Computer Science Replugged: What Is the Use of Virtual Reality in Computer Science Education?

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ABSTRACT

By following the idea of not using computers at all, Computer Science Unplugged has set the course for many interactive, social, and hands-on activities dealing with concepts and problems of Computer Science Education. Through recent developments in immersive media, technologies like Virtual and Augmented Reality could enhance such activities or even enable new ones. When providing immersive educational media that induce a sense of presence in the virtual environment, the illusion of unmediated learning experience can be delivered. Hence, the concept of "Computer Science Replugged" can benefit from the affordances that Computer Science Unplugged thrives on while facilitating or enabling activities that might be impossible, dangerous, or expensive to carry out in reality. In order to foster research and activities associated with the Computer Science Replugged approach, this paper concludes with research questions for using immersive media in Computer Science Education.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Social and professional topics** → **Computing education programs**; **Computer science education**.

KEYWORDS

Computer Science Unplugged, Immersive Learning, Virtual Reality, Technology-Enhanced Learning

ACM Reference Format:
Andreas Dengel. 2018. Computer Science Replugged: What Is the Use of Virtual Reality in Computer Science Education?. In -. ACM, New York, NY, USA, 3 pages.

1 INTRODUCTION

In recent years, a trend to reduce the use of computers in Computer Science (CS) classrooms emerged. With various games and activities, teachers can introduce CS concepts and ideas without the need of having to write code or to work with technology. With the rise of virtual reality (VR) technology, it is possible to engage in first-hand experiences while being in a mediated environment. The key characteristics of virtual environments, immersion and presence, can contribute to learning processes by creating a sense of non-mediation. These perceived-as-real experiences can benefit such CS games and activities by removing constraints of real environments that may interfere with students learning or even enable new approaches that are impossible or dangerous in reality. This work-in-progress paper presents the idea of *Computer Science Replugged*, which takes ideas for physical activities and tries to find ways to improve them by using immersive technology, and suggests research questions for investigating the *Computer Science Replugged* concept further.

WiPSCE '19, October 23–25, 2019, Glasgow, Scotland

ACM ISBN -…$15.00
DOI: 10.1145/3361721.3362113

2 THE IDEA OF COMPUTER SCIENCE UNPLUGGED

Computer Science Unplugged activities try to make various contents from CS easy and fun to learn by using game-like settings, metaphors, and hands-on interaction. Computer Science Unplugged "takes the unusual approach of exposing children to the great ideas of Computer Science without using computers" [2]. While a key principle of Computer Science Unplugged is the development of computer-independent teaching methods for CS, other principles for designing activities for teaching and learning CS are: focus on CS concepts rather than programming, making the activities kinaesthetic through involving teamwork, making the activities fun and engaging, low cost, release under a creative common license, making the activities gender neutral and rather focus on cooperation than on individualistic approaches, and adding a sense of story to the activities [2].

Computer Science Unplugged activities are a great way to motivate children to learn about various topics of CS. While all activities are fun and engaging in their own way, some of them take a while to organize, include only a bunch of students, or assign different roles to the students, where some of them can engage in the activity while others rather play a supportive role. Such constraints can affect the students' learning success. Further, while some of some activities seem sound in theory, their practical realisation can be difficult: For example, simulating the Diffie-Hellman Key Exchange procedure using colour mixtures [1] works fine when measuring the exact amount of colour used but is impractical as an activity to be carried out with students. Similar problems occur when preparing hands-on activities including hardware components: Assembling or disassembling computers can be a great learning opportunity, but it can be expensive to get the hardware and even dangerous when done wrong.

To address such problems, many games or simulations that include virtual 3D worlds have been developed in the recent years in order to teach about CS concepts (e.g. [5, 17, 19]). Educational Virtual Environments (EVEs) are safe, easy to set up, and easy to

use/re-use once the required hardware is procured. But, when following the initial concept of Computer Science Unplugged, one may ask: Is this still first-hand experience that engages the learner? By using a mediated environment, the key thought of exposing children to the ideas of CS without using computers becomes quite contradicted. But what if the students would not perceive their virtual environment as mediated? Could we still use the benefits of EVEs while providing first-hand experiences? The following section suggests an approach on how to use of VR in Computer Science Education by developing immersive activities following the Computer Science Unplugged approach.

3 BEING THERE: VIRTUALIZING COMPUTER SCIENCE UNPLUGGED

Though the ideas of this paper can be applicable to Augmented Reality as well, we will mainly refer to the use of VR in terms of an environment which consists solely of virtual components [12]. The main idea of VR is to immerse the user into a virtual environment by using technology (e.g. head-mounted-displays, CAVE systems, etc.). The key characteristics of virtual environments are immersion and presence. While immersion can be understood simply as a quantifiable description of the used technology [16], presence can be seen as the induced perception of non-mediation [8], as the feeling of 'being there' [6].

A popular approach from Steuer [16] distinguishes the components of (technological) immersion into *vividness* and *interaction*. *Vividness* in terms of the representational richness of the virtual environment (the way how the environment presents information to the senses) consists of two factors: sensory *breadth* (presenting information across multiple senses) and sensory *depth*(quality/bandwidth of the presented information). The *interactivitiy* as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" [16] is characterized by *speed*, *range*, and *mapping*. Hereby, the *speed* of interaction refers to the system's response time; the *range* of interactivity refers to the number of attributes which can be manipulated in the virtual environment; the *mapping* characteristic is associated with the connection between human actions and actions within the virtual environment [16]. Studies show that an various factors of immersion contribute to students' learning outcomes: for example field of view [9], used technology [10], and ego-centric vs. exo-centric perspective [11].

Presence can be distinguished into physical presence, social presence, and self-presence. While physical presence is associated with the perception of para-authentic (related to a real correspondant) or artificial objects (without a correspondant in reality) as being non-mediated, social presence refers to the experience of social actors (para-authentic or artifical). Self-presence focuses the experience of a para-authentic self or an artificial alter-self(selves) as being non-mediated [8]. Presence is thought of to be a unique characteristic of EVEs [11]. Studies show that the level of immersion has a strong impact on presence (e.g. [7, 15]).

It has to be noted that the discussion of immersion and presence is way more complex than presented here. We decided in favor for this distinction as it allows to separate the supply-side of the educational technology from the subjective use side (the perception and learning activities) of the learner [3]. Doing so, immersion becomes part of the methodological decisions of the teacher who decides which software is provided with which hardware at which point of the learning process; presence mediates the student's learning activities in terms of perception and interpretation. Of course, the provided level of immersion can predict the sense of presence to a certain level, though Dengel and Mägdefrau note that person-specific factors like motivation, cognition, and emotion influence the learner's sense of presence as well [4]. By using immersive technology, the induced feeling of presence can provide a perception of non-mediation and, therefore, a first-hand experience. Hence, it is possible to use VR hardware and software to simulate activities that might be impossible, dangerous, or difficult to carry out as a real activity.

According to Puentedura, technology can be integrated into the classroom as a task's substitute (without any functional change in the task), as an augmentation (where technology acts as a substitute with functional improvement), as a modification (offering a significant task redesign), or as the redefinition of a task (creation of new tasks that were previously inconceivable). Puentedura argues that technology, therefore, can function as an enhancement of existing contents (in terms of substitution or augmentation) or as a transformation of education(when being used as a modification or for redefining tasks) [13]. It has to be noted that, of course, whenever it is possible to carry out an activity in reality (where technology would act as a mere substitute), this approach is to be preferred. This is not only because presence is highest in the actual reality itself, but also because of the benefits of social interaction. To determine further how VR can contribute to learning, an analysis regarding the potential of VR representations for teaching and learning is necessary. Schwan and Buder state that VR is a powerful tool to enhance learning processes by providing spatial, multimodal visualizations which can be

- *accuartely displayed*: accurate simulations of real situations/ objects with a high level of detail (e.g. a simulation of an airplane cockpit),
- *schematizing*: simplified versions of real situations/ objects with a lower level of detail and with a focus on the important/relevant characteristics (e.g. a simulation of the human brain) ,
- *substantiating*: abstract contents/concepts visualized illustratively (e.g. a spatial representation of physical laws), and
- *metaphorical*: analogies to real/abstract concepts (e.g. visualizing the function of a motherboard by using a virtual person exchangig data packages between different buildings) [14].

Most Computer Science Unplugged activities use substantiating (like counting binary numbers using dots [18]) or metaphorical (like simulating public/private key encryption through a treasure box with chocolate [18]) approaches. But also schematizing ideas can be of interest for designing engaging activities (e.g. visualizing error detection algorithms in a simplified way with black and white cards [18]). When using VR technology for enhancing (or enabling) activities that follow the initial idea of Computer Science Unplugged, these three areas should be focused to provide virtual representations that support learning.

As the term Computer Science Unplugged seems a little bit odd when using immersive technology, it was decided to coin this approach Computer Science Replugged (we "replug" existing or new unplugged ideas in order to enable or enhance them). Thus, Computer Science Replugged consists of hands-on activities combined with immersive technology providing the perception of non-mediation. Doing so, we still follow the idea of being independent from using computers as an educational medium as the medium is only used to simulate the experience (while the technology itself disappears in the experience) rather than being an instrument for teaching and learning (as it would be the case for coding tasks on a desktop PC).

4 RESEARCH QUESTIONS FOR USING IMMERSIVE MEDIA IN COMPUTER SCIENCE EDUCATION

While the idea of using virtual 3D worlds for Computer Science Education is not interely new, the approach of utilizing the sense of presence emerging in immersive virtual environments experiences may have the potential to make just the right adjustments to existing activities without losing their charm of providing first-hand experiences. Furthermore, it can be possible to realize activities that were impossible, dangerous, or too expensive to carry out before. The investigations presented above lead to questions for future research:

- Which Computer Science Unplugged activities can benefit from using immersive technology?
- Which concepts and ideas of Computational Thinking can be visualized using VR technology in ways that were not possible before?
- What is the role of immersion and presence in EVEs for learning CS?
- What other factors contribute to learning CS in EVEs and how do they interact with learning processes and outcomes?

While it can also be interesting to compare real Computer Science Unplugged activities with virtual Computer Science Replugged approaches, this might not be expedient: As stated before, virtual activities should not substitute real activities but rather complement them. But, especially regarding the fourth research question, a comparison to traditional classroom settings can be interesting in terms of what other factors relevant to learning might be influenced by engaging virtual activities. Right now, Computer Science Replugged is an idea which has to be investigated further; immersive EVEs for Computer Science Education have to be developed and tested. Through the use of immersive media, the focused contents of Computer Science Unplugged activities can be displayed for one or many users in a way that can be rather visualizing or interactive. By inducing a sense of presence, Computer Science Replugged software can provide 'first-hand' and 'hands-on' experiences in an engaging way. It is also important that future investigations include the role of the teacher to determine which stage in the learning progress contribute from additional guidance when using immersive media and how using technology influences social structures in the classroom.

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