Evaluating the Educational Value and Usability of an Augmented Reality Platform for School Environments: Some Preliminary Results

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Abstract: - The ARiSE project will develop an AR platform and associated pedagogical scenarios of use, enabling teachers to promote new teaching practices for teaching scientific and cultural content in primary and secondary schools. The project aims at testing pedagogical effectiveness of introducing augmented reality (AR) into the classroom. The objective of this paper is to report on the evaluation of a research prototype that has been tested with users during a summer school. The paper is focusing on the positive and negative aspects collected from the usability questionnaire and on the insights derived from focus group discussions.

Key-Words: - augmented reality, e-learning, pedagogical evaluation, usability

1 Introduction

In the developing knowledge-based society information technologies play a particularly significant role. However, even the most advanced technologies will not give a necessary effect, if their usage in the educational system is not adequate to the current development of technologies and increased educational needs [6].

Traditional methods of educating students have well-proven advantages, but some deficiencies have also been detected. A typical problem has been how to engage students with appropriate information and communication technologies (ICT) during the learning process [7].

There are different possibilities of how a computer can contribute to teaching and learning. A very simple solution is to use a computer as playback media, taking advantage of the multimedia capabilities of the device. E-learning platforms hold additional features depending on the solution they are aiming at. A classical setup involves one computer for one person without any contact to anybody else or the environment. This situation is called "isolated learning [8].

However, learning is fundamentally built up through conversations between persons or among groups, involving the creation and interpretation of communication. Thus, conversations are means by which people collaboratively construct beliefs and meanings as well as state their differences. Learning involves making sense of experience, thought, or phenomenon in context. Student representation or understanding of a concept is not abstract and self-sufficient, but rather it is constructed from the social and physical context in which the concept is found and used. Brown et al. [4] emphasized the importance of implicit knowledge in developing understanding rather than acquiring formal concepts. It is, therefore, essential to provide students with authentic experiences with the concept. Students can engage in learning conversations in distributed multimedia environments. Multimedia technologies, such as graphics, simulations, video, sound and text, allow instructors to use multiple modes and representations to construct new understanding and conceptual change of enhancing student knowledge [5].

According to Azuma [2], AR supplements reality, rather than completely replacing it. AR systems are featuring an integration of real and virtual (computer generated images) into real environments, real time 3D interaction and targeting all senses (visual, auditory and haptic).

The primary purpose of the international research project ARiSE (Augmented Reality in School Environments) is to test pedagogical effectiveness of introducing augmented reality (AR) into the classroom and creating remote collaboration between classes around the AR display systems [1].

ARiSE will develop an AR platform and associated pedagogical scenarios of use, enabling teachers to promote new teaching practices for teaching scientific and cultural content in primary and secondary school. The aim of the project is to offer to the group of students the possibility of 'playing' with virtual objects and thereby to perform learning by doing instead of learning by reading. In order to evaluate the created AR learning platform in terms of pedagogy, the first summer school in Malta intended to conduct AR platform testing, focus group discussion and verbal teachers' questioning (interview).

The ARiSE project is carried on in a consortium of seven partners: Franunhofer IAIS (Germany) – coordinator, Siauliay University (Lithuania), AccrossLimited (Malta), ICI Bucureşti (România), Czech Technical University in Prague (Czech Republic), Siauliai City Juventa Basic-School (Lithuania) and Rabanus-Maurus Gymnasium Mainz (Germany).

The objective of this paper is to present some preliminary results regarding the educational value and usability of an AR-based platform for school environments. In this respect, we report on the evaluation of the 1st prototype that has been tested with users during the summer school. The main objectives of the test were to evaluate the usability of the AR platform and to asses the pedagogical effectiveness of using AR in schools. In this respect, the evaluation is formative in that it aims at giving a fast feedback to developers o how to improve the 1st prototype and develop the next two prototypes.

Therefore, this paper is focusing on the positive and negative aspects collected from the usability questionnaire and on the insights derived from focus group discussions.

The rest of this paper is structured as follows. The evaluation set-up and method is described in Section 3. The next section presents the evaluation results with a focus on positive aspects / advantages of the AR platform and negative aspects / limitations of this technology for schools.

2 Evaluation set-up and method

2.1 The AR platform

The AR platform consists of 4 independent modules organized arround a table on which real objects are placed. The platform has been registered by Fraunfofer IAIS under the trade mark Spinnstube®. A more detailed presentation of the platform has been done by Bogen et al. [3].

In Figure 1, the photo of a module is presented.

The project will implement three prototypes based on three interaction scenarios. The 1st prototype is targeting Biology and has been tested with users during the 1st summer school held in Hamrun, Malta. The real object is a flat torso of the human digestive ststem.

Fig 1. A module of the ARiSE platform

A paddle has been used as interaction tool that serves for three types of interactions

- Selection of a real object
- Selection of a virtyal object
- Selection of a meniu item

2.2 Participants and tasks

Five teams participated at the summer school with a total of 20 students from which 10 boys and 10 girls. None of the students was familiar with the AR technology. 16 students were from 7th class (13-14 years old) and 4 from 11th class (16-17 years old).

The test has been conducted at the office of the partner AcrossLimits in Hamrun, Malta. Because of the limited space, the system modules have been grouped in two platforms sharing the same table and real object (the digestive system).

The participants have been assigned 4 tasks: a demo program and three exercises. The tasks have been presented via a vocal user interface in the national language of students. According to the test plan, each team should test the prototype in two working sessions: demo + 1st exercise and 2nd + 3rd exercise.

2.3 Method and procedure

2.1.1 Usability questionnaire

Testing has been done according to the summer school agenda, following a procedure agreed by ICI

and Siauliai University teams. Focus group with students and teacher. The usability questionnaire had 12 questions (on a Likert 1-5 scale) and 2 open questions: free description of most positive and most negative aspects.

All students responded to the questionnaire after the test session. However, due to some organizational problems, the Maltese children tested all four tasks during one test session while the rest of the students tested the prototype twice. Therefore we collected 32 questionnaires which provided us with 96 positive aspects and 92 negative aspects (usability problems).

2.1.2 Focus group discussions

Due to actual reasons, the respondents from Malta failed to arrive for the interview, and therefore no assessment of their opinions was made. 4 schoolchildren from Germany (two girls and two boys; none of those learned about the human digestive system before), 4 girls from the senior forms from Romania (learned about the human digestive system before) and 4 boys from Lithuania (learned about the human digestive system before) joined in the discussions.

Thus, 3 Focus groups having 4 respondents each were formed. Considering the number of the participants in the group, they felt into the *mini group* category and under this criterion fully agreed with the methodological requirements for Focus qualitative research. Hence, the total number of the participants involved into activities was 12. Each of the groups had 2 discussions i.e. the first one with each of the groups was arranged after their first attempt to work with the AR platform, the second one - after their second attempt to work with the platform the following day. There was a single day off before the first and second attempt. The discussion process was monitored by the teachers and their students who were not directly involved into debates.

In order to confirm the validity of research data (on the basis of triangulation approach), the respondents were tested. The learners got on with the tasks either before or after using the AR learning platform (Pre-test and Post-test). A hypothetical assumption that the participants' knowledge and a general understanding of the human digestive system should change using the AR teaching/learning platform was made. However, at this stage, due to some reasons the test results in fact, were not assessed, and therefore not taken as the basis for evaluating the AR learning platform (the reasons were established on the basis of monitoring the teaching/learning process using the AR learning platform.

- First, the learners were particularly focused on learning how to use the AR platform rather than on biology as a subject. They were not quite sure of how to apply the platform and instruments (for example, the paddle) and to technically complete the subject clear tasks
- Second, the teachers-participants did not perform their main function as teachers because their principal activity was filming the students involved in the process of using the AR platform and taking pictures of themselves in the context of the AR learning platform.
- Third, on the first day of the summer school, the software of the AR learning platform worked improperly, and thus the participants were not able to fully complete the assignments

Hence, the evaluation of the AR learning platform in terms of pedagogy shows that on the basis of the summer school results, the only data used were collected during discussions in the Focus groups and interviews with teachers. The survey included four aspects: general (first) summer school participants' impression, noticed advantages, disadvantages and usefulness of the AR learning platform reaching a better understanding of educational material.

The assessment of research data discloses that findings fall in the following four groups: 1) general impression, 2) noticed advantages, 3) noticed disadvantages, 4) recommendations.

3 Evaluation results

3.1 Positive aspects

3.1.1 Aspects derived from questionnaires

Positive answers mentioned by students have been collected, sorted and summarized by key words (attributes). The resulting list of keywords with their associated frequency has been further grouped into 14 categories of attributes as shown in Table 1.

Educational support includes aspects like: support to learn ("the knowledge learning isn't see alike effort"), clear understanding ("give a more clear idea about the digestive system"), usefulness of the demo program (" by the demo one can keep to himself the lesson good").

The 3D interaction ("the position of the organs its easy to see" or "the program allow to know the

real shape of organs") and animation ("it is well animated what happens with the food") are two other positive aspects frequently mentioned by the students.

Many students mentioned that the system is funny ("fun to work with 3D technology"), attractive ("the system is really attractive and exciting"), exciting ("program is exciting and does joke") and captivating ("captivating way to learn").

Attributes	Frequency
Educational support	23
Interesting	10
3D interaction	10
Usable	8
Funny	7
Attractive	7
Support for individual work	6
Exciting	5
Like games	4
Novel and original	4
Good quality	4
Captivating	4
Multimodality	3
Ergonomic	3

Table 1. Summary of positive aspects

The fact that students liked the similarity with a computer game (learning by doing) shows the intrinsic motivation created by the AR technology and the added value of exploiting the need to play, predominant to the age of students ("it is interesting and easy to play the game").

Another feature mentioned by students is the novelty and originality ("original idea and new"), both suggesting that working with the system is more stimulating than learning in a traditional way. Also, the vocal interface ("the voice is clear and easy to understand")and the usefulness of explanations have been mentioned as positive aspects.

3.1.2 Advantages inferred from focus groups

The learners think that the three-dimensional objects in the AR platform are much better than those seen on a computer screen. Apart from the existing shortages, the schoolchildren found the AR platform more enjoyable than a traditional lesson. They stress a keen sense of explicitness. Vague senses are not shown due to the misunderstood material. It is supposed that such situation leads to more favourable conditions for studying and learning motivation.

The students herewith indicated not only pleasure in reading but also showed that teaching material was faster mastered using the platform rather than attending the traditional lesson.

Some learners' remarks are closely connected with the ideas of humanistic pedagogy. They maintain that the AR learning platform 'is not angry' with them for making mistakes. It is even more polite that a teacher (!), and therefore creates a situation where *you can learn without stress* as then you do not feel any fear. Though the AR learning platform does not prevent from making mistakes, the learners are also supposed to have their value.

AR advantages	Frequency
3D graphics and animation	6
Suitable for individual work	5
Engaging	4
Understanding support	3
Real object	3
Voice modality	2
Monitoring	2
Suitable for group work	2
Fast learning	2
Can repeat	1
Controlling	1
Dynamic	1
Interesting	1
Acting	1
Novel	1
Good potential	1

Table 2. Summary of advantages

The students as well as the teachers favourably evaluated the possibility of not only monitoring but also of making influence and controlling invisible processes.

The schoolchildren think that the AR platform is a proper equipment for discussing abstract things that are hard to be understood, especially at the young age. In this particular case, the AR learning platform helped the learners with a better understanding of reduction in food products.

The learners agree that using the AR learning platform can help with understanding things without any preliminary preparation. However, it should be noticed that this is imagination of those who have already studied the human digestive system

3.2 Negative aspects

3.2.1 Usability problems

Usability problems as mentioned by students are summarized in Table 3.

Usability problems	Frequency
Selection	31
Interaction tool (paddle)	14
Feedback	14
Discomfort	12
Clarity of sound and writing	7

Table 3. Summary of usability problems

Most frequent was the difficulty to reach each organ with the interaction tool (the selection area was too small and the real object too big).

Second negative aspect was the difficulty to use the interaction tool (paddle) which sometimes blocked (not answering to user actions).

Other negative aspects are related to the discomfort provoked by the stereo glasses and the position of the screens. This is also due to the fact that although the platform enables the adjustment of chair and screen to the student's height, most of the students didn't do it.

3.1.2 Disadvantages perceived by students

The schoolchildren suppose that the AR learning platform is not a suitable one for gaining a fast and broad knowledge (it's not an encyclopaedic instructional aid). They agree it is more appropriate for training.

As the 'paddle' (controlled 'cursor') didn't work properly, it had a negative impact on the first students' impression that became more convincing on the second day when the system started working more accurately, prevented from becoming familiar with the AR learning platform and expressed the learners' annoyance that was recorded during monitoring. The schoolchildren think that the 'paddle' is too large. It should be sharper and similar to the arrow.

The students had difficulties with touching particular places of the real object. They suppose that the object was too big and that the below placed mirror was in a wrong position.

Some learners needed more detailed instructions on how to accomplish assignments and particularly their technical performance using the 'paddle'.

Stereo glasses are not adapted to different learners' age groups, and thus cannot be put on.

3.2 Discussion

The first consumers' impression about the AR learning platform is positive. The product is evaluated as highly useful. However, it should be emphasized that it works as a supplementary tool that cannot replace traditional learning.

The AR learning platform creates conditions for a better understanding, and therefore is acceptable for younger learners encountering difficulties with perceiving abstract, invisible processes.

The AR learning platform increases students' motivation to learn. The possibility of learning by doing, touching a real object with hands, monitoring and changing the place of the object has been positively evaluated. The learners' ability not only to monitor but also to control certain processes has been perfectly evaluated.

In a similar vein, usability evaluation has been conducted in order to provide with early identification of usability problems. The prototype will be improved following the recommendations of evaluator and many problems will disappear.

However, it is worthwhile to compare positive aspects and advantages of the AR platform in order to provide developers with useful suggestion for future work.

In order to triangulate results from both sources (questionnaire and focus group) we will further aggregate the data in Table 1, in order to identify usability factors that are specific to the AR platform.

Usability factors	Frequency
Educational support	23
Funny, attractive, exciting	19
Usability and ergonomics	15
Interesting and novel	14
3D interaction	10
Captivating, like games	8
Support for individual work	6
Multimodality	3

Table 4. Usability factors

Usability factors presented in Table 4 are summarizing how students perceive the usability of an AR platform. It seems that they mostly appreciated the increase in the intrinsic motivation to learn (funny, attractive, exciting, interesting and novel, captivating and resembling to games). The positive evaluation of the support for individual work was someway unexpected, since the platform is supposed to support collaboration around a real

object shared by the users. However, it is related to the interest shown by the students to concentrate attention for individual performance, alike players of computer games.

The usability factors having a positive influence on usability are consistent with the perceived advantages of the AR technology for school.

Summary of AR advantages	Frequency
3D graphics and animation	6
Suitable for individual work	6
Understanding and learning aid	5
Engaging and dynamic	5
Acting on the real object	4
Monitoring and controlling	3
Suitable for group work	2
Voice modality	2
Interesting and novel	2
Good potential	1

Table 5. Summary of AR advantages

Many students liked the support to work without teacher. They liked the possibility to repeat exercises in order to improve learning performance. However, focus group discussions also revealed that they enjoy the idea of sharing a real object (model) when learning.

Another important finding of the focus group discussion is that students liked the idea that t it is possible not only monitoring but also controlling a process.

4 Conclusion and future work

At this stage, a pedagogical evaluation of the created AR learning platform is only based on the assessment of the summer school participants' opinions about advantages and disadvantages of the AR technology. Thus, some issues will need to be clarified carrying on further educational research.

Based on the results from the evaluation of the 1st ARiSE prototype we can infer the following conclusion:

- The system has educational value – the lesson is easy to understand, the system is appropriate for individual learning and shows a high potential for the educational process.
- The system is attractive, stimulating and exciting for students – exercises are alike computing games. The students liked the interaction with 3D objects and the animation using AR techniques.
- The vocal interface explaining the exercise goal is a useful feature of an AR platform, where users prefer the 3D interaction instead of reading text on the screen.

The usability problems, perceived disadvantages and limitations of the 1st prototype are also suggesting some future work directions in our research:

- Tools and interaction techniques should be enriched and improved as speed and accuracy.
- The system should provide with more than one tool / interaction technique for pointing and selecting of objects.
- Selection should be possible within the visible area and feedback should be provided when leaving the selection area.

Acknowledgement:
We gratefully acknowledge the support of ARiSE research project under the umbrella of the European Sixth Framework Programme (FP6 – 027039).

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