Developing a design-based research methodology for designing MR technologies for mountain safety

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This paper outlines the first stage of a design-based research (DBR) project exploring the literature and establishing a research methodology for the design of mixed reality (MR) environments to enhance informal learning in preparation for engagement in high-risk environments. The context of the project is mountain safety education for expert climbers to prepare them for the critical risks involved in extreme mountain climbing environments. The paper outlines the scope, background, proposed research methodology and initially identified design principles for designing MR technologies for mountain safety. The research draws upon literature applying new pedagogies for informal learning, including heutagogy or self-determined learning.

Keywords: Design Based Research, Mixed Reality, Informal Learning, Heutagogy, Authentic Learning.

Introduction

High altitude mountaineering is a high-risk environment requiring high levels of preparation and risk awareness. CNN reported on 24 May 2016 that avalanches killed 35 climbers on Mount Everest during the previous two years including 16 in one devastating day in 2014 (Dewan, 2016). At least one person has died climbing the mountain in Nepal every year since 1900. “Everest is a mountain of extremes”, said Jon Kedrowski (Huffingtonpost, 2012), a geographer and climber who summited Mount Everest in 2012, when 10 climbers died. At altitude, the body can deteriorate in a variety of ways. For example: Eric Arnold, 36, of the Netherlands, died at night while heading back after a successful summit on Everest. A heart attack was suspected. Arnold was a triathlete based in Rotterdam. Also, an australian woman, Maria Strydom started suffering altitude sickness. She had reached Camp 4, the final camp before the summit but she died from high-altitude cough and acute mountain sickness. Subash Paul, 44, died at Base Camp from altitude sickness and Seema Goswami suffered severe frostbite injuries near Camp 4.

All mountaineers are wary of risk factors in the mountains but there are still fatal accidents happening every year despite of an awareness of risk factors. The risk increases in high altitude mountains (above 5000m) such as Himalaya ranges and Andes ranges, as mountaineers are more exposed to deadly dangerous risk factors including altitude sickness, endless crevasses, ice cliffs and frostbites. Even though most mountain climbers have a great range of experiences and are well trained, they often have less experience in high altitude mountain ranges due to financial difficulties and difficult accessibility to adequately prepare for these high-risk environments.

A search of the current literature relating to education strategies for high risk environments reveals that there is a gap in this research area. Therefore, there is a significant need to develop new learning strategies for these high-risk environments. Hence this research explores ways of better educating climbers of the very real risks of high-altitude mountain climbing. It can be extended to other high-risk areas such as firefighter and police force’s working environments.

New media technologies such as **Augmented reality** (AR) and **Mixed reality** (MR) provide the potential to design and deploy highly authentic learning environments (Birt, Moore, & Cowling, 2017; Cochrane, 2016; Cochrane, Narayan, & Antonczak, 2016; Edmonds & Smith, 2017). **Augmented reality** (AR) provide a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. **Mixed reality** (MR), is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Augmented/mixed reality are technologies that layer computer generated enhancements atop an existing reality in order to make it more meaningful through the ability to

interact with it. The key term for AR and MR, is flexibility. MR offers learning environments combining physical and virtual worlds. It is flexible and portable compared to the three-dimensional real physical world, and provides a low risk environment in which to explore high-risk real-world environments. Dunser, Steinbugl, Kaufmann, & Gluck (2006) argue that researchers can create environments in which users can act without being exposed to certain dangers that potentially occur in real environments. According to them, "using VR enables researchers to create exactly the same stimulus conditions for all participants or to vary certain environment variables in real-time and thus gives researchers more control over experimental settings" (p. 126).

Using a design-based research methodology, this research explores the design of an App which uses these MR and AR technologies to create high altitude environments, therefore, enabling mountaineers to experience and troubleshoot risky obstacles such as altitude sickness, endless crevasses, ice cliffs and frostbites within a safe simulated environment. In terms of Vygotsky's (1978) zone of proximal development, these new technologies enable the mountaineers to learn themselves in informal settings through the App acting as a virtual more experienced peer.

Literature Review

In this section we identify some of the key literature that informs this research, including foundational learning theories that inform the research project. The research emphasises the importance of constructivist learning, problem solving, critical thinking and collaboration in learning environment. Designing AR and MR technologies for mountain safety is perfectly situated to integrate these very important pedagogical elements into an interactive environment. The proposed app based on AR and MR technologies will provide the learners the opportunity to discover their own knowledge, through individual learning, reflecting and collaborative learning.

Foundational Learning Theories

In today's complex rapidly changing world new technologies enable new pedagogical approaches in diverse learning environments. There are no university degrees in high altitude mountaineering, thus self-directed and self-determined approaches are needed in the development in new teaching and learning strategies to prepare mountaineers for these potentially life-threatening environments. Learning theories such as Behaviourism and Cognitivism are not fully sufficient to prepare learners for the critical life-saving decisions that must be rapidly made in these rapidly changing and diverse environments. As a result, the proposed research conducts a study of Constructivism, Social Constructivism and heutagogy as foundational modern learning theories for developing a design-based research methodology for designing learning experiences for high-risk physical environments.

Constructivism is one of modern learning theories and heutagogy is self-determined learning that builds upon Constructivism and Social Constructivism. Constructivism is a learning theory that "equates learning with creating meaning from experience (Bednar et al., 1991). Learning is more meaningful to students when they are able to interact with concepts in the learning process. Constructivism states that learning is an active, contextualized process of constructing knowledge rather than acquiring it. Knowledge is constructed based on personal experiences and hypotheses of the environment. Constructivism utilizes interactive teaching strategies to create meaningful contexts that help students construct knowledge based on their own experiences. According to Ertmer and Newby (1993); "Learners do not transfer knowledge from the external world into their memories; rather they build personal interpretations of the world based on individual experiences and interactions." (p. 63) Constructivism is active in the learning process and helps engage and motivate students by making them take a more active role in the learning process. It is also reflective so the students control their own learning process, and they lead the way by reflecting on their own experiences. Also, it is collaborative and evolving in the learning process.

Building upon Constructivism, Social Constructivists view that learning is meant to be a social process that occurs when individuals take part in social activities. Meaningful learning occurs when individuals are engaged in social activities such as interaction and collaboration. Social Constructivism emphasises the importance of culture and context in the process of knowledge construction. According to Vygotsky (1978), knowledge is constructed through social interaction and is shared rather than an individual experience. He states that human beings create meaning from an educational experience by learning with others. He views interaction with peers as an effective way of developing skills and strategies within the Zone of Proximal Development. Vygotsky (1978) defines the Zone of Proximal Development (ZPD) as; "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (p. 86). He insists

that teachers use cooperative learning exercises where less competent learners develop with help from more skilled peers.

Heutagogy is self-determined learning that builds upon Constructivism, Social Constructivism and Andragogy. According to Hase and Kenyon (2001), Heutagogy is a self-determined learning and it involves the primary changes in the role of the teacher. The learners have the primary role in heutagogical learning environment and are learner-centred as opposed to teacher-centred learning. "Heutagogy, the study of self-determined learning, may be viewed as a natural progression from earlier educational methodologies - in particular from capability development - and may well provide the optimal approach to learning in the twenty-first century" (p. 2). Self-determined learning is more concerned with how people develop the capacity to navigate the unknown and enable learners to have the ability to manage their own learning environment to meet their learning needs. It has a focus on what the learners want to learn. According to Hase and Kenyon (2001), self-determined learning provides the learner empowerment, capabilities and open-ended learning environments. Also, reflective practice is one of important characteristics of heutagogy.

Methodology

Initial Design Principles identified from the literature:
- Utilising a DBR methodology
- Social Constructivism and the ZPD
- Informed by heutagogy
- Utilising frameworks for mobile AR and VR learning environments

Amiel and Reeves (2008) argue, educational or design-based research involves the identification of design principles that are tested through implementation and evaluation of a design prototype app, that is then iteratively redesigned with further evaluation and feedback from users through generic process for conducting design research in education, leading to the development of transferable design principles that can be applied to other knowledge contexts. Therefore, this research will benefit educational contexts beyond that of Mountain Safety. Figure 1 shows the process of Design-based research as Amiel and Reeves (2008) described.

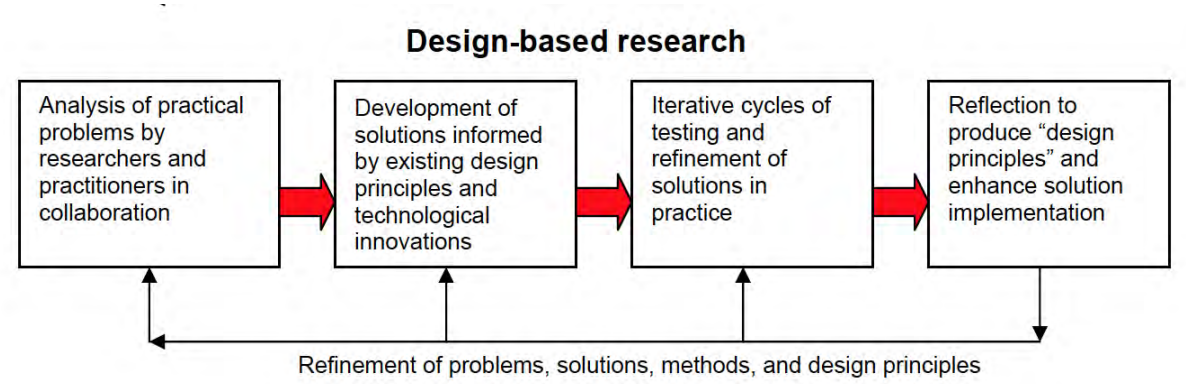

Figure 1: Design-based research, from Amiel, T & Reeves, T. (2008, p34).

Vygotsky (1978) insists that the learners can learn beyond the limits of what they can on their own when aided by a more experienced peer within the Zone Of Proximal Development. The role of App could be a virtual more experienced peer in this case. The App will enable mountaineers to be well prepared before their actual climbing journey.

Design of the Study

Research questions
- What are the key design principles for developing MR applications for high risk educational environments?
- How can MR applications be most effectively utilised to enhance learning in extreme outdoor situations?
- How can MR applications influence climbers' learning experiences compared to when they are in real environment?
- How do climbers respond to risk factors in extreme outdoor situations after using MR applications?

Methodology

This proposed research methodology is a design-based research project, that will produce a prototype App based on AR/MR technologies for the new educational strategies for high risk environment. This research will be undertaken in four iterative phases that align with the four stages of the DBR methodology (McKenney & Reeves, 2012).

- The first phase, analysis and exploration, will be focused on review of the literature in relation to identifying design principles for education around mountain safety and risk factors in high altitude mountain ranges, and the principles of AR/MR design. Feasibility interviews with climbers from climbing communities in New Zealand.
- The second phase, design and construction, would be producing a prototype app based on AR/MR technologies and also it involves 1st evaluation and analysis on 1st prototype app. As a result, I will redesign 1st prototype app based on 1st evaluation and analysis.
- The third phase, evaluation and reflection, will be focused on 2nd prototype app development and evaluation on 2nd prototype app. The final stage of the third phase will be refinement of the app. The research explores the learning behaviour while the learners use the app. This will involve multiple iterations of redesign and evaluation and the refinement of the design principles.
- The final phase, maturing intervention and theoretical understanding, will be mainly focus on recommendations and design research principles on successful safe climbing in real environments using the app.

Participants

This proposed research will be conducted with small focus groups from NZAC (New Zealand Alpine Club), NZ Mountain Safety Council, DOC (Department of Conservation), Sherpas, expedition groups in Himalaya range, local guides from Europe Aps and Patagonia range and climbers from various countries. They will be invited to take part in the research. After developing a prototype app, it will be used both in non-climbing situation and climbing situation. The climbers will encounter possible situations in high altitude mountain environments through the app even though they are not in the mountain ranges. However, the climber also uses the app in real locations such as base camps in high mountain ranges while they are preparing summit push. The climbers do self-learn through the app. The app will show not only deadly dangerous risk factors such as altitude sickness, endless crevasses, ice cliffs and frostbites, but also a live direct or indirect view of a physical, real-world environment in high altitude mountain ranges, which are augmented by computer-generated sensory input such as sound, video, graphics or GPS data.

Ethical considerations

The research will not put the participants in situations where they might be at risk of harm as a result of their participation. Also, there are no conflicts of interest and misconduct as there is no hierarchy relationship between the researcher and the participants. The research data, results and the app will be shared once developed in the public domain.

Data collection and analysis

The research conducts methodological triangulation to measure learning outcomes. This involves using more than one method to gather data such as interviews, questionnaires and biometric feedback. For biometric feedback, the research uses Gear VR to detect heart rate and gather data so I can compare their responses before and after using the app.

1. Developing 1st prototype app.
2. 1st evaluation, feedback and analysis on 1st prototype app
3. Redesign 1st prototype app based on 1st evaluation, feedback and analysis.
4. 2nd evaluation and analysis on 2nd prototype app.
   Redesign 2nd prototype app based on 2nd evaluation, feedback and analysis.
5. Finalising the app and design research principles in the field.

Anticipated/possible challenges

One of the possible challenges will be getting people to respond through the app evaluation/feedback process. It will be also challenge to form a focus group as a few of them are living in remote areas where communications are limited. Video conferencing for remote focus group participants will be available.

Conclusion

This paper outlines the foundational learning theories and research methodology behind the development of mobile mixed reality environments for high risk learning environments. The ASCILITE Conference presentation will outline the research progress and elicit expert feedback from the conference attendees to help refine the research methodology.

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Please cite as: Hong, J., Cochrane, T. & Withell, A. (2018). Developing a design-based research methodology for designing MR technologies for mountain safety. In M. Campbell, J. Willems, C. Adachi, D. Blake, I. Doherty, S. Krishnan, S. Macfarlane, L. Ngo, M. O'Donnell, S. Palmer, L. Riddell, I. Story, H. Suri & J. Tai (Eds.), Open Oceans: Learning without borders. Proceedings ASCILITE 2018 Geelong (pp. 401-405).

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