DEVELOPMENT OF AN EDUCATIONAL GAME: AUGMENTED REALITY APPROACH TO EDUTAINMENT

Luka Petrović[1], Danijela Stojanović[1], Aleksandra Labus*[1]
[1]University of Belgrade, Faculty of Organizational Sciences, Serbia
*Corresponding author, e-mail: aleksandra@elab.rs

Abstract: *In this paper, the authors examine the problems, capabilities, and benefits of implementing augmented reality technologies in higher education and integrating them into formal e-learning in the form of edutainment. The main goal is to design and develop an educational interactive game that features augmented reality and would enrich the teaching process with interesting content as well as motivate students and stimulate their acquisition of knowledge. The developed game is based on current internet mobile technologies, with AR aspects realized through the use of the Vuforia platform, and is implemented as a part of a smart classroom. It includes a web application for teachers to create tasks, small parts of the curriculum that are being tested, a mobile application that students use to interact with the game and solve tasks, an augmented reality module that supports distance learning and a component for integration with Moodle LMS. This paper will focus on the AR aspects of the game and the benefits that can be gained with its use in education. The game has been implemented within the educational process at Faculty of Organizational Sciences, University of Belgrade*

Keywords: *Augmented Reality, Internet of things, game-based learning, edutainment.*

1. INTRODUCTION

The educational process is ever changing and evolves over time. This progress stems a requirement to fulfill the needs of the students that change over time (Education, 2011). With the coming of the digital age and the daily innovations which represent it, it has never been harder or more important to redesign current methods of teaching and formulate a new approach that will accommodate a society living on the thin line between the real and digital worlds (Bowen, 2015). There is a need for modern education in all age groups with special focus on children starting their education as they are a generation born into the modern world and are introduced to many forms of technology since birth (Yelland, 2006). Technologies of augmented reality in education are increasingly being used and show great potential and contribution to the teaching process from the pedagogical aspect.

Many innovations in education come from the constant rapid development of Informational and Communicational technologies, especially Internet (Gyorgy, Suciu, Alexandru, & Militaru, 2014; Labus, Despotović-Zrakić, Radenković, Bogdanović, & Radenković, 2015). The effects of implementing internet technologies in e-learning have been a focus of many studies (Means, Toyama, Murphy, & Baki, 2013).

There are numerous articles and research papers with incorporating smart technologies or new methods in education as their focus of attention but a lot of them approach the subject matter from a purely theoretical view (Cook & Das, 2004) while other works don't always demonstrate the full integration of game-based learning in conventional education systems (De La Guía, Lozano, & Penichet, 2013; Kipper, 2013; Shen, Wu, & Lee, 2014). In this research, we try to contribute to filling this gap by developing a game within a smart learning environment and that aims to enhance the user's perception by utilizing the power and popularity of augmented reality.

2. LITERATURE REVIEW

A. Augmented reality

Augmented reality is a technology that has an astounding number of applications such as business, medicine, gaming and other forms of entertainment and education (Liou, Yang, Chen, & Tarng, 2017). Using AR in educational games leads to hybrid games, games in which digital and physical objects can interact with one another (Mircea et al., 2011). It is a new medium, combining a multitude of different computer aspects to offer a unique approach to continuous and implicit user control (Lee, 2012). This approach can enhance the quality and speed of training by providing a different view into the subject matter (Kamphuis, Barsom, Schijven, & Christoph, 2014). An example of this is the use of AR in medical training (Gu & Duh, 2011). By switching from 2D images to 3D models generated by smart devices, medical students can better grasp the concept of many elements in their field of study like anatomy. Advances in mobile devices and their graphics processing and rendering increases the gaming potential of mobile phones . By combining mobile 3D game engines with Augmented Reality technologies it is possible to create a platform that is capable of enriching our reality any time any place. One such example is described in (Sherstyuk, Vincent, Berg, & Treskunov, 2011). In this example, authors describe the process of interacting with a 3D model of a patient. Thanks to mobile technologies, the model is not only rendered in 3D it is also responsive and fully functional. In this way, many hardware limitations of physical tools are circumvented and students are capable of gaining practical knowledge in a far greater capacity.

Currently, most of the innovative approaches to education are implemented as part of higher education. This is because universities have the necessary technologies and skilled personnel that are not only capable of conducting such classes but also willing to research new approaches to teaching (Begg, Dewhurst, & Macleod, 2005). That being said, it isn't restricted to universities as there are attempts to do the same on a high school level (Papastergiou, n.d.).

B. Educational games

Studies have shown that there is a great need for a better way to provide education. Due to rising demand for highly educated people, educational institutions cannot provide the necessary supply. This leads to creating more efficient means of teaching that can speed up the process and increase its quality (Savander-Ranne, Lunden, & Kolari, 2008). Many studies have shown that alternative and modern approaches to teaching yield better results (Stojanovic, Bogdanovic, Nedeljkovic, 2016). Some of the techniques that have been recently looked into are the use of modern technologies in the form of teaching tools and the use of edutainment in the teaching process (Knežević, Despotović-Zrakić, Labus, Jezdović, Ivković, 2016). Educational games find themselves used in research papers more and more and their potential is heavily discussed. They are interesting to students and possess the ability to motivate them beyond normal lecture capacity. This makes researchers explore their beneficial influence on the learning process (Petrović, Jezdović, Bogdanović, & Despotović-Zrakić, 2017). Use of games to facilitate learning is not a new concept and was used for a long time. The first form of such games is physical games. These games use physical objects to bring knowledge to students (Zagal, Rick, & Hsi, 2006). Since then, educational games have come far. Innovations in technology have created new forms of games that follow the trends and maintain their appeal to a younger audience, with the latest trend being mobile and AR games (Gros, 2007). Using video games in a teaching environment is nothing new (Alshanbari, 2013). Studies have shown that playing video and computer games can have a positive effect on players' cognitive abilities like decision making, speed thinking and reaction speed (Prensky, 2003). Another aspect of gaming that can be used to facilitate better learning is competitiveness. The competitive side of gaming leads to better motivation and a greater amount of effort being poured into performing actions whether they are of educational character or not (Burguillo, 2010). They also help focus attention to a single point which can be used for a more effective transfer of knowledge, with lesser losses of information due to "white noise" of distracting happenings all around us (Griffiths, 2002). In psychology, the greatest form of this is called "flow" and it describes a state of full immersion into an activity that focuses all of a person's concentration into a single goal (Csikszentmihalyi, 1975b, 1975a). When used in conjunction with gaming and "flow", education can be an interesting, motivational, immersive and above all else a productive activity, for example, a goal-driven educational game (Kiili, 2005). Using new technologies to change traditional types of games and adapt them to new trends makes them more interesting to newer generations and increases their effects (Petrović, Stojanović, Labus, Bogdanović, & Despotović-Zrakić, n.d.)**Error! Reference source not found.**. With the development of 3D games, we can see a rise in their popularity over the 2D type (Koops, Verheul, Tiesma, de Boer, & Koeweiden, 2016).

There are several parameters that can be used to evaluate the quality of an educational game (Aslan & Balci, 2015):
- Acceptability: the level of completion of the learning goals;
- Challenge: the level of motivation;
- Clarity: the level of understanding;
- Interactivity: the level of interaction between the student and the game;
- Reward: it enables the student's satisfaction after the completion of goals.

C. Internet of Things

Internet of things has found itself being used for various purposes, like traffic, data analysis and for our purposes the most important one of all – education. There can be many implementations of IoT in education but the most often example is in universities.

Many classrooms today are connected to the Internet and have the advanced technological equipment, such as tablets or interactive boards. This type of classroom is called the smart classroom (Song, Zhong, Li, Du, & Nie, 2014). These classrooms are equipped with all kinds of tools and technologies necessary to provide an enhanced learning experience that builds on top of the classical face to face model with a virtual, off-site approach by providing a flexible and inspirational environment (Mikulecký, 2012). These classrooms are the ideal place to implement educational games as they meet the necessary technological requirements (Xiliang, Xin, Yafei, & Mengkun, n.d.). By relying on the recent internet and mobile technological boom, limitations of smart environments are pushed even further. Using smartphones, as they are currently the equivalent of a pocket-sized computer- a fact that was unimaginable even as recent as 10 years ago, learning can happen everywhere, physical presence can become a thing of the past (Suo, Miyata, Morikawa, Ishida, & Shi, 2009).

3. DESIGN

A. Project requirements

The goal of our study was to create a tool that would transform the antiquated teaching mechanics into an exciting and immersive experience as well as monitor the effects it has on the student's motivation and knowledge acquisition. During our research, we have explored the processes of envisioning and designing methods to bring our idea into fruition as well and developing hardware and software components based on current technological standards that are necessary for implementation into a real environment. Based on its potential in education, augmented reality technologies have been chosen as a core of the solution. The result was an educational game based on AR that test's the players' knowledge on a given subject in a fun and inviting manner and monitors their progress and achieved results. The game aims to motivate students to embrace learning as a positive influence in their life by presenting it as a challenge set on a medium that the user is already accustomed to.

B. Game concept

The concept of the game revolves around the process of giving the correct answers to given questions. What differs in comparison to a standardized test is the way in which the examinees not only solve the problems but also the method of submitting their answers. By designing questions in an interactive way that forces the students to apply their acquired knowledge in a practical manner that is both fun and educational, tests can be taken to a new level. One approach to this is creating workstations or polygons for each assignment and distributing them to remote locations. This creates a goal-driven approach or in game terms manifests the illusion of "quests". Polygons can consist of any number of elements, from simple images to be used with AR modules to IoT infrastructures that demonstrate some core features of smart objects. Another approach might be through a computer or in recent times mobile education, with apps instead of pen and paper. This too can test both the theoretical knowledge i.e. quizzes or simulate some real-world situation for the student to manage. Our approach was a mixture of aforementioned solutions joined together, a model that is composed of a server which represents the core of the system and many distributed platforms made for solving each task in a different way, but obeying the standards of the central unit and integrating into it.

C. Architecture

The architecture of the developed system is shown in figure 1. The system is split into core and distributed elements with a middleware to connect them much like a bridge would. Among the core elements, we have a virtual machine to house the central web server. The server host many items that are integral to the system such as an administrative tool in the form of a web application that is used by a teacher to administer the whole testing and grading process. The most important part of this tool is to create the logical form of assignments that are presented to students during testing as well as serving as building schemas for their physical representation. Other components that make the central server their home are the main database used for storing all transactions and the many web services used by all of the system's various components. It is the services that are the gateway between the centralized core and the distributed network of participants and locations. The most important tool from the aspect of the player is the controller. Representing the middleware, the controller serves as a means of communication between the player and a black box that is the game. It is present in the form of a mobile application on a smart device such as a phone or tablet. Using its User Interface it can collect input from the user and has integrated features to connect to the APIs of the server and physical data of the environment. The last segment of the system is a collection of the many distributed locations, mostly smart environments adapted for the purpose of solving at least one task. Communication between components is realized through the use of web services, RFID tags (Miglino, Ferdinando, Fuccio, Rega, & Ricci, 2014), and QR codes (Kan, Teng, & Chen, 2011). User management and grading are interconnected with Moodle LMS.

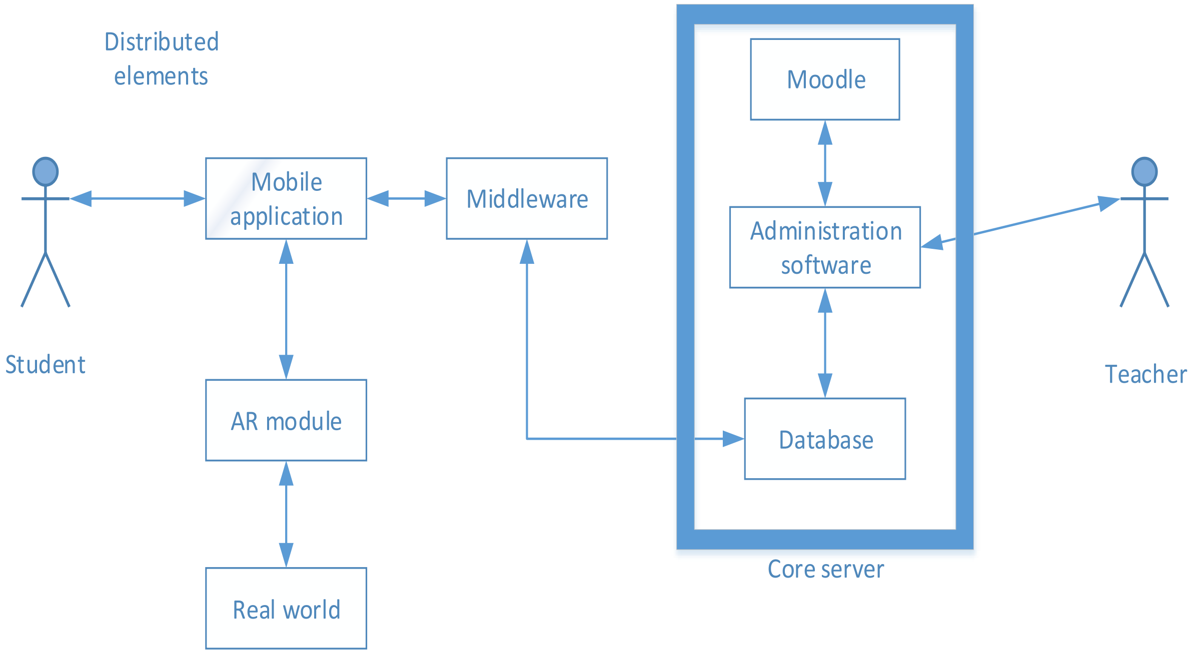


Figure 1: The architecture of the game

Mobile application

The mobile application is the player's gateway into the complex system of the game. It is the only way to interact with the physical objects necessary to solve tasks as well as the only interface that receives tasks from the server. In order to accommodate a wide range of task types, it uses task metadata to adapt to the current type and generate only the capabilities necessary at the moment (Simić, Despotović-Zrakić, Labus, Radenković, Bogdanović, 2015). It does this by being split into modules that are used as building blocks to form a whole during the loading of a new task, as seen in figure 2. The application can be divided into two parts, the Vuforia part, that enables the use of augmented reality, and the Android part that facilitates everything else.

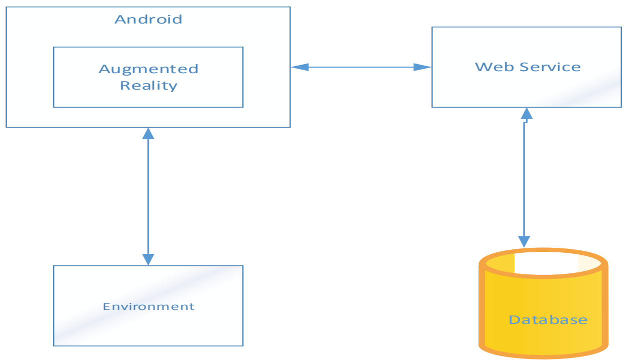


Figure 2: Mobile application structure

Augmented reality module is used to enhance the user's view of the real world and it does so by interacting with a camera view and analyzing every frame, trying to find a designated image within it. If an image is recognized 3D elements are overlaid over it. There are three types of AR modes available:

- Cloud Recognition which holds all target images as well as metadata files in a cloud server. This mode recognizes a target and reads the accompanying metadata file. This file contains names and positions of 3D models that should be rendered.
- Virtual Button which recognizes only a single target but in exchange supports user interaction. On successful target recognition, first of a list of 3D models is rendered as well as 2 buttons, left and right. When hovering underneath a button, the displayed model is changed either to the left or right of the list position of the previously displayed model.
- Explore which works similarly as Cloud Recognition in that its targets and metafiles are stored in the cloud. The main difference lies in views rendered on recognition. Unlike the first type, Explore only has 1 model available, a text panel and title and text that are displayed inside it are contained in metadata text files.

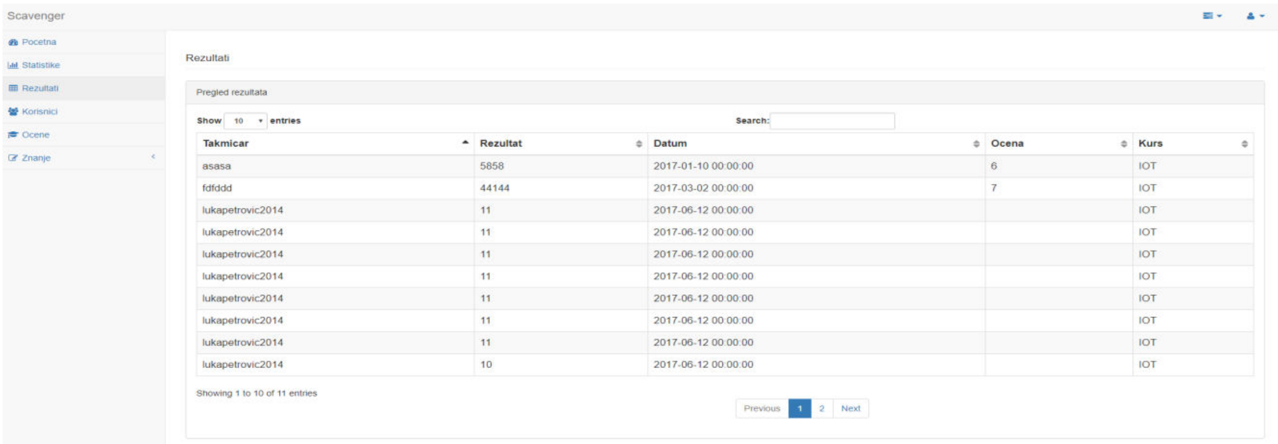
To successfully implement the game, it is necessary to prepare an environment for it. At the very least it is needed to prepare a location for all the image targets present. If there is a need to also collect data from the environment in some way, this environment includes workstations on multiple locations and equipment for students (Petrović, Jezdović, Stojanović, Bogdanović, & Despotović-Zrakić, 2017).

Workstations are equipment present on site for each task. If the task is envisioned to be solved with the aid of external factors and devices, then all the necessary hardware and software must be set. Since the game is played in multiple locations, they are scattered throughout the envisioned playing field.

Location of each task can be anywhere, in the classroom, in the faculty building, or outside. For example, a task can be related to measuring the temperature, and the equipment can be placed in a classroom. Or, a task can be related to plant watering, so the workstation will be placed in the garden.

Administration software

The administrative tool is used by teachers to organize tests (playing of the game), to create new tasks or modify existing ones, review achieved results for a given student and grade them. By using this tool, we prepare data that is available to other parts of the system through our web services. In figure 3 we can see the screen used for reviewing achieved results.



Takmicar	Rezultat	Datum	Ocena	Kurs
asasa	5858	2017-01-10 00:00:00	6	IOT
fdfddd	44144	2017-03-02 00:00:00	7	IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	11	2017-06-12 00:00:00		IOT
lukapetrovic2014	10	2017-06-12 00:00:00		IOT

Figure 3: Results overview screen

Moodle integration

In both the mobile and web tools authentication is done via Moodle. By entering credentials a call to a public Moodle API is made with a request for authentication tokens. Only after confirmation of identities has taken place users can begin their work. Another call to the Moodle service is activated after the game ends. The client application sends the achieved results to the server for professors to grade with the help of the web application. After the grades have been set, they are set as Moodle assignment scores.

D. Game scenario

The test is split into groups of 1 or more assignments, let's call them subjects. The students, or in this context players, are given a mission to clear as many subjects as they possibly can within the time limit. They are given assignments in sequential and random order with questions from all subjects mashed together. To complete the subject, students are required to correctly answer exactly 1 assignment from that subject's subset. Once an answer is submitted its validity is put to the test. A correct one will award the player full points for that question as well as mark the subject solved. Any subject that is marked as solved will no longer be among the possible questions for that student. On the other hand, if the answer was not correct, there is no change and players are given the next task. There is no direct penalty for solving a task incorrectly as it might be received and correctly solved at a later point in the game, however, the time required to redo it decreases the acquired points at the end of the game (as the remaining time is part of the grade). New tasks are generated from a collection of all assignments from the unsolved subjects so in the case of a wrong answer the user can get that same question, another question from the previously tested subject or a question from a completely different subject. A potential penalty occurs if the player cannot correctly finish a task even after multiple attempts. In this scenario, not only is the utilized time deducted from the score, so are the points that each completed task brings.

To begin the game, students have to go to the predefined start location and acquire a player controller that is already configured. After imputing their credentials and successfully logging in to their Moodle account, they proceed to choose the option to begin testing. After starting the game, the timer begins the countdown. By getting random tasks, students are sent to different locations and their paths diverge from the start. Next is the process of solving tasks one by one in a similar fashion until a task from each group is solved or time runs out. Each assignment has information that it presents to the player by displaying it in the controller at the moment it has been received. Among the info present is the location which the player has to go to, the question which needs to be answered as well as metadata needed to generate all the necessary components. Metadata is used to generate user interfaces that the player sees, such as the way of inputting the solution (keyboard, RFID tag, QR code) or interfaces for connecting to the environment (AR, IOT…) After arriving at the specified location, students proceed to interact with the environment in a way defined in the text of the task and its metadata. Productive interaction will yield data necessary to complete a task prove mastery over the subject. Each task is also scored according to the difficulty of completion. Completing harder tasks rewards more points but it may cost more time. The final score of the test is determined by the number of subjects closed, difficulty points of each task and the remaining time. As previously stated, the game is played in iterations, which is shown in figure 4.

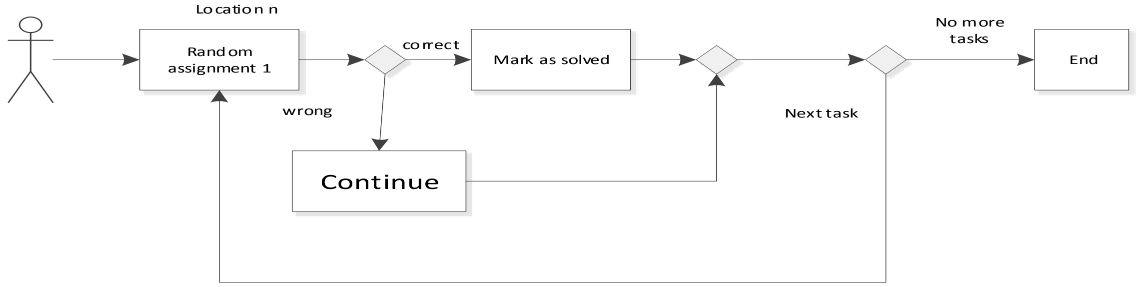


Figure 4: The game scenario

Since not all tasks are of the same difficulty, they cannot be graded in the same way, so the final score is calculated based on the remaining time and the sum difficulty level of each successfully completed task. The detailed game process is displayed in figure 5.

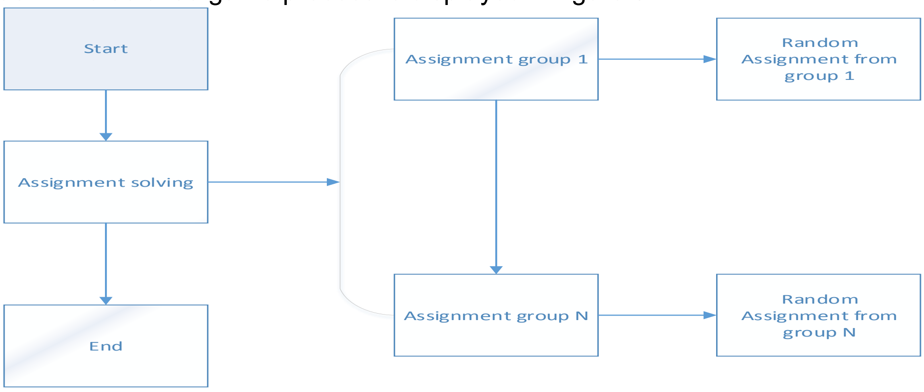


Figure 5: Task overview

Throughout the game, the student can review the solved assignments. After completion of all the assignments, or after the time has elapsed, the score that student achieved is calculated, shown to the student, and inserted into the administration application and Moodle.

An extra feature of the game is a hint option. Tasks are equipped with messages meant to point the student in the right direction in case there is trouble coming up with an answer. To use the help or not is up to the players themselves. Solving tasks awards grade points that make the final grade but there is another use for them. By collecting enough points a special button is made available. By pressing it students sacrifice points that have been used in the button but gain help on a complicated problem. Choosing this option lowers their final result but possibly awards another closed subject.

E. Assignments

A schema of an assignment is shown in figure 6. The displayed assignment is from the AR type. The student is required to scan the environment with the AR camera provided as part of the handheld device and recognize elements that are generated in the view. Based on his conclusions he reaches the answer and submits an answer.

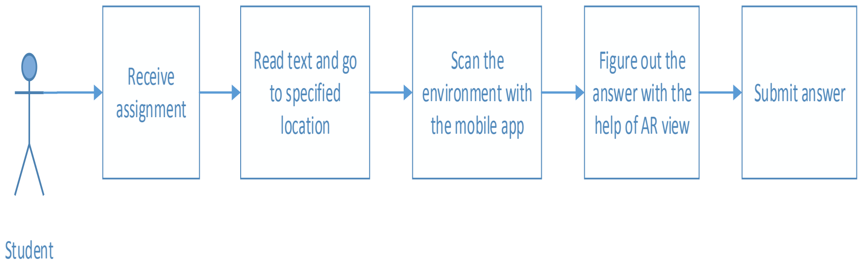


Figure 6: AR Assignment workflow schema

As an example, an AR assignment called Diagram completion will be presented. After arriving at the designated location, multiple pairs of IoT platform diagrams and QR codes will be present. A question can be seen on the first of multiple available screens of the mobile application and its text will tell the player how to activate the AR features of the game and that he needs to scan the diagrams and find the complete one. After reading the instructions and navigating to the AR screen players choose one of three available AR modes (see figure 7) and aim the camera at the first diagram and on-screen multiple 3D models of IoT elements will show up in different locations.

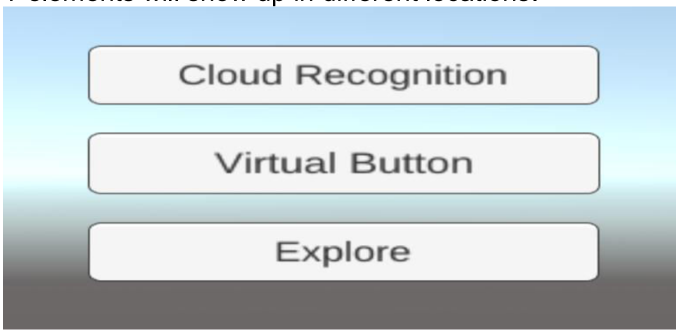


Figure 7: Vuforia module selection

Each diagram is missing at least one key component. Students need to find a diagram that when combined whose missing components are present in its 3D render. Such a combination of diagram and models is considered complete and is the correct one. Submission of the solution is done by navigating to the next application screen and pressing the button to scan the QR code paired with the previously selected diagram. QR tags hold codes for solving tasks. Tags paired with correct answers will match the assignment codes and mark the assignment as completed during check-up while all others will fail to match. Navigation through the application windows is done by swiping left and right on the device screen. Based on the task metadata, the mobile application will generate only the needed windows (figure 8). Generally, there are 3 windows present, the information window that holds the text of the question and necessary instructions as well as the location while the other two windows are dynamic and represent the widow for solving and the solution input window respectively. In the showcased example AR camera has been used for the former, while for the latter a QR code scanner was generated.

Figure 8: Task text and textual solution input

Another example of an AR task is named Model recognition. This task also tests the knowledge of the IoT models but is of lesser difficulty. The goal is to simply find the item that was specified in the text.

The process is the same as in the previously described example with small differences. Firstly there is only one diagram present on location, with a multitude of QR tags marked with numbers. After opening the AR window, 3 models will show up on screen, an IoT object and 2 buttons to change the center object. By using the primary model as number 1 and increasing the enumeration of every next model to the right of it by 1, or decreasing it by going left we can get the answer. We number models until we reach the required one and scan the QR code marked with that same number. In both examples, it is possible to look at the augmented reality from all sides and angles but it is also possible to rotate and scale models by interacting with the screen. This feature makes it easier to see details if necessary.

Figure 9: Vuforia task example

4. RESULTS

For the evaluation of the developed game, a pilot testing was organized at the Faculty of Organizational Sciences, University of Belgrade, within the Department of Electronic Commerce (e-lab) during the Summer School attended by undergraduate 4th-year students. The goal was to test the efficiency of using the developed game while learning about the Augmented Reality technologies. The research was conducted in accordance with the code of professional ethics. All students willingly agreed to contribute to this research.

The research involved 7 students who attended the Internet of things course. After using the application, students filled in a poll in which they gave their opinion on the way each task was solved. The questionnaire had 10 questions and the students could demonstrate their opinion on the offered five-step scale from "I completely agree" to "I completely disagree".

Each student received a mobile phone on which a mobile application was installed. Their tasks were to launch the application, log in to the Moodle system, and press the button in the displayed menu - launch the game. The system then selected one of the tasks randomly. If the student does not solve the exact task, they have the ability to re-test within a given time again. After the expiration of the time or after solving all the tasks, it was necessary to press the button "finish the game". Two of the offered tasks were Vuforia type.

The student had the task of reading the text on the screen of the mobile phone, then going to the assigned location from the task. Within the application, it was needed to move the screen to the right and click on the scan, then select the option specified in the text of the task and position the device so that the image is visible on the camera. The students needed to select a 3D model that matched the task's solution, double-click the "back" button, move the screen to the right and click on the scan. The device had to be positioned to see the QR code corresponding to the selected model. The last step was to move the application screen to the right, enter the read message into the displayed field, and click "Submit". Finally, students who participated in the research-filled in the questionnaire, answering questions about the application itself. In the given survey, students expressed their opinions on the application, but also answered questions that were related to satisfaction in solving each of the three questions asked.

A. Knowledge test results

The table shows the opinions of students related to the use of the extended reality application while solving the tasks set.

Regarding whether tasks were easier to solve by using the application, 71.43 percent of students said they fully agreed with the view that it was easier to solve the task with the application, while the other 28.57 percent of students replied that they could not decide.

No one answered that they partially or completely disagree that their tasks are easier to solve using the application.

Table 1: Questionnaire data

Question	% Strongly agree (score = 5)	% Agree (score = 4)	% Neutral (score = 3)	% Do not agree (score = 2)	% Strongly disagree (score = 1)	Mean score	Standard deviation
The task is easier to solve with using the application.	71.43	0.00	28.57	0.00	0.00	4.36	0.82
The task is easy to learn.	85.57	14.29	0.00	0.00	0.00	4.71	0.49
It's boring for me to solve this task like this.	14.29	14.29	28.57	14.29	28.57	2.64	1.29
I had the feeling of controlling the situation while solving the task.	42.86	57.14	0.00	0.00	0.00	4.36	0.54
Too bad that there were no more tasks of this type.	42.86	28.57	28.57	0.00	0.00	4.14	0.78
There was enough time to solve this task.	71.43	28.57	0.00	0.00	0.00	4.64	0.54
There was insufficient time to solve this task.	42.86	0.00	28.57	14.29	14.29	3.43	1.40
There was too much time to solve this task.	14.29	14.29	14.29	42.86	14.29	2.43	1.21
I prefer the classic test for solving this type of task.	14.29	14.29	14.29	28.57	28.57	2.43	1.33
The task is more fun to solve with the application	85.57	14.29	0.00	0.00	0.00	4.71	0.34

When asked if the tasks were easy to learn, 85.71 percent of students replied that they fully agreed, and one student partially agreed. Students in a percentage of 85.71 percent agree that it is more fun for them to solve tasks using the application, and as much as 42.86 percent think it is a pity that there were no more tasks of this type. When asked if they have a sense of controlling events while solving tasks, 57.14 percent of students agree in part and 42.86 percent of students fully agree. Students' indecisiveness is evident over time in solving tasks. We see that 42.86 percent think that there was insufficient time to solve the tasks, while in the same percentage; the students think that there was too much time to solve the tasks. It is believed that this way of solving tasks for students is new and, depending on their readiness and skills in the use of new technologies, their position on this issue varies. A certain number of students, 28.57 percent cannot decide and put their opinion in a large number of questions. This means that although they agreed that the given application was useful, they were not convinced that it fits their needs.

B. Opinions about the application

After completing the coursework, students expressed their opinion on the most sensitive and most negative aspects of the application.
As the most positive aspects, they stated:

- Ease and simplicity,
- Interactivity,
- Interest,
- Facilitates learning and
- Virtualization.

According to the answers, the most negative aspects were:

- QR code is not being scanned,
- The application can crash,
- Slowness,
- Taking a lot of device storage space.

In the further stage of the research work, and the development of applications of expanded creativity for educational purposes, the answers of students who could not decide when it comes to needs and expectations, save time, easier tasks, in particular with the aim of improving the application as well as more successful and more efficient educational process.

5. CONCLUSION

The evaluation was conducted during practical lessons with undergraduate students in the course of the Internet of Things. Testing was done with a small group of students. The results showed that the application of augmented reality, used in conjunction with the game model, has the potential for implementation, that students considered it useful and fun, and that it contributes to their knowledge, as well as the quick and easy overcoming of the subject material. It also provided guidelines and suggestions for improving the application of augmented reality in widespread use in the educational process. In addition to improving the technical aspects of the system, the future work will be directed towards the development of a larger number of tasks, further integration with Moodle and complete technical and educational assessment of the system.

ACKNOWLEDGMENT

Authors are thankful to the Ministry of education, science and technological development, grant no 174031.

REFERENCES

Alshanbari, H. (2013). Video Games in Education. *Hassacc*. https://doi.org/10.1145/950566.950583

Aslan, S., & Balci, O. (2015). GAMED: digital educational game development methodology. *Simulation*, *91*(4), 307–319. https://doi.org/10.1177/0037549715572673

Begg, M., Dewhurst, D., & Macleod, H. (2005). Game-Informed Learning : Applying Computer Game Processes to Higher Education. *Innovate*, *1*(6), 7–13. Retrieved from http://www.innovateonline.info/pdf/vol1_issue6/Game-Informed_Learning-__Applying_Computer_Game_Processes_to_Higher_Education.pdf

Bowen, W. G. (2015). *Higher Education in the Digital Age. Updated Edition. The William G. Bowen Memorial Series in Higher Education*. *Princeton University Press*. Retrieved from http://widgets.ebscohost.com/prod/customlink/hanapi/hanapi.php?profile=4dfs1q6ik%2BHE5pTp1ZLu0eGT1tTR28jqzaLXyajL2dTV482lyNzZoJmu5NS8q%2BnpkKU%3D&DestinationURL=http%3A%2F%2Fsearch.ebscohost.com%2Flogin.aspx%3Fdirect%3Dtrue%26db%3Deric%26AN%3DED573206%26s

Burguillo, J. C. (2010). Using game theory and Competition-based Learning to stimulate student motivation and performance. *Computers and Education*, *55*(2), 566–575. https://doi.org/10.1016/j.compedu.2010.02.018

Cook, D. J., & Das, S. K. (2004). *Smart Environments*. *Smart Environments: Technology, Protocols and Applications*. https://doi.org/10.1002/047168659X

Csikszentmihalyi, M. (1975a). Beyond Boredom and Anxiety: Experiencing Flow in Work and Play.

The Jossey-Bass Behavioral Science Series. https://doi.org/10.2307/2065805
Csikszentmihalyi, M. (1975b). Beyond boredom and anxiety. *Book Reviews*, 703–707. https://doi.org/10.2307/2065805
De La Guía, E., Lozano, M. D., & Penichet, V. M. (2013). Interacting with Objects in Games Through RFID Technology. *Radio Frequency Identification from System to Applications*, 166. https://doi.org/10.5772/53448
Education, H. (2011). *Higher Education : Students at the Heart of the System*. *Higher Education* (Vol. 6). Retrieved from http://www.wwwords.co.uk/pdf/validate.asp?j=plat&vol=6&issue=1&year=2007&article=6_Sander_PLAT_6_1_web
Griffiths, M. D. (2002). The educational benefits of videogames. *Education and Health*, *20*(3), 47–51. https://doi.org/10.1145/950566.950583
Gros, B. (2007). Digital Games in Education : The Design of Games-Based Learning Environments. *Journal of Research on Technology in Education*, *40*(1), 23–38. https://doi.org/Article
Gu, J., & Duh, H. B. L. (2011). Mobile Augmented Reality Game Engine. In *Handbook of Augmented Reality*. https://doi.org/10.1007/978-1-4614-0064-6
Gyorgy, T., Suciu, G., Alexandru, V., & Militaru, L. T. (2014). Use of New Technologies in Education. In *The International Scientific Conference eLearning and Software for Education*.
Kamphuis, C., Barsom, E., Schijven, M., & Christoph, N. (2014). Augmented reality in medical education? *Perspectives on Medical Education*. https://doi.org/10.1007/s40037-013-0107-7
Kan, T.-W., Teng, C.-H., & Chen, M. Y. (2011). QR Code Based Augmented Reality Applications. In *Handbook of Augmented Reality*. https://doi.org/10.1007/978-1-4614-0064-6
Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *Internet and Higher Education*. https://doi.org/10.1016/j.iheduc.2004.12.001
Kipper, G. (2013). *Chapter 3 - The Value of Augmented Reality*. *Augmented Reality*. https://doi.org/10.1016/b978-1-59-749733-6.00003-6
Koops, M. C., Verheul, I., Tiesma, R., de Boer, C. W., & Koeweiden, R. T. (2016). Learning Differences Between 3D vs. 2D Entertainment and Educational Games. *Simulation and Gaming*, *47*(2), 159–178. https://doi.org/10.1177/1046878116632871
Labus, A., Despotović-Zrakić, M., Radenković, B., Bogdanović, Z., & Radenković, M. (2015). Enhancing formal e-learning with edutainment on social networks. *Journal of Computer Assisted Learning*, *31*(6), 592–605. https://doi.org/10.1111/jcal.12108
Lee, K. (2012). Augmented Reality in Education and Training. *TechTrends*. https://doi.org/10.1007/s11528-012-0559-3
Liou, H. H., Yang, S. J. H., Chen, S. Y., & Tarng, W. (2017). The influences of the 2D image-based augmented reality and virtual reality on student learning. *Educational Technology and Society*, *20*(3), 110–121.
Means, B., Toyama, Y., Murphy, R., & Baki, M. (2013). The Effectiveness of Online and Blended Learning: A Meta-Analysis of the Empirical Literature. *Teachers College Record*. https://doi.org/10.3991/ijac.v3i2.1322
Miglino, O., Ferdinando, A. Di, Fuccio, R. Di, Rega, A., & Ricci, C. (2014). Bridging digital and physical educational games using RFID/NFC technologies. *Journal of E-Learning and Knowledge Society*, *10*(3), 89–106.
Mikulecký, P. (2012). Smart Environments for Smart Learning. In *9th International Scientific Conference on Distance Learning in Applied Informatics* (pp. 213–222). Retrieved from http://conferences.ukf.sk/index.php/divai/divai2012/paper/view/873
Mircea, M., Holland, S., Chen, Y., Zagoranski, S., Divjak, S., Frasson, C., … Huang, S. H. (2011). Augmented reality in education. *Computers and Education*. https://doi.org/10.1109/SAMI.2014.6822433
Papastergiou, M. (n.d.). Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*, 1–12. https://doi.org/10.1016/j.compedu.2008.06.004
Petrović, L., Jezdović, I., Bogdanović, Z., & Despotović-Zrakić, M. (2017). Razvoj edukativne igre zasnovane na Internetu inteligentnih uređaja. *INFOTEH-JAHORINA*, *16*.
Petrović, L., Jezdović, I., Stojanović, D., Bogdanović, Z., & Despotović-Zrakić, M. (2017). Development of an educational game based on IoT. *IJEEC - INTERNATIONAL JOURNAL OF ELECTRICAL ENGINEERING AND COMPUTING*. https://doi.org/10.7251/IJEEC1701036P
Petrović, L., Stojanović, D., Labus, A., Bogdanović, Z., & Despotović-Zrakić, M. (n.d.). Harnessing Edutainment in Higher Education: an Example of an IoT Based Game.
Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment*.

https://doi.org/10.1145/950566.950596
Savander-Ranne, C., Lunden, O.-P., & Kolari, S. (2008). An Alternative Teaching Method for Electrical Engineering Courses. *Education, IEEE Transactions On*. https://doi.org/10.1109/TE.2007.912500
Shen, C. W., Wu, Y. C. J., & Lee, T. C. (2014). Developing a NFC-equipped smart classroom: Effects on attitudes toward computer science. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2013.09.002
Sherstyuk, A., Vincent, D., Berg, B., & Treskunov, A. (2011). Mixed RealityManikins for Medical Education. In *Handbook of Augmented Reality*. https://doi.org/10.1007/978-1-4614-0064-6
Song, S., Zhong, X., Li, H., Du, J., & Nie, F. (2014). Smart classroom: From conceptualization to construction. In *Proceedings - 2014 International Conference on Intelligent Environments, IE 2014* (pp. 330–332). https://doi.org/10.1109/IE.2014.56
Suo, Y., Miyata, N., Morikawa, H., Ishida, T., & Shi, Y. (2009). Open smart classroom: Extensible and scalable learning system in smart space using web service technology. *IEEE Transactions on Knowledge and Data Engineering*, *21*(6), 814–828. https://doi.org/10.1109/TKDE.2008.117
Xiliang, P., Xin, W., Yafei, W., & Mengkun, L. (n.d.). Internet of Things based Education: Definition, Benefits, and Challenges. https://doi.org/10.4028/www.scientific.net/AMM.411-414.2947
Yelland, N. (2006). *Shift to the future: Rethinking learning with new technologies in education*. *Shift to the Future: Rethinking Learning with New Technologies in Education*. https://doi.org/10.4324/9780203961568
Zagal, J. P., Rick, J., & Hsi, I. (2006). Collaborative games: Lessons learned from board games. *Simulation and Gaming*. https://doi.org/10.1177/1046878105282279