Supporting Constructivist Learning and Teaching with the Aid of VR-based Consumer Tech: A Case Study

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***Abstract*— Technology leads to massive changes in the economy, in the way we communicate and relate to each other and in the way we learn. Thus, the classical paradigms of teaching and learning and their corresponding design models can now be supported by consumer tech. This article presents an example of experiential learning, a design model which implements constructivism, using a virtual reality application for computer architecture. The experimental results related to how the students perceive it underline the benefits and challenges brought by this type of application.**

Keywords—consumer devices, virtual reality, constructivist learning, digital education

I. INTRODUCTION: CONSUMER TECHNOLOGIES IN ENGINEERING EDUCATION

Nowadays we can witness the proliferation of consumer devices in digital education, mostly smartphones and tablets that find their place in a world of consumer electronics and information technology products. In the same time, virtual reality (VR) is mostly used in gaming and entertainment, but it gains more and more popularity being used in academic purposes as well. Teachers engage electronic devices in the educational practices, beginning to use VR in academic settings, having as purpose to create virtual environments that encourage students to learn through experience, through action and through discovery and exploration, thus implementing a constructivist way of teaching and learning [1]. The new concept allows students to apply theoretical knowledge as well as practice their skills within real-world situations [2], using their personal mobiles and computing devices.

The current paper underlines the increasing popularity of consumer devices among the academic practices, presenting a VR application used to describe the computer architecture and its main hardware components, tested in the university environment, having as main purpose to highlight the benefits brought by software and consumer electronics to education and technology.

II. TECHNOLOGICAL OPPORTUNITIES FOR TEACHING AND LEARNING IN A DIGITAL AGE

Given the impact of the new technologies in terms of educational progress, we are facing a fundamental change in education and challenges for teachers in the current digital age. Yet our educational institutions were built largely for another age, based around an industrial rather than a digital era. Thus, teachers are faced with a massive challenge of change, in order to deliver courses suitable for today's cultural and social values, as well as greater diversity of students and to adapt to the lifelong learning market of our days [3].

In this context, we can witness a revolution in the consumer technology industry as a result of digital evolution and affordable costs for mobile and VR equipment, which brings huge opportunities for technology-based learning and teaching. Teaching in a digital era is a highly complex occupation, which needs to adapt to a variety of contexts, subjects, matters and learners.

Among the most popular teaching paradigms, we can list the objectivism or behaviorism, stating that a course must present a body of knowledge to be learned e.g. facts, formulas, terminology, principles, theories; the cognitivism, which focuses on comprehension, abstraction, analysis, synthesis, generalization, evaluation, decision-making, problem-solving and creative thinking; the constructivism, meaning that the knowledge is mainly acquired through social processes or institutions that are socially constructed such as schools, universities and online communities, mostly based on personal experiences and hypotheses of the environment; and the connectivism, which means the knowledge is built outside the individual, within networks [4-6].

Constructivist teaching is based on the belief that knowledge is constructed from our perceptions. Based on this view, we construct new knowledge rather than simply acquire it by passively receiving information or via memorization. This theory states that the assimilation of new information is achieved by relating it to our existing knowledge and cognitively processing it. Students have to work towards building their own meaning and understanding, testing it against reality and constructing meaning as a result. From a constructivist point of view, brains have more plasticity, adaptability and complexity than current computer software programs. Human factors such as emotion, motivation, senses or values make human learning very different from the way computers operate. Following this reasoning, the authors created the current VR-based application to support the way human learning operates, rather than fit the human learning into the restrictions of behaviorist computer learning.

There are different approaches that support constructivist teaching paradigm, such as experiential learning, cooperative learning or apprenticeship. Simon Fraser University defines the experiential learning as “the strategic, active engagement of students in opportunities to learn through doing, and reflection on those activities, which empowers them to apply their theoretical knowledge to practical endeavors in multitude of settings inside and outside of the classroom”. According to Kolb’s experiential learning model, there are four stages that highlight the constructivist model: the active experimentation, the concrete experience, the reflective observation and the abstract conceptualization [7].

Nowadays, the classical teaching models are implemented in modern ways, using media from educational perspective, such as essays, discussion forums, seminars, tests, e-portfolios, wikis, blogs, webinars and simulations. The constructivism is very easy illustrated through experiential and assisted learning in virtual environments, simulating real-life scenarios, like the training based on virtual simulators for improving parking skills [8] or learning chemistry in a virtual environment [9].

III. SUPPORTING CONSTRUCTIVISM WITH A VR-BASED APPLICATION: A CASE STUDY

Taking advantage of the new technology-enhanced learning patterns, the authors implemented a VR-based application to support constructivism. Most people believe that VR technology represents the future of learning process in terms of learning through experience. The most existing VR applications are dedicated to assist the students either in learning, socializing or dealing with stressful situations. In the current implemented system, the main objective is to assist the user in learning computer architecture, by presenting individual hardware components, providing elementary description of each electronic device, in a virtual safe environment, where there are no risks or dangerous consequences. As for teachers and for universities, this approach is cost effective, being much affordable than the case in which experiments take place in real setups. It was demonstrated that even for students is much easier to perform a task virtually than to physical assembly a computer. The virtual reality experience is an effective learning tool, immersion and interactivity being among the key features. The main focus of the application is to make learners reflecting on their experience, so as to gain conceptual insight as well as practical expertise. It is not necessarily about a typical training (e.g. academic or professional training) but also for the individual learning.

A. General description and functionalities of LearnIT

In this paper, we will face a new challenge: we will use a VR platform to design and implement an educational software that will run in an Android-based multimedia device. In particular, this software will allow users to have a full control of their position in the virtual environment providing means of locomotion, to use their preferred hand, to add new virtual environments, to start and stop the application when convenient, reacting realistic and without inconsistencies [10]. The user can read a description of each hardware component by holding the head tracker in a steady position, pointing to that specific object. As a controller we can use a mobile phone, working as a laser pointer to select the elements in the interface, the cursor being displayed at the same depth as the targeted object. The users’ spatial perception is meant to be as realistic as possible as well as the virtual environment clarity. To fulfill this requirement, the objects and the environment are using a real scale. In terms of performance and stability, the application runs without crashing, rendering at a high and constant frame rate. In case it takes more than 3 seconds to load, the application provides a real-time feedback to the user.

For user guidance and future improvements of the application, we track the user actions and provide individual feedback, keeping all learning data stored.

B. Architecture and implementation details

The architecture of the application is built using a well-known design pattern: Entity Component System (ECS), which is an Entity-Component type architecture based on the Unity engine, mostly encountered in the video games architecture and other highly interactive applications.

The base principle is that entities do not have their own logic, being implemented by their components. Each entity contains several components having a specific functionality.

The ECS pattern works on the “composition over inheritance” principle, avoiding the problems of multiple inheritance and offering flexibility in defining entities [10]. This functionality is useful when we add a certain behavior to an object by adding components to its entity. It is necessary to adopt a flexible approach when creating interactive applications, keeping the application very accessible and easy to modify for continuously testing environment during the development phase.

The application logic is illustrated in a simple schema in Fig. 2, following the ECS design pattern.

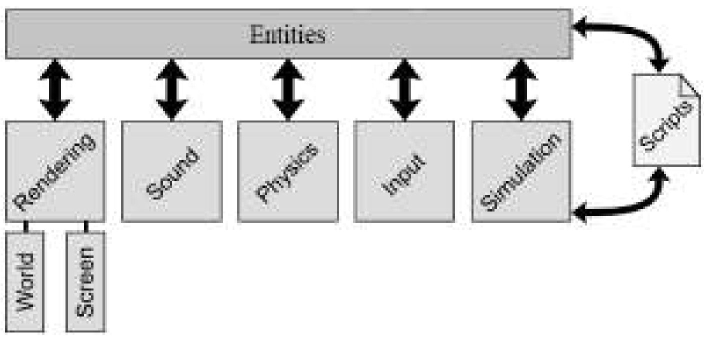

Fig. 1. LearnIT ECS architecture

The implementation is intended to be affordable in terms of the hardware required and accessible to the majority of users. It is also intended to be flexible enough to facilitate the creation of new learning experiences or the addition of other enhancements. Since the implementation of the application targeted the users, as well as the content creators, the most key factors in choosing our requirements were considered the accessibility, the usability and the flexibility of the system. On the contrary, almost all similar existing applications are rigid and not all of them are opened for creating and adding new content.

On the hardware side, as stated in the previous paragraphs, the application is based on the use of consumer electronics equipment. The authors implemented the application for Daydream View, the new Google VR platform, the functionality being realized placing a smartphone in the front compartment of the device and enter in the VR through the headset's lenses. During the testing phase, the Google Cardboard was also used as a compatible device, due to its low-cost accessibility.

From the software implementation perspective, the main challenge was to create the virtual environment itself. The application was developed using Unity 2017.1 and Google VR SDK, which is a Unity package that provides all the basic compatibility and functionality needed to run an application in virtual reality mode [12]. The realism of the virtual environment was shaped using appropriate visuals and proper scaling, based on the 3D models created using a specialized software (Cinema 4D) and photogrammetry technique (with Agisoft Photoscan software).

Being a software designed to be used with consumer electronics, the device that brought value to this project is the Daydream platform, composed of a headset and a controller. As a controller, the application uses a smartphone equipped with a gyroscope and it's integrated through Controller Emulator App provided also by Google. The rotation and acceleration data used to track the user's head rotation were captured using the magnetic sensors of the phone. The controller is used as a locomotion mean in the virtual environment, pointing to the place in the space where the user wishes to teleport, as the device does not provide position tracking (Figure 2). The current position of the controller is used to increase immersion. Another functionality of the controller is to allow user to interact with the virtual objects. The physical interaction between different objects is simulated in our software through the Unity physics engine giving the objects rigid body and collision. The two attributes allow the simulation of physical behavior of the objects and the approximation of intersections and collisions.

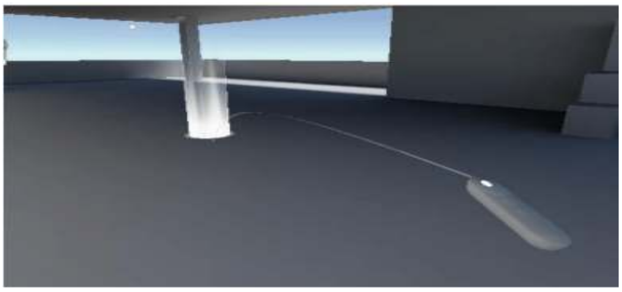

Fig. 2. Teleporting the user

The construction of visual effects and textures is realized by exploiting the Unity engine capabilities, as well as nuances of the objects or lighting. To improve the level of performance, we used a pre-calculated light so the iteration time necessary to calculate the light of the environment will decrease. To keep the scene as realistic as possible, spatial sounds were added for some of the user's actions e.g. when resume an item, teleporting or successfully execute a task. To manage the behavior of the user and objects, Unity integrates scripts. To write the scripts, we chose C# due to its popularity in the industry among games engines. Each script builds a class derived from the MonoBehavior, which is a built-in class, with two pre-defined functions: Start() and Update(). Both functions are called to initialize and update the frame of a game. By using the build settings, we added the scenes into the desired order in the executable file. Figure 3 illustrates scenes from the application. To run the application in android virtual reality mode is required to have Android version 4.4 and later, due to compatibility reasons [12; 13].

Fig. 3. Scenes from the application

IV. User perception about LearnIT

As VR expands in the educational sector, we've made a study on students enrolled in a software engineering degree program at UPB, demonstrating some of the benefits of using VR and consumer devices as additional tools in the learning process.

Among the advantages and tangible impacts that VR and consumer electronics have on students during the lesson, the following were noticed: eliminated smartphone distractions in the classroom, reducing the attention gap, eliminated language barriers, social integration of students and rewarded students for their achievements which led to an improvement of performance in time.

As Davis et al. point out in their paper, according to Dale's Cone of Experience, the average students only remember 10% of what they read, 20% of what they hear and 30% of what they see, but up to 90% of their personal experience [14], resulting in students becoming more attentive during lessons, allowing them to apply theoretical knowledge as well as practicing in real world scenarios [2].

Twenty-one users aged between 21 and 30 years old were asked to test the application during the semester and provide feedback regarding their experience.

The users answered to 5 questions, 3 of them based on a Likert scale (1-strongly disagree; 5-fully agree) presented in Table 1 along with Cohen's Kappa Overall Agreement coefficient and 2 open-answer questions, listed below. Cohen's Kappa statistic measures inter-rater reliability or precision. The Kappa statistic varies from 0 to 1, where:

0 = agreement equivalent to chance;
0.10-0.20 = slight agreement;
0.21-0.40 = fair agreement;
0.41-0.60 = moderate agreement;
0.61-0.80 = substantial agreement;
0.81-0.99 = near perfect agreement;
1 = perfect agreement.

TABLE 1. FEEDBACK FORM QUESTIONS BASED ON LIKERT SCALE

Questions	Cohen's Kappa
Do you consider the app to be useful?	0.3904
Would you use solutions like VR/experiential learning on consumer devices in order to improve your skills?	0.5904
Would you use such an application as an additional tool in the learning process?	0.6761

As per the results, the inter-rater agreement scores of .676 for N=21 raters designated a substantial agreement among our users, in terms of future usability of the application.

The two open-answer questions results are presented in Figure 4 and in the next paragraph.

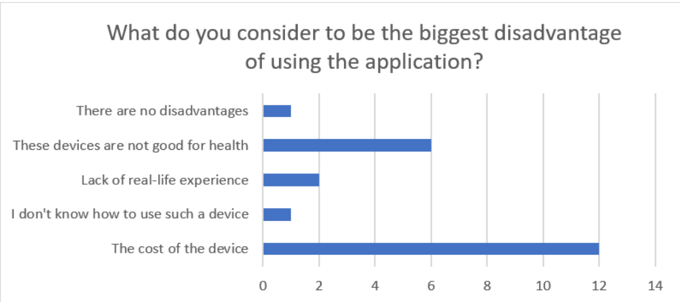

Fig. 4 . Users perception on disadvantages of the tool

Based on the gathered users perception on the LearnIT application, we received a generally positive feedback: 57.1% of the students considered the app to be very useful and 76.2% of the respondents would use solutions like the virtual reality and experiential learning on consumer devices in order to improve their skills. The biggest disadvantage was considered to be the cost of the device (57.1%). Among the disadvantages, the students mentioned the risks the devices can bring to health (28.6%), the lack of real-life experience (9.5%) and poor practice in using the equipment (4.7%). However, 81% stated that they would like to use a tool like this in the future.

At the question "In what fields or subjects do you think is useful a tool like this?" users come up with a variety of domains such as IT, mechanics, electronics, physics, chemistry, medicine, biology, engineering, constructions and even traffic simmulations and activities that involves any kind of practical experiments.

All the users enjoyed their experience, mentionning the good graphics of the virtual environment as well as the intuitive user friendly interface and functionnalities. Mostly, they agreed that using the tool augmented their motivation in learning computer architecture, showing a big interest in developing further learning through experience applications.

V. CONCLUSIONS

In this paper, we have presented a constructivist learning approach in teaching and learning using a VR-based application. Also, a small-scale experiment related to how the students perceive it was made: the results highlighted the benefits, as well as the challenges related to mass-use of such consumer applications – costs, health threats, fear of novelties.

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