

THE DEVELOPMENT OF EDUCATIONAL AUGMENTED REALITY APPLICATION: A PRACTICAL APPROACH

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Abstract

Virtual reality (VR) and augmented reality (AR) are technologies that are very attractive to the learners since they offer new experiences when learning about the real world. Those technologies can be easily incorporated in the classroom when used with mobile devices that learners already possess.

In this paper, we explore advantages and disadvantages of using virtual and augmented reality applications in educational settings. We also analyze pedagogical approaches that underpin the development of AR applications used in education. The main goal is to present a practical approach to the development of AR applications aimed at the secondary or primary level students. The paper describes the process of developing AR application content with the tool Aurasma Studio. We believe that experiences and lessons learned presented in this paper could help the teachers to plan, design and develop AR applications without spending too much time on the whole development process.

Keywords: augmented reality, educational content, AR application, Aurasma.

1 INTRODUCTION

Today's learners are exposed to various information-communication technologies, most of which are suitable for active learning when accompanied by appropriate pedagogical approaches. In recent years virtual reality (VR) and augmented reality (AR) technologies draw attention of educators since they offer new experiences to learners when they learn about the real world. These technologies are quite similar, but there is one major difference between them. In augmented reality, the user sees elements that are added from the virtual world to the real world and are blended together, while in virtual reality, the user is completely immersed in the virtual world without seeing the real world [1].

There are more and more examples of using AR and VR technologies in education, especially in the fields of biology, chemistry, mathematics, medicine, engineering etc. Examples include AR books which bring to life content of a normal book [2], virtual travels to explore coral reefs, structure of DNA or even the surface of the planet Mars [3], exploration of a human anatomy from different angles by hologram images [4], or experiencing situations and feelings of a "pregnant" woman holograms [5]. Those examples require various equipment that enable the user to interact with learning environments. For AR environments the user might use a smartphone and see the virtual content through a smartphone camera or a AR application installed on the phone. Another option is to use a head-mounted display (HMD) to see holographic images. In VR environments the user might interact with the virtual world through a smartphone-based display, a HMD, virtual reality glasses, hand-worn gestural controllers, sensing gloves or suits, but could also be immersed into a cube or dome with holographic projections.

Development of serious AR and especially VR applications in education usually requires extensive knowledge from different fields, such as computer programming, graphic design, pedagogy and educational psychology. In addition, many of development approaches and tools are not easily applicable by educators. However, there are tools that enable educators to create simple applications that require no programming or other skills.

Therefore, in this paper we present a practical approach to the development of educational AR content in the tool Aurasma Studio, underpinned by the ADDIE model of instructional design. In the conclusion, lessons learned are presented and guidelines are given in order to help educators to plan, design and develop AR applications without spending too much time on the whole development process.

2 PEDAGOGICAL ASPECTS OF VR AND AR APPLICATIONS

The approaches for developing VR and AR applications are compatible with various pedagogical approaches that fit into the “active learning” framework: constructivist learning, situated learning, game-based learning, enquiry-based learning [6]. Compatibility with constructivist learning is reflected in interaction of the students with the learning environment and building connections to their previous knowledge. Students are active in a virtual setting where they acquire diverse information, and this also affects the retention of knowledge. In accordance with the approach of situated learning, AR has a special importance as it enables, in real time and setting, the display of virtual objects that students could not otherwise encounter and which would be difficult to visualize [6]. In game-based learning approach, the students may play AR game in a role which prepares them for everyday life, while in enquiry-based learning students explore virtual models and experiment with them. Enquiry-based learning is also called “Inquiry-based Teaching Strategy”. This approach is based on problem statement, data collection, analysis and conclusions [7]. This means that the student first determines the problem and questions he/she wants to investigate, then tries to find answers to specified questions, and finally, analyses the answers and explains them to show that he/she correctly understood them [7].

While considering the usage of VR and AR applications, the educators need to be aware of advantages and disadvantages of applying these technologies in educational settings. There are several advantages, such as active learning and display of virtual objects that would be difficult to present to the students or to explain them with the words. Another advantage is that the children are getting familiar with the use of different technologies in early age, so they would quickly understand the way of functioning and using VR and AR technologies. However, the problem may arise if the children have not previously encountered any technology. Therefore, it is necessary to know the learners to whom VR and AR technologies are provided. Another example of disadvantage is a students’ huge focus on virtual content that may cause loss of their notion of reality, which can also lead to security risks [2]. Furthermore, students can be more impressed by the effects that these technologies can provide, and consequently, not fulfilling the purpose of learning for which these technologies are intended. The loss of attention from the educational content may also arise due to rush of passing through the content wondering what will happen next [8]. Still, this does not necessarily mean that the learner wants to finish the content as soon as possible, but that he/she might work faster than the others. In this case, those who finished earlier, can help those who go slower or have technical difficulties [8]. It is important that the content does not contain too much information as some students may experience cognitive overload. It is therefore very important to get to know the students and keep in mind that they have different motivations and abilities. Some of them may have health problems (e.g. dizziness, epilepsy) that may manifest by using these technologies. Some students may experience various side effects although they are not known to have health problems. The teacher’s task is to monitor the situation and intervene when necessary.

3 DESIGN PROCESS MODELS FOR VR AND AR APPLICATIONS

There are various models for the design and development of educational content created for using with VR or AR technologies. For example, ADDIE, VRID or R2D2 models can be used.

Using the ADDIE model, the content is developed through the five phases: analysis, design, development, implementation and evaluation [9]. In the *Analysis* phase, content designer should be familiar with VR and AR technologies and their use. Designer should also determine the level of user’s interaction with these technologies. In addition, the prospective audience have to be analysed to determine to whom the content is intended, what is the audience prior knowledge level and which knowledge they will acquire after using the content. The *Design* phase requires determining what a user should see, hear or feel, how will the created content improve teaching, which resources are required for creating the content, what are the limitations of VR and AR systems and how these limitations can affect learning objectives. Particularly in relation to VR technologies, in the design phase, the design of the virtual world, the level of immersion in the world, the way of providing sensory feedback and the level of user’s interactivity with the world must be defined [9]. Next phase is the *Development* phase that demands content development based on specifications defined in *Design* phase. The entire development process must be described. Then there is the *Implementation* of the content into the AR or VR system, followed by the *Evaluation* phase. Evaluation is used to identify whether improvements of the educational content are needed. This phase also requires feedback from the students.

The VRID model is an instructional design and development model for educational virtual environments that comprises of four phases: define, design, development and evaluation [10]. The *Define* phase includes determination of a team that will create virtual setting, analysis of the appropriateness of using VR to solve an educational problem, and the feasibility study to evaluate requirements (hardware, software, technical staff, educators etc.) for implementation of VR technology. The *Design* phase consists of two strategies: macro and micro. As part of a macro strategy, the content that will be displayed in the virtual setting, its sequence and organization is determined. Besides, various materials (e.g. information resources, cognitive or collaborative tools) are described, which will serve as a support to students to facilitate the acquisition of knowledge in the virtual setting. The micro strategy refers to the guidelines for a quality presentation of created content for the virtual setting. These guidelines are based on the Mayer's cognitive theory of multimedia learning [10]. The next phase is the *Development* phase when development platform is chosen, then different components that will form the educational virtual setting are developed, and finally, an evaluation is performed by various specialists (e.g. instructional designer, user interface designer, technical specialist) and the users (so called one-on-one evaluation with one learner and one evaluator). The evaluation seeks to find out the effectiveness of learning using the created virtual setting, clarity of instruction and navigation, time needed to pass through content, etc. Finally, the *Evaluation* phase itself requires the effectiveness evaluation study and the formation of smaller groups of students who will conduct the evaluation [10].

The acronym R2D2 represents the name "Recursive and Reflective Design and Development" [11]. In general, it is a recursive nonlinear design, reflective design and participatory design [12]. Design is recursive and nonlinear which means that the proposed procedures do not have to be executed in strict sequence, but in the sequence, that seems most appropriate. The reflection means that the design process is iterative and that designers can return to any previously created part at any time and make improvements, while participatory design implies the involvement of experts and users in the design and development process. The R2D2 model basically does not differ from the ADDIE and VRID model. It consists of three stages, so called focal points: *Define, Design and Development, and Dissemination* [11]. At the defining stage, the team is chosen and the goals and purpose of creating the virtual setting are determined [12]. Goals and purpose can change during other development stages. Design and development include activities such as selection of development environment, evaluation for obtaining feedback to improve learning environments, detailed design and development of different learning environment components and the creation of a full functional virtual setting [12]. The third focal point is dissemination that is similar to evaluation. The purpose of dissemination is to deliver the environment to students, to see if everything works well and to ensure students' adaptation to the newly created environment.

4 THE DEVELOPMENT OF EDUCATIONAL AR CONTENT

To demonstrate the development process of AR educational content aimed at the secondary or primary level students, the ADDIE model was used and adapted to the AR context. The following subchapters describe the development process. The final evaluation phase is omitted from the description since the AR content was not tested in a real learning environment with the students.

4.1 The Analysis Phase

The *Analysis* phase started with the selection of the AR tool that would enable the educator to create augmented reality educational content. The choice of the tool depended on two factors: current hardware equipment and criteria for the selection of AR development tool. At educator's disposal, there was a tablet Apple iPad mini and a laptop with a several tools for media editing. The criteria for the selection of the AR tool was based on the criteria list proposed in [13] for the selection of 3D virtual worlds and additional criteria such as free download of the tool, stability of the tool, display quality and the usage of the tool without the need for additional equipment. First, twelve AR tools for the development of AR content were evaluated to select the most appropriate one. Out of twelve tools, the tool Aurasma Studio had met all required criteria, followed by the tools Augment and Tellagami.

The next step was to get acquainted with the functionalities of the Aurasma tool from the educator's perspective and then to identify prerequisites that need to be fulfilled in order that the student could use a created AR content. To view the created content, the user needs a mobile device with installed Aurasma application and the Internet connection. Interaction with the content within Aurasma does not require special knowledge and effort since it is based on a finger touch. Finally, the subject of learning

was determined: to display and explain computer components such as a hard disc, a motherboard, RAM memory and a processor. The target audience was the pupils of higher grades of elementary schools or the students of high schools who should learn about and differentiate various computer components, explain the component's parts and its function and specify significant manufacturers of a particular computer component.

4.2 The *Design* Phase

The *Design* phase comprised of identifying the scope of the content, determining the usage of media and tools needed for media editing, and sketching the interactions that will occur within the content. The educational content should incorporate different media (textual, imaginary, animated and acoustic) in order to be adapted to the students with different learning styles.

We developed our idea on Aurasma's working principle that is marker-based. This means that a marker is needed, which could be an image, printed or displayed on the screen. When the marker image is scanned using Aurasma, the corresponding content is displayed and further interactions with the content could occur.

Our idea was to use a printed image of the laptop casing components. By scanning that image with Aurasma, the application should display the name of a particular component and a picture of the component in a thumbnail. By pressing/tapping a thumbnail of a particular component, a larger image should be displayed and three options could be selected: a large component image, a 360° video of the component or basic information about the component displayed with animated text accompanied by the narrative.

To create AR content, the usage of various editing tools was planned: PowerPoint and its plugin Office Mix, Adobe Photoshop, Fyuse and Aurasma Studio. PowerPoint enables integration of textual information with the pictures, sounds and video on the slides, and the slides could be exported in a video format as well. Its usage was intended to introduce basic information about each computer component such as component's task, basic parts, capacity, most known manufacturers of this component etc. Information were planned to be delivered in animated textual form accompanied by the voice recordings acquired by the Office Mix, and then exported in a video format that could be integrated in Aurasma Studio. In addition, PowerPoint was used to create thumbnails and image frames, while Photoshop was planned for image editing and creation of a transparent image backgrounds. Fyuse is a mobile application that enables recording of a 360° video, so an interactive video of each computer component was planned. Aurasma Studio is an online tool that enables integration of multimedia elements into AR content, so it was used to link a marker image with created multimedia which overlay the image and also enable interactions throughout the content.

4.3 The *Development* Phase

The *Development* phase comprised of creation of multimedia elements that would be integrated during the *Implementation* phase. The *Development* started with the marker image. For this purpose, the HP ProBook 4730s laptop was disassembled and a photo of the computer components was taken. The marker image is shown in Fig. 1.

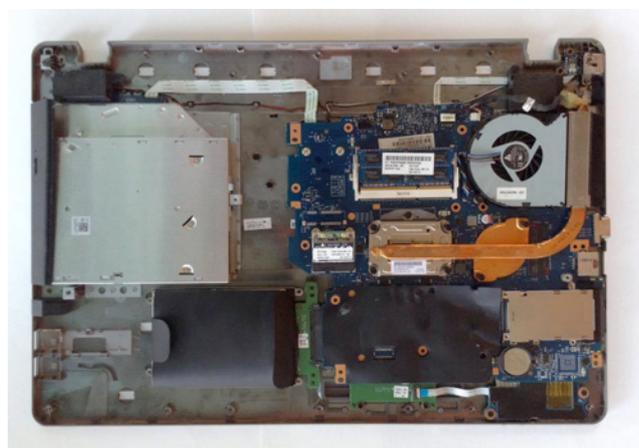


Figure 1. A marker image

When scanning the marker image using the Aurasma application installed on a mobile device, names and thumbnails of computer components should appear. Since the content was created for four computer components, a marker image should be covered by four so called “overlays”, one for each component, because it should be possible to select each one to display additional information about the component. These four overlays and a marker image are shown in Fig. 2. The marker image in Fig. 2 is shown only as a landmark that determines how the overlays should be positioned in relation to the marker image when scanned.

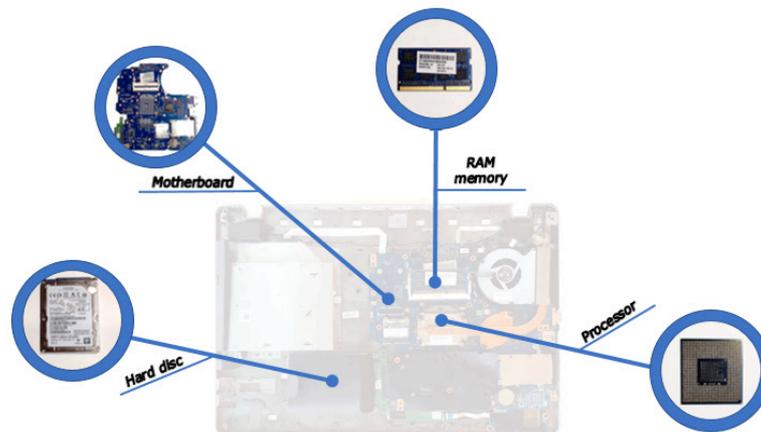


Figure 2. First level overlays

Each overlay in Fig. 2 has its own three overlays: one that displays only a component image, another that allows the selection of additional information about the selected component, and the third one that links to a 360° video display of the selected component. If additional information overlay is selected, video overlay with basic information about the selected component is displayed. As already mentioned, the video was created from the PowerPoint slides with text animations and recorded narration. A 360° video of a computer component was recorded using the Fyuse application installed on the tablet. Recording is based on moving the camera around the object that is recorded. Component to be recorded should be set to the place where it can be encircled in all directions. Good lighting and no reflection of the light to the camera are also important. Fyuse has some options for fixing shortage of a recorded video, e.g. using filters, brightness and contrast changes, saturation, etc. While recording, it's important to move smoothly and keep the recording device still, as the parts of the recording will be otherwise blurred.

4.4 The Implementation Phase

Once all the multimedia elements have been created, they need to be implemented in the Aurasma Studio. Aurasma Studio is a web tool that requires registration for its use, and it is available at the address <https://studio.aurasma.com/register>. Once registered, one can immediately login and start creating auras. Auras are AR actions that appear when a real-world image or object is scanned with a mobile device. AR actions can be images, videos, 3D animations or even games. The implementation process begins by selecting “Create New Aura” option that is visible in Fig. 3. When selecting this option, first it is necessary to upload or select an existing (previously uploaded) trigger image which corresponds to a marker image. The next step is adding overlays, i.e. adding created multimedia elements. Overlays are implemented one by one, and Fig. 3 shows how the first level overlays have been implemented.

After adding the overlays, the actions are assigned to them. All overlays, except the first ones, are initially hidden, so that they do not appear when a marker image is scanned. For each first level overlay, the action group "When Overlay is tapped, then Start an Overlay" is assigned to display the corresponding second level overlays (depending on the selected component). There were altogether three second level overlays: component's image, basic information and 360° video.

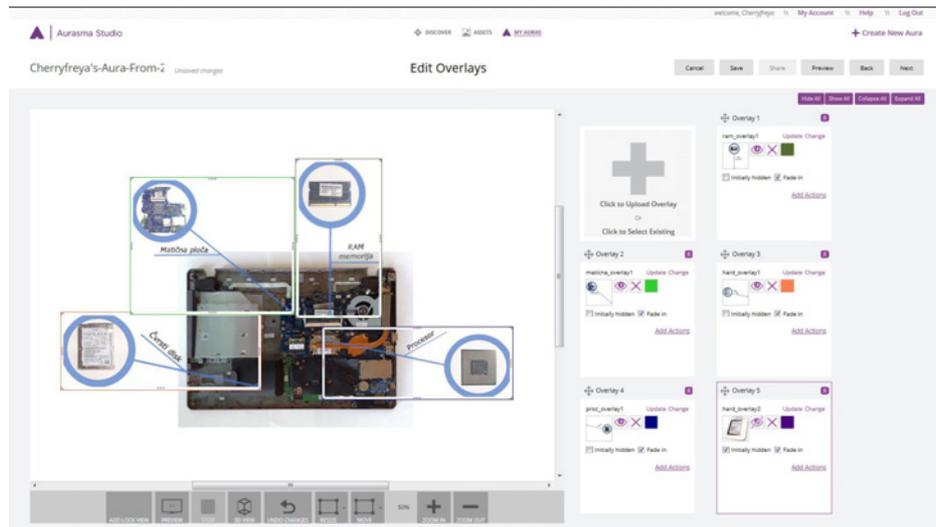


Figure 3. First level overlays implemented in Aurasma Studio

After finishing the aura with computer components in Aurasma Studio, created AR educational content was tested for its functionality. To do that, a marker image was printed, Aurasma application was installed on a tablet, and an internet connection have been established. Next, Aurasma was opened, the tablet was positioned above the printed image and the “Scan” option was selected in order to start interactions with AR content. Figure 4 shows a marker image and the content that appeared when the marker image was scanned with Aurasma application. One can explore the desired computer component by tapping a finger on component’s thumbnail or can return by finger double press. It is noticeable that the process of displaying the content and interacting with it is not as demanding as its development. With no previous knowledge about the development of AR content in Aurasma Studio, it took us about a week to elaborate the idea, describe the entire development process, and develop it as well. To recreate it, it should take much less time.



Figure 4. Scanning the marker image with Aurasma application

5 CONCLUSIONS

The purpose of using VR and AR technologies in education is to achieve better learning effects than by using traditional means of teaching and learning. However, creation of educational content applicable in VR or AR context can be a challenging task for an educator. It is necessary to get acquainted with the functionalities of the tool that will be used for authoring the educational content, as well as with the tools that will be used to create or edit various multimedia elements. In order to

develop pedagogically sound VR or AR content, it is recommended to follow one of the design process models and design guidelines.

In this paper, we presented the process of development of AR content in Aurasma studio. Following the ADDIE model [9] and few guidelines mentioned in [7], we have chosen the educational topic that is hardly tangible or hard to visualize in the real environment: the computer components. In addition, our design approach enabled multiple paths of interaction with the topic which have been presented with the text, narratives, images and 360° video. Functionalities of Aurasma studio have enabled us to easily develop the content and integrate prepared multimedia elements.

During the development phase, several issues were found important, such as the marker image and overlays in Aurasma. First, the marker image must be as detailed as possible so it can be quickly recognized, or recognized at all. Recognition will be better if the image has a tonal variation and contrast, if it's large enough and printed on matte finished paper instead of glossy paper which might reflect the light to the camera. When working with overlays in Aurasma Studio, it is desirable to name them meaningfully for easier handling. Overlays should be arranged so that they do not overlap each other, especially if actions are assigned to them. Because of overlapping, user may not be able to accomplish the action.

Overall, when developing AR application content, the educator should assess available resources (hardware, editing tools, additional equipment) and assure that the educational topic is appropriate for integration into the AR context. Since AR content creation usually requires substantial amount of time and knowledge of various editing tools, it is desirable to create the content that would be difficult to explain using only 2D images, plain text or speech. In addition, application content needs to be flexible, applicable in different scenarios and moments of the lesson, with a possibility of exploring displayed content, in accordance with the research-based approach [7].

Finally, creators need to evaluate the quality of the created AR contents. This is important in order to reduce the probability of students' cognitive overload and misunderstanding. The easiest way to determine the quality of the created AR content is to enable the students to use it, then collect their feedback, and make improvements to AR application content if needed. The more guidelines considered, the probability of creating low-quality content is reduced.

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