has to operate absolutely reliable in order to be integrated in teachers` instruction.

Evaluation shows that introducing AR into classrooms is in line with the needs of educators and that the SCeTGo project has the potential to be applied in school environments.

It provides teachers with a tool in order to facilitate students' learning.

The highly scored interest of participants to engage in such exhibits and their learning contents is one of the important pre-conditions to improve usages of AR technologies in school. It verifies a successful future integration of exhibits based on AR-technology in instruction, which could be easily included in school lessons as long as they operate absolutely reliable.

In conclusion, the evaluation could support that the SCeTGo approach offers a modern science centre experience outside the walls of the science centre in school classrooms and thus crosscutting the boundaries between formal and informal learning. SCeTGo seems to be appropriate to integrate AR in schools and offers conditions to have an impact on education in long term.

As many examples exit in the past, when innovative approaches have proven its continued functionalities, they will make their way into classrooms anyway.

Acknowledgements

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References

[1] Azuma RT. A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 1997; 6(4): 355 - 85.

[2] Sotiriou S, Bogner FX: Visualizing the Invisible: Augmented Reality as an Innovative Science Education Scheme. Advanced Science Letters 2008, 1(1), 114-22.

[3] Salmi H, Sotiriou S, Bogner FX: Visualizing the Invisible in Science Centres and Science Museums: Augmented Reality (AR) Technology Application and Science Teaching. In: Karacapilidis N, editor. Web-Based Learning Solutions for Communities of Practice: Virtual Environments for Social and Pedagogical Advancement 2009, 185-210. New York: Information Science Reference.

[4] Balog A, Pribeanu C. The Role of Perceived Enjoyment in the Students' Acceptance of an Augmented Reality Teaching Platform: A Structural Equation Modelling Approach, Studies in Informatics and Control 2010; 19(3): 313-30.

[5] Bogen M, Wind J, Giuliano A. ARiSE - Augmented Reality in School Environments. In: Nejdl W, Tochtermann K, editors. Proceedings of European Conference on Technology Enhanced Learning; 2006 Oct 1-4; Crete, Greece. p. 709-14.

[6] Wind JK, Riege M, Bogen, Spinnstube®: A Seated Augmented Reality Display System. In: Fellner D, editor. Proceedings of Virtual Environments, IPT-EGVE - EG/ACM Symposium; 2007 Jul 15-18; Weimar, Germany. Aire-la-Ville: Eurographics Association; 2007. p. 17-23.

[7] Sotiriou S, Anastopoulou S, Rosenfeld S, Aharoni O, Hofstein A, Bogner F, Sturm H, Hoeksema K. Visualizing the Invisible: The CONNECT Approach for Teaching Science. ICALT 2006: 1084-10.

[8] Martín S, Díaz G, San Cristóbal E, Gil R, Castro M, Peire J.: New Technology Trends in Education: Seven Years of Forecasts and Convergence. Computers & Education 2011; 57(3): 1893-1906.

[9] Wittkämper M, Braun AK, Herbst I, Herling J. A Distributed System for Augment-

ed Reality Experiences in Science Centres and Museums; Technologies for E-Learning and Digital Entertainment 2007; p. 936-46.

[10] Buchholz H, Wetzel R. Introducing Science Centre TOGO - A Mixed Reality Learning Environment for Everyone's Pocket; IADIS International Conference Mobile Learning 2009 (pp. 104-110), Barcelona, Spain 2009.

[11] Buchholz H, Brosda C, Wetzel R. Science Center To Go - A Mixed Reality Learning Environment of Miniature Exhibits. In Lazoudis, A. Sotiriou, S. (Eds) Proceedings of the "Learning with ATLAS@CERN" Workshops Inspiring Science Learning EPINOIA, 2010, ISBN Number: 978-960-473-219-7. pp. 85-96.

[12] Lamnek S. Qualitative Sozialforschung, Methoden und Techniken. Weinheim. Beltz Psychologie Verlags Union; 1995.

[13] Mayring P. Qualitative Inhaltsanalyse, Grundlagen und Techniken. Weinheim: Deutscher Studien Verlag; 1997.

[14] Ardito C, Costabile MF, Marsico M de, Lanzilotti R, Levialdi S, Roselli T, Rossano V. An Approach to Usability Evaluation of E-learning Applications. Universal Access in the Information Society 2006; 4(3): 270-83.

[15] Owen, M., Owen, S.,Barajas, M., Trifonova A. Pedagogic Issues and Questions from the Science Centre to Go, Augmented Reality, Project Implementation; to be found in this issue - EDEN 2012

[16] Papert S, Resnick M. Technological Fluency and the Representation of Knowledge, Proposal to the National Science Foundation: MIT Media Laboratory 1993.

[17] SCeTGo. Science Center To Go – A mixed reality learning environment of miniature exhibits; project website; http://www.sctg.eu; [last visited 12-01-2012]

www.sctg.eu

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