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CONTRIBUTION OF COMPUTER SIMULATION IN CONCEPTUAL UNDERSTANDING OF SCIENCE

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Abstract

Learners have alternative conceptions about scientific phenomena when they enter in the class room and these ideas affect how the corresponding scientific explanations are learned. Simulation is a powerful tool that could be of great benefit to learning and a very important element in the design of innovative learning environments, centered on the needs of the learners and integrating technologies at the right time and for the right activity. Computer simulation has a great potential for the enhancement of the teaching and learning of science concepts. Computer simulations facilitate the learning of abstract concepts and provide interactive, authentic and meaningful learning opportunities for learners. In addition to that, through simulations learners get instant feedback and also would have the chance to make observations (Bell & Smetana, 2008). The purpose of this paper was to investigate the contribution of a computer simulation in the field of science and how computer simulation brings improvement in conceptual understanding of science concepts.

Keywords: Computer Simulation, Conceptual Understanding, Science.

Introduction

It is the need of the hour that learners especially in secondary schools would use their observation skills, analysis, and conclusion because in science education practical side and hands-on training is very crucial. Due to the increase in the complexity of knowledge and collection of information, it has appeared urgent to find a style or method to simplify and facilitate the transfer of information in the minds of students. With technological revolution and scientific development, there is a need to take advantage of computer simulation technology to develop education and solve its problems and serve the learner and the teacher is already reflected in the improvement of the efficiency of the educational process (Droui & Hajjami, 2014) [13]. In recent decades, simulation-based animations strategic methods and information technology has been using in classroom in science education for better understanding and traditionally adapt the prevailing levels of science and technology rote learning in education and facts (Sasikala, et al, 2016 [41]).

One of the best and most powerful educational computer programs in science education are computer simulation programs. Computer simulation programs can explain the concept or simplified model of a component, of a phenomenon or conceptual process in the real world. They are computer-generated effective models, which, consisting of animation, visualization, and interactive laboratory experiences. It is based on the principle of constructivist philosophy, which emphasizes that the student learns through scientific experience; these (Bell & Smetana, 2008 [5]).

Multiple skills in science learners such as observing, measuring, predicting, controlling variables, formulating hypotheses, and interpreting results can activate by using computer simulations (Droui & Hajjami, 2014 [13]; Mahdi, Laafou & Idrissi, 2018 [23]). It allows learners to reflect on their learning and allows them to explicitly develop metacognition (Droui, et al, 2014 [13]) improve motivation and interest in the class (Martinez-Jimenez, Pontes-Pedrajas, Polo & Climent-Bellido, 2003 [24]) and to present itself as an effective

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prediction tool (Lavoie & Good, 1988 [21]). One method has shown that nonverbal representations stimulate brain activity (Clements & McMillen, 1996 [11]). The forms of representation (images, animations, graphics, and digital data) can multiply through simulation. When the learner allows choosing the representations he prefers, increase his motivation for individualize learning, and follow in the footsteps of learners throughout their learning (Cholmsky, 2003 [9]).

Due to the lack of understanding of the methods of science, many students experience difficulty in science courses (McPherson, 2001). Traditional expository modes of instruction have been reported to be less effective in improving learning of biology concepts, reasoning skills, and positive attitudes toward science at the college level as compared to Constructivist teaching methods of learning (Windschitl & Andre, 1998 [53]; Faryniarz & Lockwood, 1992 [14]).

Contribution of Simulations in Science Education

For several years, research in science didactics has focused on the following question: how would simulations be useful for promoting science learning? The emphasis is on their advantages and contributions to science education. We based ourselves on a literature review of the various research carried out in this field to identify some main elements concerning the contributions of the use of simulations in science learning.

- Simplify the real systems studied: Real systems, studied in science education, are complex and dynamic. They are often presented in a simplified manner in order to allow students to focus on the critical information or skills to be developed, and therefore to facilitate their learning. In this perspective, the use of simulations turns out to be very appropriate for performing simplified procedures and cognitive tasks (Grabe & Grabe, 2004 [15]) and for reducing the gap between the dynamic and complex reality of the phenomena studied and their simplified and static teaching in the classroom (Wilensky & Stroup, 2000 [51]). We can thus propose a phenomenon which is usually complex in the form of a simple simulation which allows the pupil to develop an intuitive understanding of it.
- Present an alternative to inaccessible experiments: According to Mintz (1993) [27], one of the most promising computer applications in science education is the use of simulations to develop teaching materials suitable for experiments that we cannot perform by conventional laboratory experimentation in the classroom. In this sense, Strauss and Kinzie (1994) [43] underline those simulations replace dangerous experiments or relatively long manipulations (for example in nuclear physics, atomic physics or astronomy). They are also presented as a unique didactic tool for expensive experiments.
- Activate and develop skills: According to Roth and Roy Choudhury (1993) [37], simulations can activate basic procedural skills in science students such as observing, measuring, communicating, classifying, predicting, as well as procedural skills built into the scientific process, such as controlling variables, formulating hypotheses, interpret data, experiment and formulate models (Padilla, Okey, & Dillashaw, 1983 [33]). For their part, Lazarowitz and Huppert (1993) [22] studied the impact of the use of computer simulations in the development of procedural skills in science of 10th year students in biology. Their results indicated that computer simulation helped them master the skills of graphing communication, interpreting data and controlling variables in simulated experiments and can enable students to use the skills.
- Perform virtual experiments and explore phenomena**:** Alessi and Trollip (1985) [4] note that the simulation provides students with the opportunity to observe and interact with a real experience. In science education, simulation can play an important role in providing the opportunity for virtual experiments. Simulations allow the exploration of the behaviour of a given system and the testing of hypotheses and theories developed by the learner. Simulations offer the possibility for students to carry out their own experiments by formulating hypotheses and confronting them with observations and constructing new knowledge and making sense of what they are learning.
- Present itself as a tool for scientific investigation: Mintz (1993) [27] studied computer simulations as a tool for scientific inquiry, considered a fundamental principle for science learning (National Standard Science Education, 1996 [30]). The scientific investigation process includes making hypotheses, performing experiments, observing and recording data, and writing conclusions. He reported that simulation can increase and improve classroom work. Simulations, as an investigative tool, improve motivation and interest. They can also appear as an effective tool for forecasting in biology (Lavoie & Good, 1988 [21]). In addition, the simulation provides environments for scientific investigation and cognitive tools necessary for the scaffolding of the learning and applies

problem-solving skills. Simulations thus make it possible to explicitly develop students' meta-cognition and allow them to reflect on their learning.

- Visualize the phenomena and multiply the forms of representation**:** Since non-verbal representations stimulate brain activity (Clements & McMillen, 1996 [11]), simulation multiplies the forms of representation (images, animations, graphics, and digital data) (Cholmsky, 2003 [9]). By leaving to the learner the choice of the representations he prefers, it allows learning to be individualized and opens the door to an analysis of the pupil's ways of thinking: by observing the choice of his representations at the same time. 'Screen, through meta-cognitive tools and evaluations. Simulations can be used to increase motivation levels and also allow us to follow in the footsteps of learners as they learn; the teacher will be able to get a more precise idea of how they work and their resolution strategies; which allows him to identify reasoning difficulties in learners. Consequently, he will be able to adjust his interventions accordingly (Wetherill, Midgett & McCall, 2002 [49]). Simulations make it possible to represent both the phenomenon graphically and its manifestations, such as curves or ancillary data (Droui, 2012 [12]).
- Simulation as a complementary tool to real experiences: The question asked: can simulation be as efficient as the conventional laboratory or replace it? It depends on the concept or the situation that it is as efficient or not. For example, Choi and Gennaro (1987) [10] compared the effectiveness of simulated computer experiments versus manual laboratory experiments in teaching the concept of volume displacement to middle school students. They found that simulated computer experiments were as effective as manual lab experiments. This suggests that certain concepts such as volume displacement would be more understandable if teach through simulated computer experiment instead of a conventional laboratory experiment and thus obtain comparable results. This recommends that computer simulations can be applied to replace those laboratory activities which require cognitive interactions with content rather than psychomotor or physical interactions (e.g. taste, smell, contact interactions).
- Simulations can also be used as a supporting tool in the laboratory. Indeed, the simulations can save time and the duration of the laboratory session can be reduced by combining laboratory experimentation and simulations (McKinney, 1997; Kennepohl, 2001 [25]). In addition, research shows that students using simulations gain relatively better knowledge of the practical aspects directly related to real laboratory work.
- Simulation as a support for individualized learning adapted to need: However, according to Choi and Gennaro (1987) [10], simulations conducted with a specific objective may be the appropriate tools to minimize learning disabilities. For example, the simulations can be used to scaffold the learning of those who have relatively low imaginative capacity and which is critical for the understanding of dynamic systems. The pupil will choose for himself the time he will spend and the manipulations he will do. According to Roschelle, Pea, Hoadley, Gordin, and Means (2000) [38] it is important to have immediate feedback after a student's learning. This allows the reasoning to be corrected if necessary. The simulations being characterized by rapid responses, the learner can multiply the tests without the discouragement which characterizes the length of his usual experiments. The student can stop data entry and can resume the experiment with different entries. The number of manipulations can be increased.
- Simulation as an intermediate state in theory and practice: Generally, the teaching of science suffers from a lack of interactions between the theoretical world where the student manipulates notions and concepts, the practical world or the student manipulates concrete devices and objects. Simulation can be considered as an intermediate state between the physical manifestations of the phenomena studied and theoretical models (Richoux, Saveltat & Beaufils, 2002 [36]). We can also cite the work of Buty (2003) [7] who analyzes the potentialities and the didactic limits of the use by students of simulation software in geometric optics for the understanding of the formation of images by lenses.

In short, the pupils broaden their horizons; it makes it possible to explore more abstract or higher-level concepts, and to develop a better understanding of the concepts taught and of the phenomena and physical laws through a scientific approach (formulation of a hypothesis, testing of the idea, isolation and manipulation of parameters (Jimoyiannis & Komis, 2001 [17]). The use of simulations brings about changes in the learner and the teacher at the level of the context and at the level of the content. Simulation makes the learner active and allows instant feedback.

Conceptual Understanding in Science

Meaningful science learning called for conceptual understanding rather than memorization (Adadan, Trundle & Irfing, 2010 [2]). Meaningful learning is not the transmission of knowledge from the teacher to the students; it requires knowledge to be constructed by the learner (Jonassen, Peck, & Wilson, 1999 [18]). Students who construct well-connected and hierarchically arranged conceptual frameworks have conceptual understandings of certain concepts (Mintzes & Wanderse, 1998 [28]). When students have an understanding of a concept, they can (a) think about it, (b) use it in areas other than in which they earned it, (c) state it in their own word, (d) find a metaphor or an analogy for it, or (e) build a mental or physical model of it (Konicek-Moran & Keeley, 2015 [20]). In other words, the students have made the concept of their own. Science is a field that involves identification of the hidden concepts, define adequate quantities and explain underlying laws and theories of science phenomenon by using high-level reasoning skills. Teaching for conceptual understanding is the main goal of science education (Konicek-Moran & Keeley, 2015 [20]). Thus, students can understand the relationships and differences among the concepts of science phenomena by involving themselves in the process of constructing qualitative models. Conceptual understanding of science concept is a complex phenomenon and is also described as students' ability to apply the learned scientific concepts to scientific phenomena in an everyday life situation (Nieswandt, 2007 [31]). This includes the capacity to construct explanation, recognize new information and make connections among scientific phenomena.

Why is Science Simulation Effective on Conceptual Understanding?

Technological advances like computer simulation increasingly brought digital instructional technologies into the science classroom. Computer simulations are computer-generated dynamic models that present theoretical or simplified models of real-world components, phenomena, or processes (Bell, Gess-Newsome & Luft, 2008 [6]). In line with this, simulation as a representation or model of an event, object, or some phenomenon (Thompson, Simonson & Hargrave, 1996 [44]). Simulations are used to model that which is not easily observed in real life or are used in teaching situations where simulation offers advantages (Scalise et al., 2011 [42]). Computer simulations are programs that allow the learners interact with a computer representation of either (a) a model of the natural or physical world, or (b) a theoretical system (Weller, 1996 [48]). Simulation provides learner-centered environments that allow students to explore systems manipulate variables and test hypotheses (Windschitl, 1998 [52]). Further, these programs can be used as demonstrations by teachers, or they can be used directly by the students to explore various phenomena that would not be readily available under normal situations. Simulations also provide learners with realistic experiences from which to gain and manipulate knowledge to understand better the relationship between the concepts being investigated. Simulations can combine animations, visualizations, and interactive laboratory experiences.

By combining animations and visualizing science concepts, simulations can support the development of insight into complex phenomena (Akpan, 2001 [3]). Simulations can be used in class when there is not practical to set up equipment or equipment is not available (Wieman, Adams, Loeblein & Perkins, 2010 [50]). Another application of simulations is for doing experiments in which variables can easily be changed in response to students' questions that would otherwise be impossible to do with real equipment. Before engaging in lab experience with real equipment students can practice laboratory techniques with the help of simulations (Akpan, 2001 [3]).

They can also practice with simulations at home to repeat or extend classroom experiments for additional clarification. The studies that compared the application of simulations with traditional learning seem to indicate that traditional learning can be successfully improved by using simulations. Within traditional instruction, learners can be a useful add-on, for instance serving as pre-laboratory exercise or visualization tools. Chang, Chen, Lin and Sung (2008) [8] proved that there is significantly greater improvement in learning outcomes when simulation method is used for learning in optical lenses concept in comparison with traditionally laboratory practices. The first reason why using simulation is helpful in understanding the complex phenomenon in science. For instance, DNA, molecular structure, atom, or molecule. Hmelo, Holton and Kolodner (2000) [16] suggested that in molecular genetics especially, structures are often the easiest aspect of a complex system to learn; comprehending the structure of molecules such as DNA and RNA is important for understanding their functions. Simulations, can helpful in organizing the small pieces of information into large pieces of information and increasing the logical connections between ideas by reducing the amount of memorization (Tversky, Morrison, Betrancourt, 2002 [46]). Simulation allows learners to view and interact with models of phenomena and processes (Plass et al., 2012 [34]).

The second reason why simulation is helpful in understanding the scientific concepts or scientific phenomena in an everyday life situation. Some scientific phenomena such as cell division in science occur very fast and take place in multiple locations. Simulation can facilitate the understanding of phenomena at the molecular level and develop students' evaluation skills (Sanger, Brecheisen, & Hynek, 2001 [39]). Simulation can allow focusing on specific parts and actions by starting, stopping, and replaying. Simulation is even more likely to be facilitating that allows zooming and control of speed (Tsui & Treagust, 2004 [45]; Tverssky et al., 2002). Simulations may be used to show students scientific phenomena that cannot be observed easily in real time. For example, they can allow students to see things in slow-motion, such as lightning or speeded up, such as earth revolution. They are used to model phenomena that are invisible to the naked eye, such as cell division. Simulation utilizes in situations that require several repetitions of an experiment, for example rolling a ball down a slope while varying mass, the angle of inclination, or the coefficient of friction.

The third reason why simulation helps in better comprehension of concepts because it emphasizes on breadth and depth of science knowledge. Simulations can bridge this breadth and depth of students' knowledge because simulations have the potential to make learning abstract concept more concrete (Ramasundarm, Grunwald, Mangeot, Comerford & Bliss, 2005 [35]). Simulations can make abstract science phenomena more accessible and visible to students. For example, understanding science phenomena such as the circulatory system are difficult for some reasons. It is a complex interactive system that ranges in scale from the heart or blood vessels visible through the skin to blood cells circulating in capillaries much smaller than the human visual range. Simulation teaching has the utmost potential in making abstract scientific concepts, such as circulatory system, more accessible and visible to students. Muller, Sharma and Reimann (2008) [29] explained that simulations allow learners to represent visually and dynamically important concepts that would otherwise be invisible.

The use of simulations in the classroom has a positive finding on conceptual understanding (Ramasundarm et. al., 2005 [35]; Abdullah & Syarif, 2008 [1]; Plass et. al., 2012 [34]; Nowak, Rychwalska, & Borkowski, 2013 [32]; Sarabando, Cravinob, & Soares, 2014 [40]). The use of simulation also helps students to understand difficult science concepts (Plass et al., 2012 [34]; Webb, 2012 [47]; Sarabando et al., 2014 [40]).

Conclusion

Computer simulation plays an indispensable role in the science classroom and instruction. Simulation gives learners opportunity to observe and interact with a real-world experience. Learners can comprehend difficult concepts of science by using simulations. Experiments that are impractical, expensive, impossible, or too dangerous to run can be done by using computer simulations. Simulations can provide tools for scientific inquiry and problem solving. It also contributes to conceptual change and provides open-ended experiences.

Conflict of Interest

There is no conflict of interest between the authors in this manuscript.

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