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Attuning a mobile simulation game for school children using a design-based research approach

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A B S T R A C T

We report on a design-based research study that was conducted over nine months. It chronicles the development and implementation of *HeartRun*, a cardiopulmonary resuscitation (CPR) training approach for school children. Comparable to an unexpected emergency, *HeartRun* consists of authentic activities involving different roles, game tasks, locations and physical objects to support process-oriented learning for first responders. It aims to enhance the psychological preparedness of the rescuer and thus promotes a more prompt and appropriate response. In this paper, we describe a cycle of three design-based research (DBR) studies in which *HeartRun* was explored with school children. In order to better understand how to design mobile game environments that support dimensions of seamless learning, we analysed children and their knowledge-building practices while learning with *HeartRun*. The mobile game has evolved significantly from its initial conception through an iterative process of (re) designing and testing the synchronization between physical and digital worlds, learner collaboration and ubiquitous knowledge access, i.e. dimensions of mobile seamless learning activities. Based on our experiences, we conclude by discussing challenges and shortcomings of mobile game–based learning environments.
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1. Introduction

The potential of mobile devices to engage learners and to support learning has been widely acknowledged by educational practitioners and scientists and by now, a broad range of practical studies across varied domains and application scenarios has proven the usefulness of these technologies for the process of teaching and learning (Garrido, Miraz, Ruiz, & Gómez-Nieto, 2011; Klopfer, Sheldon, Perry, & Chen, 2011; Sánchez & Olivares, 2011). Mobile devices are used within various learning contexts and their functions are employed in multitudinous ways. Location-based learning scenarios, for example, make use of location-sensing capabilities to guide learners through cities or museums, asking them to pick up or capture information at predetermined locations, make inquiries, enter information and answer a series of factual questions presented to them through the mobile device (So, Seow, & Looi, 2009). Augmented reality (AR) visuals as used in "TimeWarp" (Blum, Wetzel, McCall, Oppermann, & Broll, 2012) or "Viking Ghost Hunt" (Carrigy, Naliuka, Paterson, & Haahr, 2010) combine learning activities in the physical and digital environment. The switch between the two engage students' involvement with digital information by drawing the attention of learners to specific landmarks or objects for example (Dunleavy, Dede, & Mitchell, 2009), this way enabling players to simultaneously focus on virtual and physical aspects of particular artefacts.

A format frequently used to take advantage of the manifold opportunities of mobile technology is mobile games for learning. For both commercial and scientific use they have been developed for various target groups and learning contexts. Research that has evaluated their educational potential found evidence for their supporting of socio-affective and cognitive learning outcomes (Mitchell, 2007; Schmitz, Klemke, & Specht, 2012), or their potential to enable situated learning offers that make a meaningful and valuable contribution to the process of learning by providing aspects such as temporal flexibility, natural communication or situated learning scenarios (Klopfer, 2008).

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However, using mobile devices for educational purposes faces challenges. It frequently implies a continuous shifting of attention between the different objects, tasks and activities (Rogers, Connelly, Hazlewood, & Tedesco, 2010), which, for a start, interrupts the ongoing learning experience. Besides getting oriented on a screen, the learner now has to find orientation in the 'real' physical environment. Learning with mobile devices differs from the learning that takes place when using desktop computing in classrooms. It is characterized by short usage sequences (e.g., entering and comparing data, looking up and reviewing information, sending texts or photos to remote people) to support foregrounded physical activities (observing, probing, measuring) in a particular environment (Rogers et al., 2010, p. 111). These seams between tasks and activities are challenges for the design of mobile learning experiences. Though the switching between the different objects, tasks and activities is sometimes credited with a potential for *sensemaking activities* because the device supports people in finding structure in an uncertain situation through using a combination of information, communication and computation (Rogers et al., 2010), it can be very distracting for the individual learner and might even have a share in learners' cognitive overload (Wong & Looi, 2011). Based on the cognitive theory of multimedia learning, Mayer and Moreno (2003) argue that presenting rich, diverse and complex multimedia elements in a confusing way easily exceed learner's available cognitive capacity. For example, multimedia presentations that use audio, narration and animations simultaneously to explain a given subject can already impose high intrinsic load on the learner and limit essential cognitive processing. The additional switch between digital and physical world, which is inherent to learning with mobile technologies, means further extraneous and in many cases redundant material that further increases cognitive load. Thus, the learner uses already limited cognitive resources to process additional information. As a result, engagement in substantial cognitive processing, a prerequisite for meaningful learning, is not possible (Mayer & Moreno, 2003). Kiili (2005), too, stresses that inappropriate ways of presenting learning material easily overload learners' working memory capacity. He notes that especially educational games run this risk because traditionally, games have consisted of rich multimedia elements. To maximize the process of learning with mobile games, instructional design needs to consider and optimize the switch of focus between the physical world and mobile digital services.

In order to avoid cognitive overload due to educational design decisions, Mayer & Moreno (2003) have proposed design principles for multimedia learning, which also guide design decisions for learning with "mobile network-centred devices" that harness the Internet to promote collaborative learning experiences (Wang & Shen, 2012). Mayer & Moreno (2003) emphasise the need for conciseness and coherence of the material presented and also refer to the redundancy principle. To maximize the process of learning with mobile games, the coherence principle implies a thorough consideration and if necessary elimination of information that is not related to content and context as it may distract the learner and thus decreases the learning (Clark & Mayer, 2011).

Especially in the field of health education this switching needs substantial consideration. Health education often takes the combination of teaching theoretical knowledge, motor skills (i.e. using a particular skill) and procedural knowledge as a basis. Traditional cardiopulmonary resuscitation (CPR) training measures, for example, strongly focus on the level of resuscitation skills, frequency of updates or contents of sessions, such as the training of CPR skills on a puppet, the right compression depth, frequency and rhythm. In order to be effective, this explicit knowledge needs to be turned into action (De Jong & Ferguson-Hessler, 1996), by simulating a real emergency situation, for example.

In general, the rate of bystander CPR at cardiac arrests is comparatively low, less than 20% (Vaillancourt, Wells, & Stiell, 2008). One of the many explanations for this is the low number of trained laypeople. In order to increase their number and thus survival rates, it is necessary to enlarge the target group for CPR training activities. Addressing school children is regarded as one toehold in this. School children are willing and prepared to provide CPR if they are trained, and they are capable of learning CPR (Lester, Donnelly, Weston, & Morgan, 1996). This is supported by studies which indicate that children aged 13–14 perform compressions on an unconscious patient as well as adults do (Jones et al. 2007). Organizations such as the American Heart Association expect that in the long run, mandatory training of schoolchildren at regular intervals will increase the number of trained adults (Cave, Aufderheide, & Beeson, 2011) and will raise awareness, interest and sense of importance of taking action in out-of-hospital cardiac arrest. In their review, Plant and Taylor (2013) point out diverse methods of first aid training that have been successful with children. They state that especially the use of "virtual worlds and multiplayer online simulation could be an attractive training and/or retention tool to use in this age group" [p. 3].

In this paper, we report research that builds upon existing evidence of the educational potential of mobile learning games. It is based on the mobile simulation game *HeartRun,* which is targeted at giving school children an understanding of cardiopulmonary resuscitation (CPR) and getting them to take action. The overarching goal is to drive research towards the design and deployment of mobile simulation games for children with a strong focus on *seamless learning activities*. According to the framework provided by Wong and Looi (2011), mobile assisted seamless learning activities comprise learning activities based on mobile and ubiquitous technology, which encompass formal and informal learning, personalized and social learning, physical and digital worlds. The seamless and rapid switching between multiple learning tasks or the combination of multiple devices are salient dimensions of mobile assisted learning environments. However, they are relatively unexplored from a pedagogical point of view (Wong & Looi, 2011). This study explores these issues.

We examined individual features of a mobile game approach through which lay responders enhance their CPR skills, while expanding their procedural knowledge of how to act in case of emergency. Our focus is directed at children and their learning practices while learning with games. Thus, the focus that guided the studies can be formulated as follows:

> How can mobile game-based learning environments that support children while engaged in an ongoing task in a physical environment be designed?
>
> What are the characteristics of an effective mobile simulation game approach, through which lay first responders enhance their CPR skills and their readiness to help, while expanding their procedural knowledge of how to act in case of emergency?

To answer these questions, this paper is divided into four main sections. Section 1 provides a summary of related work including a brief overview of mobile games for health, with a particular focus on games that teach basic life support (BLS) and resuscitation, including CPR. Section 2 introduces the game-concept of *HeartRun*. It describes the educational framework for the interplay of learner activities, physical environment and physical objects with the mobile device (smartphone). In the third section, we explain the methodology of three sequential studies that we carried out in order to answer research questions. We conclude with Section 4, discussing and highlighting design

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