Augmented Reality in education

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***Abstract*:** The paper presents Augmented Reality (AR) as a step between reality and virtual reality for the benefit of education. After some introductory example of where AR heads, the technology itself is explained. Then, we describe the modules of the AR portal that we have developed and how it can be used. We give examples of its use in university courses and activities. Furthermore we describe an experiment that we set up at a secondary school to help in popularizing chemistry and raising grades of students, besides making then enjoy involvement with the topic. Our results are very positive, so we consider our efforts to be a starting point for further developments.

***Key words and phrases*:** augmented reality, AR book, education, chemistry, AR marker

1.   Introduction

Our world has been developing rapidly for the last hundred years and this process was even increased by the spreading of Personal Computers. The domination of Information Technology influences everyone's life. "A school of today has to coach their students for a society that not yet exists. That is how the surrounding world becomes more and more complex." [1] No wonder, keeping education up to date is vital. For the last ten years, educational institutes attempted to adopt modern devices or as they are commonly called: Information and Communication Technologies (ICT) and their scope still has to be increased. Professional experiments aim at proving ICTs' efficiency, though there are some who are skeptic. Those who doubt these techniques' necessity are reasoning with the evidence of past: education used to succeed without the use of modern equipment, the good old stuff - books, board, choke - has to be enough to teach anybody for life. On the contrary, the youngest generation (generation-Z born in the prosperity of Internet) has to face a completely different reality when finishing their studies than the ones before them. [2] It is highly recommended to make use of ICTs benefits like AR in order to raise and maintain the attention of students throughout a course, not to mention it's further benefits for understanding and visualizing the topics.

2.   AR on the move

The emergence of AR (Augmented Reality) can be estimated around 1968 when Ivan Sutherland created the first head-mounted 3D display which projected a simple framed graphical view into a room. Later, in 1992, Tom Caudell who worked for Boeing as an engineer created a method that

could virtually show cables and other parts of the aircraft and its location without having to open the shield of the machine. Later AR applications were developed for pilots and crew that contained full interactive transparent screen providing the basic flight information. The next version of this solution was a helmet mounted display. [3]

In everyday life AR appeared first at live sporting broadcasts on television: prompt and actual information could be visualized, like the flag of the winner's nation in the moment of victory.

AR is a new 3D technology that merges the physical and the digital world in real time. In practice, a 3D model or animation is assigned to an AR-marker (a printed black-and-white picture) that is detected by a webcam, then the model appears on the screen, covering the marker. If you are moving the marker, the displayed model or animation (or sound…) is transformed on the flow. Sights of the real world, with virtual objects superimposed upon or composited with the real world are displayed together.

One of these options offering similar solutions is a free software, ManyCam (www.manycam.com), with which you can use different masks, glasses's, hairstyles, moreover you can change the background of a moving picture. With the help of advanced technology such as object-recognition and computer vision, the information surrounding the user may become interactive and digitally available.

Controlling computers is possible without a mouse or a keyboard. These methods are helpful for disabled people who can manipulate cursor with their own gestures. CamSpace is one of these possibilities (www.camspace.com), creating a control device from any object that allows the use of gestures or everyday products as a control device.

Due to the remarkable evolution of mobil technology, extended moblie development is expected next to computer revolution. In the future, the monitor is about to be replaced by AR glasses, furthermore contact lenses. AR-technology is spreading in industry, commercial marketing and entertaining. Probably a few years later, it will invade education too.

3. AR technology

Different types of positioning techniques can be distinguished using AR.

The first position and direction based AR was used on cell phones. The purpose is to add information on the screen in form of text, picture, 3Dobject or video. The added information was positioned by POI (Point Of Interest), which is an expression for a place used by different programs. The POI defines the place of points which can be important for somebody [4]. These points could be general information (street, house number, phone number), or geographical coordinates as well. The information needed in order to extend the real picture is obtained by a compass, GPS and speed-up sensor.

The GPS (Global Position System) allocates where exactly the mobile instrument is and with the help of its exact distance from the POI can be calculated. The compass shows in what direction the cell phone is oriented and thus those PIs can be visualized in the cell phone's which are in that direction, horizontal with the level of the Earth. The speed-up sensor can show the cell phone angle of inclination compared with the horizon and from this calculate the exact POI

position. Today we can find quite a few adaptations like technology, like Wikitude (www.wikitude.org), Layar (www.layar.org) and Junaio (www.junaio.org).

Figure 1. Wikitude in use

Another type of AR positioning is the marker based. In this case the camera is searching for a special picture, which is significant and can be easily recognised and distinguished from the environment. It is worth using an error recognising code, so that the small faults would not be recognised by the AR marker. The marker is a unique black and white picture on white background, with a determinant black sqaure border

The first step is to detect the black border. The next is the defined contours made up of polygons that are filtered on squares. After we get the squares, we need to take a sample from inside and outside points near contours in order to filter the possible marker. The outside of the contour must contain bright points till a specified and the inside of the contour (to a specified distance) must contain a dark border. If the marker has these characteristics, then the real picture within the marker can be distinguished with higher probability. [5] This can be done easily with OpenCV picture editing library (opencv.willowgarage.com/wiki/). After successful detection, the marker can be replaced by virtual elements, the position of which can be calculated from the marker-movements to make the necessary transformations and to extend the virtual reality on the screen with the real picture.
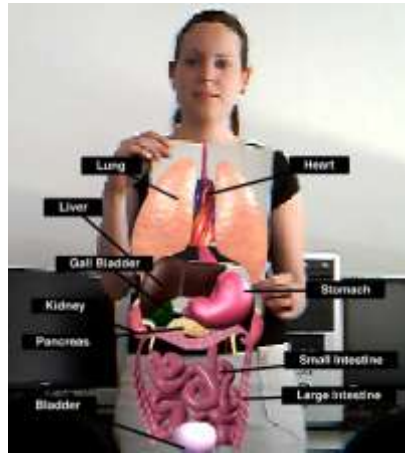
Figure 2. AR-marker

Figure 3. AR in use

http://www.learnar.org/

AR technology does not require an AR-marker, but can be substituted by fine-tuned pattern recognition modules. The mask example in the previous chapter can use facial recognition software. In this case you don't need a physical AR-marker since the software recognizes the facial polygon of a person and puts the mask over it. Thus the mask will stick on the face while moving.

FD – Face Detection is a computer based technology to optimize a human face and position it within a digital picture. FD detects the polygon of a human face and does not take into consideration the environment (trees, people, bodies and other secondary objects). [6].

Figure 4: Face detection (http://www.theinquirer.net/inquirer/news/1041755/track-face-realtime)

4. AR portal

As part of the Software Technology Lab course Virtual Reality project we developed an AR portal to review and to present AR technology (http://arportal.elte.hu/). The goal is mapping and

comparing the existing and most enchanced AR technology of the present day. This portal does not only serves asan information base, but a possibility for interested students to experiment, and for developers to produce experimental database of AR media elements. The portal is made up of different components as shown below [7]
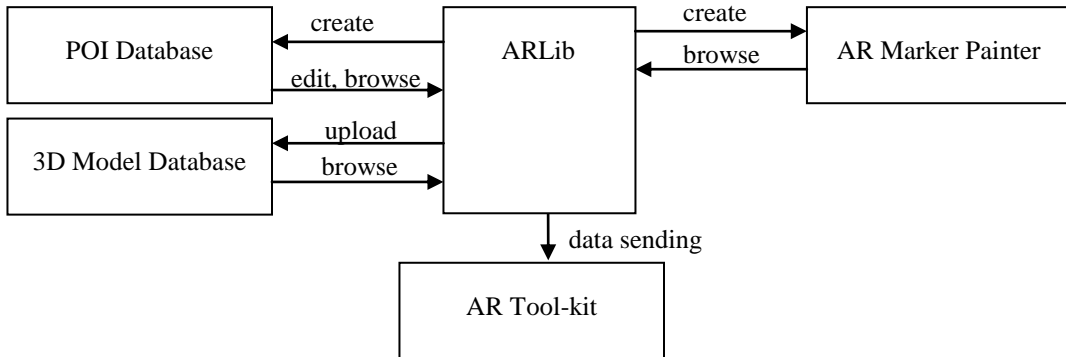

Figure 5. AR-portal system

4.1. POI component

First we created a surface for POI database to accumulate the position and direction based AR technology. It is possible to visualise Points of interest with help of this component; we can portray important places, interesting points. Its use is very simple: with the POI editor one needs to create a file with points of interest, strictly to comply with all colour-tactical rules, including tags and other optional terms.

POI files type are t.ex GPX, CSV. After this, if everything is properly set up according to colour-tactical rules, marked places will show up on the map. This component has 3 other functions as well. It is possible to edit, search and export files. The database stores the necessary POI files. This component makes it possible to create and test POI databases that are mostly used on cell phones.

4.2. AR marker component

The next component is the AR Marker Painter, that is a normalised Java applet. Using this component one can plan, design and draw different markers and can save them on the computer or on the portal database. For painting the marker we use 5 different drawing tools, figures, greek letters and ready-made backgrounds. Because of the certified Java Applet the user can save on his computer the Java based created picture.

4.3. ARLib component

With the mentioned components we can create different entitates or use the ones already created. When creating a new one, the program automatically generates a new file to save in the main database, while the different entitets can be stored on a common panel. Handling all these we need a uniform management table. The ARLib component handles this uniform table.

4.4. ARToolkit component and its use

The most important component is the FLARToolKit program. This is a Flash based open source code library and with this we can develop extended virtual applications. This program is based on the NyARToolkit (http://nyatlajp/nyartoolkit/wiki/index.php), which is the ARToolKit (www.hitl.washington.edu/artoolkit/) version based on Java. The FLARToolKit recognise from the sysin picture the marker and calculates this position in 3D, using computer „viewed" algorithms for this. After calculations the program positions the model, video or picture.

For 3D graphical elements it is possible to use different 3D Flash Engines (Papervision3D, Away 3D, Sandy, Alternativa 3D). Within this component we can choose readymade markers already uploaded on the portal and one of ready 3D models prepared as extended 3D elements. The portal then navigates us to a page where our FLARToolKit based ActionScript application is placed. In order to use the resulting 3D augmentation, one has to run the script and allow access to the web camera, then print the marker and hold it in front of the camera. As a result one can see the chosen model on the screen right at the position of the marker We can use a personal marker (with dae.extension).

The 2 main methodes of program are:

```
private function init3D(e:Event) :void {
    scene = new Scene3D();
    camera = new FLARCamera3D(FlarParams);
    camera.z = -30;
    view = new Viewport3D(640, 480, true);
    lre = new LazyRenderEngine(scene, camera, view);
    var request:URLRequest = new RLRequest("params.txt");
    request.method = URLRequestMethod.POST;
    var loader:URLLoader = new URLLoader();
    loader.dataFormat = URLLoaderDataFormat.VARIABLES;
    loader.addEventListener(Event.COMPLETE, completeHandler);
    loader.load(request);
    model = new DisplayObject3D;
    function completeHandler(evt:Event) :void {
      var modelMatList:MaterialsList = new MaterialsList;
      var modelMat:BitmapFileMaterial=new BitmapFileMateri-
al(loader.data.text)
      modelMat.doubleSided=true;
      modelMatList.addMaterial(modelMat,loader.data.mat);
      modelframe.load(loader.data.mod, modelMatList);
      model.addChild(modelframe);
      scene.addChild(model);
      }
    addChild(view);
    addEventListener(Event.ENTER_FRAME, loop);
    }
private function loop(e:Event) :void {
    if (marker != null) {
    model.transform = PVGeomU-
tils.convertMatrixToPVMatrix(marker.transformMatrix);
```

```
    }
    lre.render();
}
```

With the **init3D** method the 3D model and the indicator is initialised. The server obtaining the parameters from the portal and during the communication with the user the data exchange takes place. If it is included, we can also use the texture of the model. The role of the **loop** method is to recognise the marker, and the model attached is handling the linear transformations.

5.   AR in education

AR is likely to be a new form of demonstration where there is no need to have any physical model presented, hence it should be available for students at home (only a printed AR marker, a webcam and a computer with internet connection is required). [8] AR books, AR development and logical games are just about to appear in education. See some examples below.

The use of AR-technology could be incorporated in many subjects i.e. maths lessons of geometry, or 3D representation of cells in biology, [9], in chemistry displaying molecular structure [10] or in PE a team sport simulation can be created. Additionally, any subject can be more colourful, interesting and interactive using augmentation.

Furthermore education may profit from AR development or logical games [11]. In computer science lessons students can familiarise themselves with the background of AR and they can create their own AR projects.

For instance, beginners can create their own 3D pop-up books at ZooBurst. After having registered, storytellers can create their own world in which their stories can come to life. An AR-marker can be assigned to the virtual book that helps the physical book to become live. (www.zooburst.com)

On a next level, students could construct 3D model with 3D authoring tools and an AR-marker accompanied by their own AR source codes.

6.   AR books

A study by Marshall et al. has revealed that people still prefer physically existing books since they favours physicality, transportability, flexibility, robustness etc. [12] On the other hand digital media offers possibilities of interaction. Digitally augmenting and enhancing real books gives the advantage of both. With AR technology books can be supplemented with additional visual information uniting pictorial content of a real book with virtual elements that add educational content. The user can switch between pages by the physical action of turning the page. Certain pop-up books enhance the interaction by allowing the user to push, pull, roll, and press different interactive features present in the book.

AR-books have also caught the attention of teachers because of the opportunities for interactive display, simulation, three dimensional graphic, sound and animation which could help understanding complex processes or the sight of 3D models.

The topic covered in "magic book", is not a recent innovation since this type of book was discussed at the Billinghurt and Kato's activity in 2001. [13] It is also important to mention Wellner's Digital Desk that is one of the foundation-stones in this field since it has united the virtual and physical world in the beginning of 90's. [14]

Traditional books can be complemented with AR technology by augmenting them with 3D objects or animations. Heroes of the plot may come alive as they can be perceived in two or three dimensions while playing some animation.

8.   AR assistance on 3D modeling course on ELTE IK

Using books with AR technology is still not common nowadays, but the first steps have been made. At ELTE University Faculty of Informatics Department we created a half virtual, half analogue printed course book for 3D modelling course.

A course „3D Modeling with Maya" was started in 2009-2010, where students could get a general idea about 3D modeling, using Autodesk Maya (http://autodesk.com/maya) software. During the courses they become acquainted with modelling in 3D, but students had difficulties visualising the 3D objects that they were supposed to create. There are several books on this topic, but because the visualization is only in 2D, understanding the illustrationsis not always easy. We used the AR portal and methodological skills to develop an AR course booklet that students could use for their practical assignments.

Using the course booklet students can follow a real 3D model creation step-by-step. During the course it is not the created final model that is important, but the road taken in developing the model using prior knowledge. Because of this, if they miss any part of the 3D modelling process they cannot understand the complete procedure and it is difficult for them to follow the instructions. In order to make spectacular illustrations for the booklet, we used AR markers. If the students hold these in front of computer's camera they could see and rotate the model's actual state. Making this course booklet is not utterly necessary, but is well worth the time invested. W we saved each step of the model in the required format and upload it to the AR portal, and placed a marker into the text within course booklet.
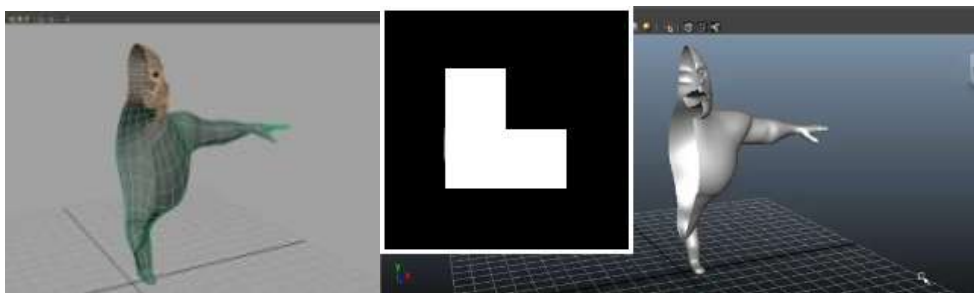

Figure 6. A part of the course book: Step 12. – Mirroring of model

 Of course this booklet for the course was only the top of the iceberg, we could mention many examples where books like this could be used.

9. Virtual university building

We also produced the complete 3D model of the south building of our Lagymanyosi Campus, from outside and inside. The most difficult was the building creation. After we obtained the architectural plans and made the building, painted the walls, created the textures and the model was ready. This model was then used for a brochure describing the different programs at our Faculty and the marker triggering the model of the campus was used as a design element together with a QR code that lead to the site where the script is run. This became a very popular attraction at our open days.

As a further enhancement interaction has to be integrated into the model, that helps orientation within the building. This idea is being developed as a diploma work .The entrance will be controlled by markers, doors can be opened, lights can be switched on and off and one can behave as if inside the building itself.

10. Chemistry AR note

10.1. Creating of AR-exercise book and preparation

We decided to create an AR technology-based high school lesson. In our mind it should be an AR-exercise book that can be used at home. The basic idea was to integrated AR-markers into the self-made lesson plan.

Our chosen subject was chemistry. One of our reasons is that, among student – according to our survey and statistics of continuing education – it is one of the subjects that achieving the title of the „most unpopular subject" and besides, students perform at a very low average. It is a fact that in Hungary over the past few years just a few students majored in teaching chemistry at any of the teacher training universities. Besides, 2011 is the International Year of Chemistry, so we would like to popularize chemistry and raise its importance.

During the design of the project we through those students surely would be open to innovations and they would gladly try AR-books, even if these are related to a chemistry curriculum. The overall opinion of the chemistry teachers was that it would be in itself a good result if children took out their chemistry books at home. The poor performance in this subject is not only due to its difficulty, but in the fact that it is not compulsory to graduate from chemistry, so many of the students don't even try to understand and learn it.

After we choose the subject we had to decide which part will be processed. The main aspect was that proceeding of chosen part of curriculum need dimensional illustrations, animations and experiments. The choice was made on the structure of molecule, which is anyway not an easy topic for students. It is a part of curriculum class 9. [15]

Our goal was to represent a successful example for AR technology – and combine a classic student book with the new 3D modeling. We split the students in 2 groups and only one of them got the AR course book, the other group received the course book without AR version. Our hypothesis was the students who study from books with AR will get better results during the

tests comparing with earlier achievements and will have better outcome comparing with students who are using course books without AR.

In preparation and testing the AR exercise book the chemistry teacher, Molnár István was a great help and assistance, he wrote the chemistry curriculum and test for the exam.

The finished course had the following subjects:

The basic skills about molecules formation, what is covalent bound, electron transfer, molecule structure, σ-bond, π–bond, primary and secondary bonding (polar a no polar bond). One of main task was to present the molecules formation, how the molecular orbitals are working, the linear, tetragonal, pyramid and V-systems.

We expanded the elaborate curriculum with 7 AR-marker, five of them be ordered to a 3 dimension illustration of a structure of molecule, one of them be attached to an animation and lately one be ordered to a video of an experiment.
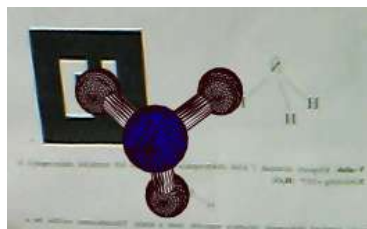

Figure 8. AR-note NH_3

Figure 9. AR-note AR marker of PCl_5[1]

Figure 10. AR-note PCl_5

It was very important for us to find out if these illustrations will be helpful during the understanding of the new concepts of the curriculum to motivate students preparing at home and to know if the complete rotating 3D molecular structures can be understand by students. After we made the curriculum with AR-marker and 3D model, animation and video, we ordered the AR-marker to the object on AR-portal what is made by ELTE T@T labor.

10.2. Use of AR-note

The „ready to use" notebook was tested by us and then we could start the school test too. In the experiment participated two secondary schools: the technical college Janos Neumann and the secondary school Ferencz Rákóci II.; with 184 students from class 9 and 10. Majority of chemistry teachers who were contacted by us welcomed inquiringly the prepared material. Unfortunately not all of them could take part in the experiment because they didn't teach the chosen topic or hadn't got the necessary classes. Were many teachers who asked for the material in order to use it in the future.

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[1] http://arportal.elte.hu/arkemia/bin-debug/arkemia.html

The teacher's orientation was followed by introduction for students. We did a survey about web camera using by students.

We were lucky because in each classroom almost every student had a web camera, and it was easy to split them in 2 groups: an AR group and a control group. Students in first part of name list were divided to the AR-group. Students, who don't have a webcam, can use it in the school.

For curriculum we needed two lesson hours, in the beginning the students watched a presentation about AR technology and about how to use the received AR exercise book at home. Lesson was held in customary form apart from the first 10 minutes of lesson. The members of control group received the exercise book without AR codes version. We told them next time they will get the exercise book with AR codes. During the lessons the teachers haven't used the AR manuals, they thought in usual way. After they finished with the courses, the students could keep the manuals and they could prepare at home for the next hour examines.

On the next lesson was followed a test with 11 tasks in 20 minutes. In test we put three questions specifically about molecules' spatial post and hopefully the AR modeling helped the understanding.

94 courses books have been divided and 90 students were tested.

10.2. Results

We had right in our hypothesis: the members of AR group had better results in test. The experiment was made at the end of first semester and in this case we could use the 1th semester notes. The rating was made in five numbers from 1 to 5, the worst was number 1 the number of students was approximately the same in both groups. The AR group average in chemistry was 2,44; the control group had 2,64.The average of test was 3,2 at AR group and 2,62 at control group. We observed that the control group had almost the same results, the AR group developed significantly (0,76).
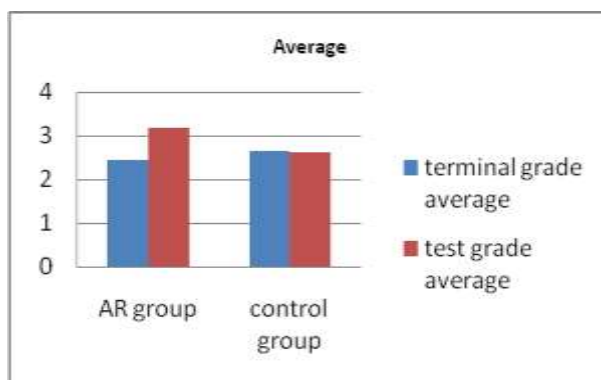

Figure 11.: Test's result in two group

The members of AR group had the following results: 60 % had better notes, 38 % the same and only 2 % had worse notes comparing with the notes before test. The results at control group were more ambivalent: 27% with better notes, 42 was the same and 31 % had worse notes.
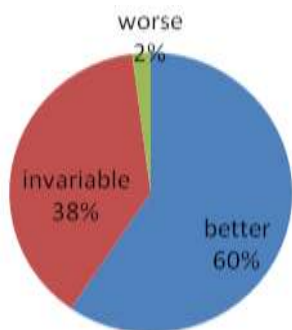
Figure 12.: Test's result of AR group compared to average of chemistry
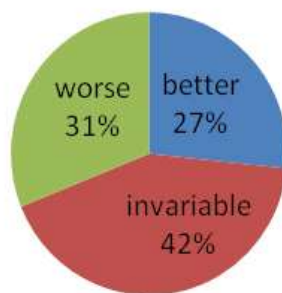
Figure 13.: Test's result of control group compared to average of chemistry

We observed the results for3 test with 11 questions, because it can be used significantly for AR technology results. In the following you can see the right answers from students in different groups:

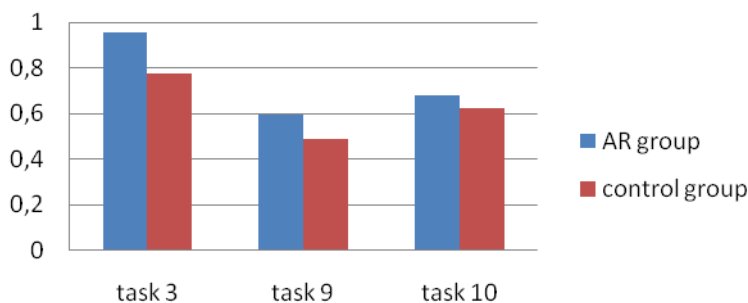| Group/Task	Task number 3	Task number 9	Task number 10
AR group	95,74	59,57%	68,09%
Control group	77,78%	48,89%	62,22%
Table 1.			

Figure 14.: Result of three specifically questions

On the whole our experiment was successful. Both teachers and students had positive opinions about AR manuals, they were interested and would use in the future.

A few opinions and feedbacks from students and teachers:

„When I told to others the possibility to create a computer visualized geometrical structure, possible to rotate, visible at home- computer, everybody was very excited waiting for next presentation. When the time arrived, we could watch the ELTE south building in 3D conjugated

with AR marker. At presentation many haven't understand how this is working and later more were interested about during the courses. After our experiences the modelling working at home, sometimes with a very strong light wasn't clear visibility or with a slow internet connection the rotation was discursive.

After test I asked the students who got AR manuals, what they see the models and the material. For them it was important the fact the subject was collected and the models were better to understand like the pictures on board or in the books.

A few students said the same about the pictures, but after their opinion it is necessary the explication part, without that it would be difficult. None of them had negative opinion.

From teacher's opinion, naturally this „experiment" is coming with more work. Collecting and made the right pictures, it takes time, but the results compensate for long working hours. In average 3-4 tenth percent evaluation was made between on a test average and a terming note.

I would work (and planning to work) with this technology and I can imagine a course book with it. The students could use not only at home, but the teachers could improve the presentations and teaching in classroom with a 3D picture.

In conclusion: I can't tell anything negative about. Nobody needs new computer knowledge for using . I think a digital course book could help to improve students approach for natural science." (István Molnár, chemistry teacher)

„ I think is easier to learn with this..." (Student)

„It was very interesting for me, it would be great if we could have something similar in a few subjects. We could made funny things with... Sometimes it was difficult for computer to recognize the picture, but it was fun!" (Student)

„Basically I don't like chemistry, a long time ago I loved. First I didn't' liked I was in the group who got some extra home work, but when I found out what is all about I get curious. And I liked ☺ (student)

„ I got 2 for my test!!! Now my parents let me for party ☺ let's have this AR thing again" (student)

In our future plans is making a 3D model of molecular construction for high school curricula, even in collaboration with students and with AR codes; this could be more interesting, t.ex the molecular construction picture in 2D or the atomic formula construction. These could be used at an AR card at home or in school. Later even a possible chemistry book could be created.

This project can be extended for many subjects: mathematics, biology, and physics.

8.   Summary

In our paper we introduced the relevance of augmented reality (AR) and presented how the technology works, showing some examples of popular products and the direction where it is heading. We described our own developments in this area, explaining the different modules of the AR portal and their use. We demonstrated some of the applications in university education and then elaborated on an experiment within secondary school. Our present findings so far convinced us that AR technology could be a very good practical extension to textbooks and exercise

booklets, since they give virtual hands on experiences to understand better the models within learning context. Our positive results convinced us to continue with our research in this area.

Literature

[1]   Óhidi, A.: Az élethosszig tartó tanulás és az iskola, Új Pedagógiai Szemle, 2006

[2]   Zsolt Kulcsár: Az interaktív e-learning felé, 2009

[3]   Caudell, T. P. and Mizell, D., W.:"Augmented Reality: An Application of Heads-Up Display Technology to Manual Manufacturing Processes", Proceedings of 1992 IEEE Hawaii International Conference on Systems Sciences, 1992, pp 659-669.

[4]   WIKIPEDIA http://en.wikipedia.org/wiki/Point_of_interest

[5]   GERENCSÉR, P. (2010): Kiterjesztett valóság alkalmazások Android platformon.

[6]   Yang, M.-H.: *Recent Advances in Face Detection* (2004)
        http://vision.ai.uiuc.edu/mhyang/papers/icpr04_tutorial.pdf

[7]   Tamás Matuszka, Erdődi Péter, Cseh Péter: AR portál, III. Oktatás-Informatikai Conferencee Proceeding (January 2011), 197-201.

[8]   Huba Hajdú, Otília Pasaréti: AR technology in the social education, III. Oktatás-Informatikai Conferencee Proceeding (January 2011), 129-134.

[9]   T. Fugger, N. Hornung, F. Koller, The herbarium:An interactive augmented book of trees

[10]   K. Asai, H. Kobayasi, T. Kondo, Augmented instructions – a fusion of augmented reality and printed learning materials, 2005

[11]   Juan, M. C., Rey, B., Prez, D. Tomas, D., Alca,M.: The memory book, 2005

[12]   C. C. Marshall, Reading and interactinvity in the digital library: Creating an experience that transcends paper. 2005

[13]   M Billinghurst, H. Kato and I. Poupyrev. The magic book – moving seamlessly between reality and virtuality. Compter Graphics and Applications, 2001

[14]   Wellner, P. Interacting with paper on the DigitalDesk. Commun. ACM 36, 7 (1993)

[15]   The National Curriculum for Hungary (2007)