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Enhancing Exploratory Learning Using Computer Simulation in an E-learning Environment: A Literature Review

Paul Kanyaru & Elizaphan Maina

Kenyatta University, Nairobi, KENYA
Computing and Information Technology Department

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Abstract

Computer simulation has been shown to elicit exploratory behavior and creativity in learners. Various researches have indicated that during an exploratory learning process students can acquire knowledge either through inquiring or exploring an open learning environment. Further, the research shows that as opposed to instruction-based learning, exploratory learning is mainly based on self-motivation by learners. Therefore, computer simulation when used to enhance exploratory learning concept especially in an e-learning platform, has been seen to achieve the learning objectives as explained by Bloom taxonomy. In this regard, computer simulation has been seen to help learners conceptualize important concepts especially in science subjects. Additionally, the use of simulation is regarded as an aid to improving understanding of various concepts as well, as helping increase breadth of knowledge.

Keywords: exploratory learning, computer simulation, e-learning environment.

1. Introduction

Prevalent learning theories have shown that the learner is no longer viewed as an "empty vessel," but rather as an actor who is actively involved in constructing and reconstructing of knowledge base (Metsärinne & Kallio, 2007). As such, this point of view is apparent in modern studies that have shown the importance of the active role a learner plays in the learning process and the importance of the foreknowledge. In view of this, various types computer assisted instruction exist that support this type of learning approach. Such an example is the use of computer simulation that has been seen to elicit exploratory behavior in learners (Salleh, Tasir & Shukor, 2012). It has been shown that during exploratory learning, students are able to acquire knowledge through either inquiring or exploring in an open learning environment. Further, students are able to explore a certain domain by self-motivation rather than being instructed. According to various researches, all approaches to exploratory learning are based on four principles; learners can and should control their learning, knowledge is multidimensional, learners approach to tasks are diverse and it is possible for learning to feel natural (Iqbal, 2012; Metsärinne & Kallio, 2007; Njoo & De Jong, 1993). In addition, different tools are used to enhance exploratory learning that includes microworlds, hypertext and games & simulations, but this study will focus on simulation as implemented in e-learning systems.

Correspondence: Paul Kanyaru, MSC (COMPUTER SCIENCE) Student at Kenyatta University, P.O BOX 25923-00100, Nairobi, KENYA. E-mail: murikuh@gmail.com.

2. Methodology

We limited this systematic literature review to the use of computer simulation in exploratory learning and its application in e-learning platforms.

2.1 *Research questions*

(1) How does computer simulation affect students understanding of concepts in an e-learning environment?
(2) Does computer simulation increase breadth and depth of knowledge for a learner in an e-learning environment?
(3) How does use of computer simulation affect student's conceptualization capability in an e-learning environment?

2.2 *Data sources*

This review sourced its data from four electronic databases: Google Scholar, Springer, IEEE, and Science Direct.

The researchers conducted databases search and received 535 results, but only included the first 200 most relevant results. The search for the most relevant articles was conducted using well-defined query criteria as shown below. (Computer simulation OR "simulation") AND (Exploratory learning OR e-learning OR "e learning" OR exploratory e-learning).

The search was conducted in October 2018, and the researchers made the search base as broad as possible in order to get as much results as possible that would try to answer our research questions. The Figure 1 is a summary of the query criteria and the search results.

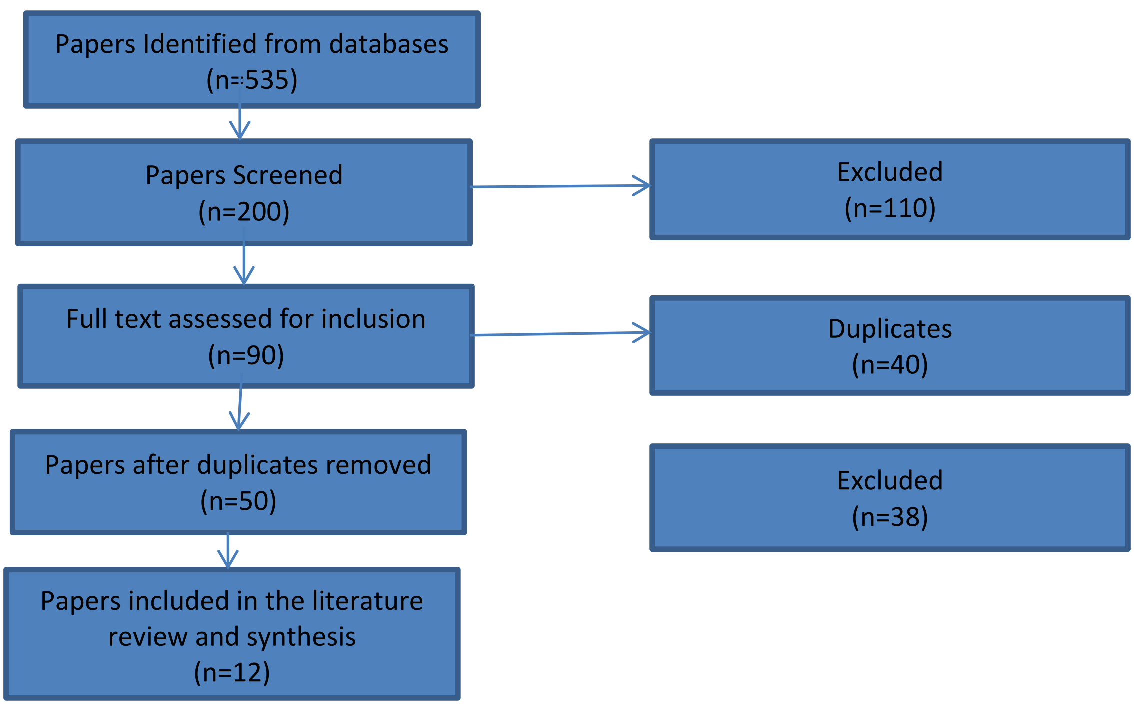

Figure 1. Summary of the query criteria

3. Learning objectives and Bloom taxonomy

The value and importance of computer simulation in higher education cannot be overlooked especially its relationship with learning objectives. The general and core objective of learning describes skills and knowledge students need to gain, and they are always core to the design and validation of any educational system (Miller, Nentl & Zietlow, 2014). Various frameworks like Bloom's taxonomy have been used extensively to explain learning objectives (Ekren & Keskin, 2017). According to various studies, simulation has been framed as a technology that engage students in deep learning (Ekren & Keskin, 2017; Miller et al., 2014). As such, skills like critical thinking and problem solving are central to achieving learning objectives. According to Bloom Taxonomy, learning objectives could be classified into three domains. Cognitive domain looks at the skills that regard knowledge, comprehension and critical thinking in regard to a particular subject. On the other hand, affective domain describes skills that make people react emotionally and thus it happens the behavioural level. Lastly, psychomotor domain looks at the application of the learning in solving problems (Ekren & Keskin, 2017). With the emergent of technology and its integration with education, there was need for the Bloom taxonomy to be revised so as to cater for different generations of learners as well as modes of learning like e-learning. As shown by the revised Bloom taxonomy, the classification system was designed to help instructors clearly define learning objectives. As such, designers of e-learning systems need to realize that writing clear and precise objectives of learning is essential to the success of the students (Ekren & Keskin, 2017; Miller et al., 2014). In view of this, the revised Bloom Taxonomy is vital in defining e-learning objectives, as well as the associated behaviour of the learner, which is influenced to meet the learning objectives.

According to Bloom, one of the levels of the model is knowledge (Ekren & Keskin, 2017). Research has shown that this level is the easiest to implement in the e-learning environment. Through an e-learning platform, and especially that utilizes simulation, it is easy to impart knowledge in form of facts, terms and basic concepts. The other level is the comprehension, which refers to the ability to understand something. The idea behind this element is to ensure that the learners have received the information provided in the e-learning course and can understand advanced concepts and techniques. Another level in the model is application, which refers to the ability of the learner to interact with the e-learning system through exercises and simulations with the endeavour of applying the acquired knowledge. This stage requires designers of the system to focus on using real life situations that are familiar to learners. The learners can then apply the learnt facts, knowledge and rules to solve problems. At the analysis level, the learner has developed an understanding of the subject and can analyse problems and gather the correct information that helps in making decisions. At the evaluation level, the learner has become an expert and can be trusted to make recommendations based on analysis of a situation. The final level in this taxonomy is the creation step that requires learners to come up with original work based on the concepts learned. Being the highest level of the Bloom taxonomy, learners come up with their own work as a way of demonstrating that they have mastered the subject (Ekren & Keskin, 2017; Miller et al., 2014). This shows that a designer of an e-learning system must follow the cognitive domain of Bloom taxonomy so as to come up with a system that ensures learning objectives are met.

4. Review of past literature

4.1 *Definition of concepts*

Teaching science concepts requires a proper approach that will facilitate conceptualization of important ideas. Consequently, a computer simulation will provide a model for teaching events, objects and phenomenon (Metsärinne & Kallio, 2007). This are applied in teaching to model concepts that are difficult to observe in a classroom environment. A computer-based simulation allows students an opportunity to interact with a computer representation through a model of a physical world or using a theoretical system (Tawil & Dahlan, 2017). Therefore, a computer simulation creates a learner centered classroom environment that enables students to explore systems, use variables and examine hypotheses.

Enhancing exploratory learning is a major problem in conventional classrooms. A computer simulation program can effectively be utilized by a teacher as a demonstration so that students can explore several phenomena that would be difficult to understand in a conventional classroom. Secondly, computer simulations enable learners to experience a realistic understanding that facilitates manipulation of knowledge. As such, students benefit from achieving a better understanding of concepts under investigation. For instance, animations can be combined with visualizations to improve insight development of a complex physical phenomenon (Yas, Ahmed & Tala, 2014).

4.2 *Developing content and processing skills*

Studies on impact of computer simulations in promoting exploratory learning have demonstrated a positive finding. Researchers have observed that computer simulations can enhance exploratory learning through developing content, processing skills, encouraging complicated goals and facilitating a conceptual change. Basically, majority of studies have shown an increase in achievement for science skills through using computer-based simulation in learning and teaching (Thong, Lin, Siong & Lin, 2008). For example, simulations can replace learning or teaching where equipment is not available and cannot be set up (de Smale, Overmans, Jeuring & van de Grint, 2016). Also, it is an important teaching tool for performing experiments that are ordinarily impossible to undertake. This is because variables can easily be altered in simulations to promote learning prompted by questions from students, which is impossible to achieve using a real equipment. Here, computer simulations allow students to practice laboratory techniques prior to engaging in lab experience with actual equipment.

Studies on comparison of computer simulations and traditional classroom learning have demonstrated that the former can enhance exploratory experience. Learners become a valuable add-on in a traditional classroom because they act as pre-laboratory experiments. For example, (Salleh et al., 2012), it has been proved that computer simulations enhance learning of optical lenses. In a conventional classroom, textbooks offer a two-dimensional representation of concepts which is improved to three dimensional through simulations. For example, visualization created by computer simulations enhances mental constructs that facilitates critical thinking to describe and explain objectives. According to Njoo and De Jong (1993), computer simulations in a dissection lab makes it possible to identify correct and wrong answers through improving the skills for what-if and possibilities. Utilization of computer simulations enhances positive understanding of concepts and gaining of new skills. This enables students to improve their general understanding of complex science concepts.

4.3 *Improving understanding*

Enhancing exploratory concepts require computer simulations to make understanding easier. According to Tawil and Dahlan (2017) it has been postulated that structures are an easy way of understanding a complex system like DNA and RNA enables students to understand their functions. Here, simulations are important so that they can organize small pieces of information to become large so that it can reduce the amount of memorization that would be required to achieve a better way of determining a logical relationship of underlying ideas (Tawil & Dahlan, 2017; Metsärinne & Kallio, 2007). Computer simulations provide learners with an opportunity to view and interact with models representing a particular phenomenon and processes.

Thong et al. (2008) have revealed that computer simulations enhance student understanding through attaching mental images. Similarly, other researchers had earlier identified that a mental model is a required level of understanding and interpretation of an existing concept that is influenced by experiences, beliefs, history and personal opinion (Miller et al., 2014). Mental models should be generated by students to enhance understanding of new concepts. As such, teachers rely on models as a basis on enhancing learners' ability of generating individual models through computer simulations.

Exploratory learning requires understanding of scientific concepts in the context of a daily scientific phenomenon. Certain scientific phenomenon occurs within a very short period of time at different places. Using computer simulations will enhance development of student evaluation skills (Iqbal, 2012). Through replaying and stopping focus can be created on important parts. As such, students are able to understand a scientific phenomenon that would otherwise be difficult to understand in real time.

4.4 *Depth and breadth of knowledge*

Studies have demonstrated that computer simulations can improve the breadth and depth of knowledge through making abstract concepts become more concrete (Tawil & Dahlan, 2017; De Freitas & Oliver, 2006). The abstract concepts will be provided and made accessible to learners through computer simulation models. For example, the circulation system is a complex phenomenon, but this is simplified through a simulation model. According to Wall and Ahmed, (2008), computer simulations offer an opportunity to allow learners to represent visually and enthusiastically integral concepts that would be lost. Here, non-observable scientific phenomenon can be provided. Difficult scientific processes can be animated to enhance understanding which would not be enabled by textbooks. Basically, computer simulations allow students to visualize a difficult phenomenon.

Another important finding from research on computer simulations is through facilitating engagement in learning. Research has shown that there has been improvement in the level of students participation and motivation during preparations for simulation exercises (Thong et al., 2008). As such, computer simulations enable advancement of learning goals, process skills, discussions, argumentation and identification of science concepts. This was found to be consistent with other studies that have suggested that successful student engagement to computer simulations the learning process should be authentic and meaningful (Yas et al., 2014).

5. Conclusion and recommendation for further research

As shown by various researches, computer simulations are often geared towards acquiring skills. Therefore, exploratory learning being an approach of learning and teaching that inspires students to observe and examine original materials, enables students to unravel existing relationships between contextual knowledge and unacquainted content and ideas. Technological advances have shifted the perception of teaching through introduction of instructional learning approaches. Computer simulation is a computer-based program that creates things and relates them using a cause and effect connection. In this regard, computer simulation is a teaching and learning model, which can be used to present theoretical components in the real world, thus achieving the learning objectives. Although the use of simulations in e-learning is not an overly new concept, it has not been utilized maximally. Therefore, I propose that due to resistance to technology especially from tutors' stand-point, e-learning platform should be blended with the traditional method of instruction. Further, caution should be exercised while introducing such high level techniques like computer simulation since what has worked in other education systems may not work in the Kenyan curriculum context.

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