Can the augmented reality sandbox help learners overcome difficulties with 3-D visualisation?

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Abstract: Research has shown that students have difficulties in understanding topographic maps and landforms associated with contour patterns and therefore have problems in reading and interpreting topographic maps and relating these 2-dimensional representations to a real 3-dimensional environment. However, maps are a fundamental tool for understanding geographical concepts and solving geographical problems. Current research indicates that this is not uniquely a South African problem and various attempts have been made to address this problem such as the use of videos, models and fieldtrips – each with their own limitations and difficulties. Nevertheless, the ability to visualize in 3-dimensions from a 2-dimensional representation is an essential skill in understanding and interpreting topographical maps. To address the problem of 3-D visualisation, an augmented reality sandbox (AR-Sandbox) was introduced to a Geography classroom, to Grade 11 students at a Secondary school in Johannesburg, South Africa. The aim of this study is to determine the effectiveness of using the AR-Sandbox to enhance the learning of – and improve the learner's performance – in mapwork, and thereby address the problems experienced with 3-D visualisation. The results of the pre-test and post-intervention test are presented and show that the AR-Sandbox is an effective tool for enhancing an understanding of landscapes rather an improving performance in the construction of cross-sectional profiles.

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Introduction

Mapwork is an essential component in the study of geography (Maonga 2015, Larangeira & Van Der Merwe 2016). Offermo (2016) argues that learning how to interpret and create maps is important because they present data in a compact and clear manner. In South Africa and in many countries around the world, problems associated with the understanding of mapwork at school level have received significant amounts of attention over the years (Innes & Willigen 2008). However, the focus has been on three-dimensional (2D) maps rather than on the three dimensional (3D) visualization of contour pattern and landforms.

Learners of geography have difficulties in understanding concepts of contour lines and landforms associated with contour patterns; or they simply struggle to visualize a 2D map as a 3D landscape. Map skills and digital technologies have become a major focus of geographical education in the last decade (Wilmot 1999). Technological developments such as augmented reality (AR), Google Earth (GE) as well as Immersive virtual environments (VE) are available to deal with the issues faced by both teachers and learners in teaching and understanding some of the concepts such as contour pattern landforms. AR and VE are technologies used to visualize an enhanced image of an environment by overlaying various computer-generated images (Carrera et al. 2017). Teaching with GE, according to Hsu et al. (2017) has shown an improvement in learner's understanding of topographical maps when compared to teaching with conventional instructional method.

An AR-Sandbox is a tool used to visualize a topographic map in a 3D-model. The AR-Sandbox comprises a distance scanner, a projector and a box of kinetic sand. The projector and the scanner are attached above the sandbox. The scanner is used to measure the altitude of the sand in the sandbox; the computer software is then used to process data to produce a topographic map image of the sand surface and elevation colours and contour lines are shown as well. The projector then projects this image back onto the sand giving the images of landforms with contours in three dimensions. The projector is attached above the sandbox and the distance scanner is attached on a boom, below the projector (see Fig. 1). The software was downloaded from QGIS (https://qgis.org), which is a free and open-source cross-platform desktop geographic information system application that supports viewing, editing, and analysis of geospatial data; and the GRASS software package from QGIS was used, in particular.

As a new technology in a classroom we aim to determine the effectiveness of an AR-Sandbox as a digital tool to help grade 11 learners overcome the difficulties in 3D visualization of 2D maps.

The problem with spatial representation

Mapwork forms the practical component of the Geography syllabus in all grades. Maps are spatial representations, thus the successful use of maps requires an understanding that they are 2D illustrations of the 3D world that we live in. The interpretation of a spatial representation, a map, is mainly grounded on previous knowledge and previous experiences (Carter et al. 2002). According to Apostolopoulou & Klonari (2011), their natural environment influences children's perception of maps. It is argued that children living in rural areas or in mountainous areas have a better understanding of these reliefs than children living in urban areas or in plain areas.

Research indicates that problems with performance in mapwork have been both an international and national concern for some time (see Kali & Orion 1996, Kali et al. 1997, Libarkin & Brick 2002, Calderone et al. 2003). Ezeudu & Utazi (2014) noted that poor performance in mapwork has reduced the enthusiasm and weakened the morale of students for Geography in secondary schools in Nigeria. The writers of mapwork textbooks, Geography learners, teachers and examiners of school certificate Geography further acknowledged this (Ezeudu & Utazi 2014). In the U.K. examiners complained, that many candidates did not have simple map skills; for instance, they could not interpret simple contour patterns; and in South Africa, similar reports appeared from the 2008 and 2009 Geography Chief Marker (Batyi 2011).

Geography is the study of society and the world as well as the manner in which the people behave and influence the world around them (Gaudence et al. 2013). However, teaching some units such as mapwork and the physical environment remains a challenge to teachers as students struggle to understand and perform well in such units. Studies show that despite the positive trend of enrolment of geography learners in high schools, there is a low level of performance among these learners (Wilmot & Dube 2016). Even though an upward trend of enrolment has been reported, only about 53% of the learners in grade 12 are able to achieve 40% (Wilmot & Dube 2016). Preparation for the Grade 12 exit examination usually begins in grade 11. However, grade 11 pupils struggle with conceptual material especially in mapwork and perform poorly in mapwork assessments. These learners find it difficult to understand landforms associated with contour patterns and particularly constructing cross-sectional diagrams from maps, from which they can interpret 3D landforms. The teaching approach that the teacher may adopt is one factor that may affect learners' performance as

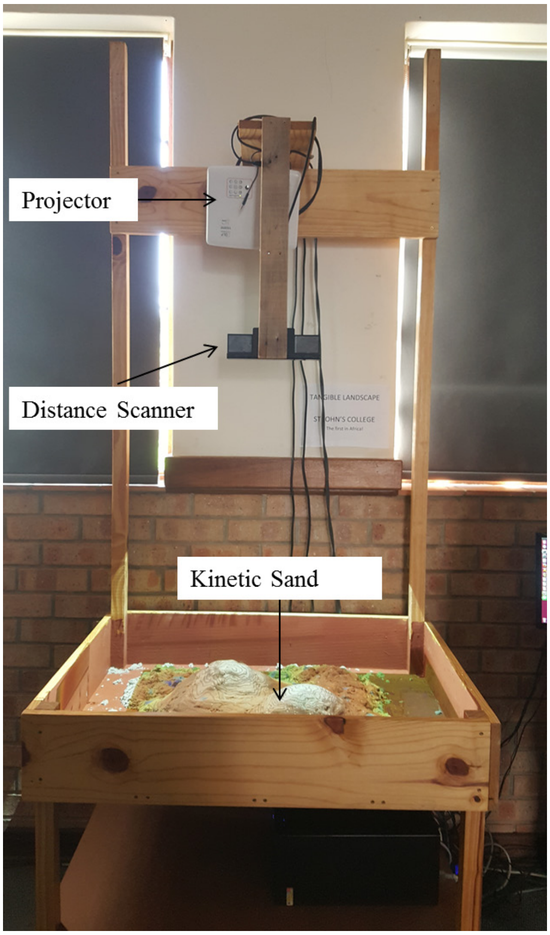

Figure 1. Set up of the AR-Sandbox used in this intervention (photo B. Fleming)

well as lack of teaching resources. Teachers mostly use traditional methods of using a chalkboard and 2D diagrams such as, pictures in the textbooks for teaching. However, various attempts have been made to address this problem (for example see Calderone et al. 2003, Drennan & Evans 2011). These interventions can be static, in that they cannot show the dynamic nature of the environment, or they need mediation from the teacher or peers especially when their own exposure to the natural environment has been limited.

In schools that are well-resourced, the introduction of technology is becoming more commonplace which has pedagogic and practical value for both teachers and learners. As such the introduction of the relatively inexpensive AR-sandbox into Geography classrooms offers the opportunity to combine both traditional and modern teaching methods to assist learners with mapwork. It consists of a tangible landscape that can be modified in real time, and the resultant maps can be generated immediately. As there is a lack of research on the use of an AR-Sandbox when teaching mapwork in schools in South Africa, we investigate the influence of this tool on grade 11 learner's performance in geography mapwork in a secondary school in South Africa.

Methodology

The primary method employed in the process of data collection was that of a pre-test, an intervention using the AR-Sandbox and a post-test. A group of 25 grade 11 learners participated in the study. The learners are from a resourced, government-funded urban school. The group was taught mapwork using conventional classroom teaching methods (lecture, class activities and diagrams) about contour landforms.

Pre-test: The pre-test was given to all the participants. They were given a 1:50 000 map and asked to draw a cross-section profile from A-B. The profile crossed 2 small hills. All 25 learners had 1 hour to complete the assessment under normal test conditions. The pre-test was marked (Fig. 2) and the results collated before the group was divided randomly into two subgroups: one of these worked on the AR-Sandbox intervention and the second group only worked on multiple cross-sectional diagrams.

AR-Sandbox intervention: The AR-Sandbox was used to represent a 3D view of contour landforms and the learners were asked to created different landforms in the kinetic sand. They worked in groups and individually, with instructions to make different contour landforms, such as valleys, hills, spurs, steep and gentle slopes and then observe the contour lines displayed by the projector on top of the kinetic sand. They could then compare these computer generated maps to the original topographic maps. Alternatively, they could reconstruct the landforms shown on the topographic map and compare that to the computer generated map. During the intervention the teacher and peers mediated the process for each other, offering correction and advice and generating much discussion throughout the processes.

Mapwork Iterations: The learners in this subgroup were given different maps and asked

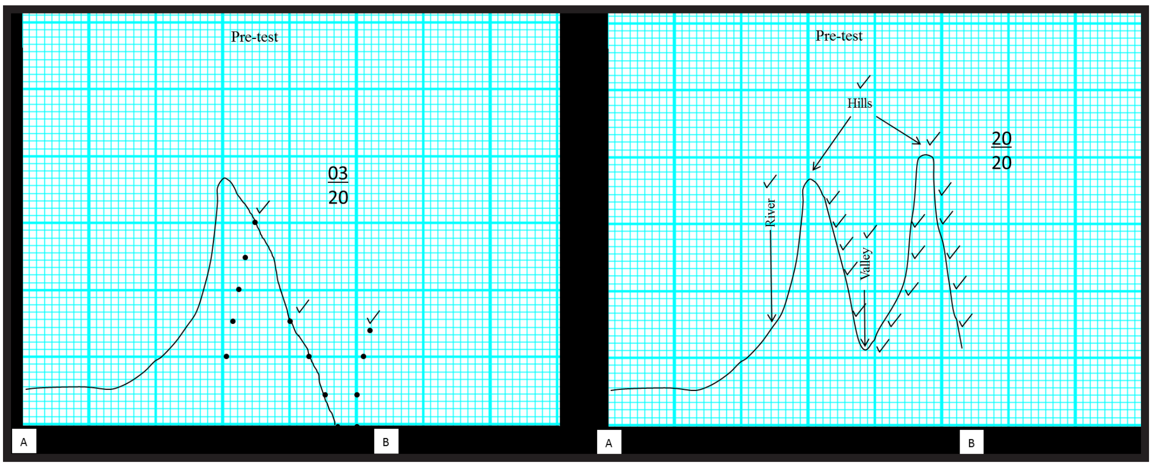

Figure 2. Examples of the pre-test results. The first shows very little understanding of the related landforms and the second is correct

to draw cross-sectional profiles of different landforms. The aim was to determine whether students could improve their performance by iteration alone, as performance could improve through familiarity with the exercise. This group was also allowed discuss the work or ask for assistance from the teacher and their peers.

Post-test: A post-test was administered to determine whether there were differences in achievement or performance. All the learners participated in the post –test. The learners were given a more challenging cross-section profile to draw and completed it under similar test conditions and time as the pre-test (Fig. 3).

Results and Discussion

The learners were receptive to the interventions as the creation of topographic maps from 3D representations (i.e. the kinetic sand) gave students the opportunity to visualize both 2-D and 3-D projections simultaneously. The process of working with the AR-Sandbox and having the teacher and student interact with the tool was more effective than traditional teaching methods.

The pre-test results showed that students were able to draw cross-section profiles off simple contour patterns, although 30% of the group failed the exercise (Fig. 4). Surprisingly, the post-test shows that there was not a significant improvement in performance from the learners who used the AR-Sandbox. Instead 40% of the group achieved between 50-75% which was 10% up from the post-test; and 10% less scored 75+% (Fig. 4). The most interesting result showed that with multiple iterations, the learners are well-able to improve their results, even if they do not understand the landscapes. All the learners however, noted that they preferred the interaction around the AR-Sandbox and the opportunity to discuss the landforms with their peers and the teacher. Nystrand & Gamoran (1991) argued that teachers play a huge role in the engagement of learners that will eventually lead to their understanding of complex concepts. If learners are required to always fill in the missing words, take multiple choice tests or to repeat aloud after the teacher, without paying attention to the content, then understanding and mastery of a particular topic will be limited. The kind of questions a teacher asks and kind of responses in the classroom also plays a significant role in enhancing understanding of a particular topic by the learners. The intervention that allowed for the interaction between the learners and the teacher was ideal to enhance understanding of the mapwork concepts and learners reported an increased confidence in working with maps as a result. Nystrand & Gamoran (1991) further noted that such responses modify the topic or affect the course of discussion in some way which will certainly enhance the learners' interest and understanding of the topic.

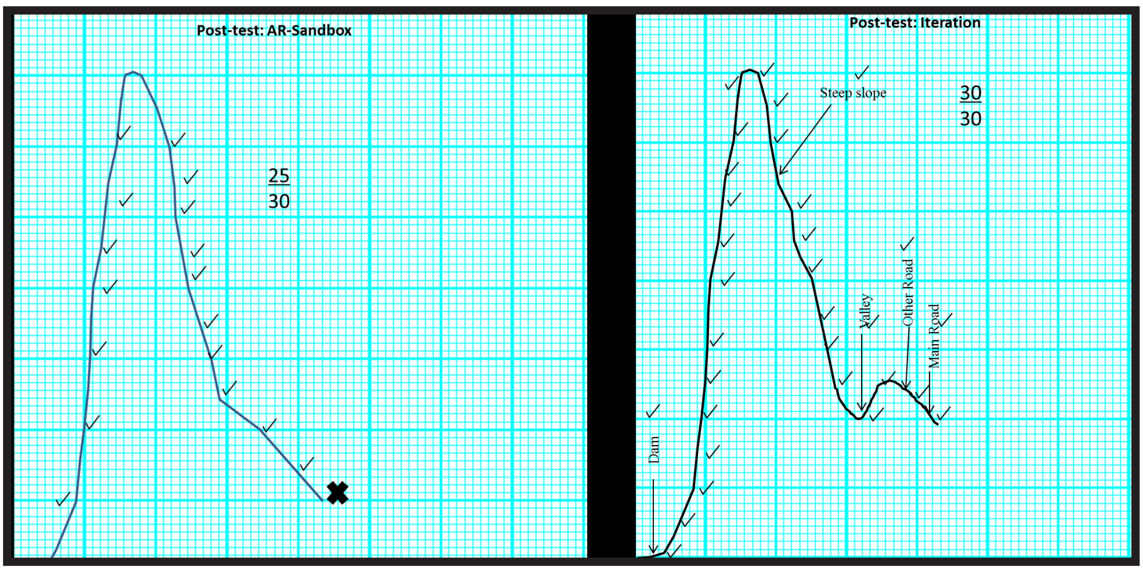

Figure 3. Examples of the post-test results. The first shows an example from a learner in the group who worked on the AR-Sandbox and the second is from the group who did multiple exercises

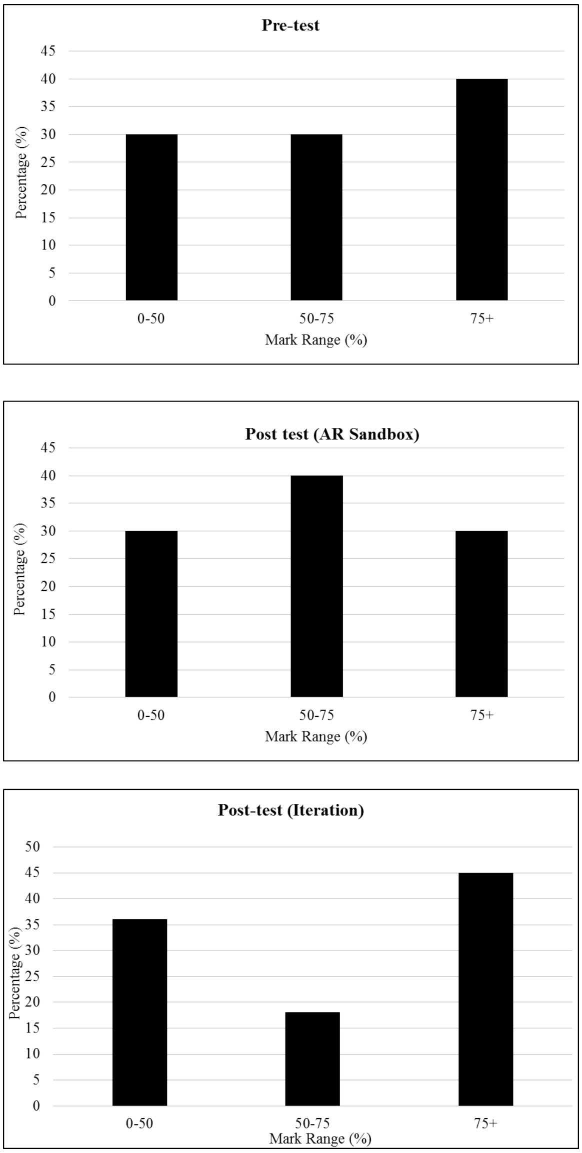

Figure 4. Results of the pre- and post-test, including the AR-Sandbox intervention and the iterations

Conclusion and the way forward

The use of the AR-Sandbox as an intervention did not significantly improve the performance of the learners in constructing cross-sectional profiles. Instead there was a marginal decrease in their overall performance after the intervention. However, this study does show that learners can improve their overall performance through repetition of an exercise. The success of the AR-Sandbox was in that it provided a tool for the learners to consolidate their understanding of landforms and generate discussions around 2D representations of a 3D world. However, the lack of resources in most South African schools is a major issue that contributes to limited access that learners may have to such technologies and as much as an AR-Sandbox may be an answer to the mapwork problem, many school cannot afford that kind of technology. Furthermore, using the construction of cross-sectional profiles may not be the ideal instrument to test the effectiveness of the AR-Sandbox as a tool in the mapwork classroom. Therefore, future research and analysis will focus on alternate methods to evaluate the AR-Sandbox.

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