The Influences of ICT on High School Students' Understanding in Physics Courses: A Review of the Literature

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The Asian Conference on Education & International Development 2016
Official Conference Proceedings

Abstract

This paper focuses on elaborating the influence of ICT on students' understanding in physics courses. The discussion emphasizes deepen understanding on three key issues (1) what the methodologies are used in ICT implementation in classroom, (2) how ICT improves students understanding in physics, and (3) what factors help ICT effective in physics learning. The information was collected through literature associated with ICT and physics learning. Generally, the studies revealed three main methodologies which are mostly implemented to examine the influence of ICT in physics. Furthermore, studies found that ICT is able to change a classroom environment and the need of the collaboration among school administrators, teachers, and policy makers in order to optimize the use of ICT in the learning processes.

Keywords: ICT; students' understanding; physics

Introduction

Physics plays a crucial role for the environment sustainability. It explains the processes of phenomena and the component of materials in the universe (Thiong'O et al., 2013; Smetana & Bell, 2012). However, the number of students who registered in physics courses for upper education is reported decrease across the world. For example, Trumper (2006) argued that students major in science were decrease significantly in senior high school in Israel (p. 49). This phenomenon also happened in England and Wales (Osborne et al., 2003), and Nigeria (Adegoke, 2011). Seeing to this phenomenon, the experts motivated to investigate the reasons why students tend to drop physics in their higher education.

Saleh (2006) stated that many students think physics is the most difficult lesson among other subjects in the school. Physics needs more complexity of study such as memorising, analysing, evaluating, and calculating in solving physics problem. Moreover, some of physics courses seem more abstract because their physics phenomena are invisible and hard to be imagined by students. Students are more interested in physics when they find those physics phenomena relevant to their life (Adams et al., 2006; Trumper, 2006). This kind of complicated study makes most of students achieve low score and do poor performance in classroom. Students believe that physics deals with higher risk to get failure in their study. Therefore, avoiding physics is a step to avoid failure.

Another reason is a`poor teaching method (Adegoke, 2011). Many teachers, especially in developing countries, transfer physics courses using conventional instruction. Presenting the complicated and abstract materials based on the passages in the textbook does not seem effective to address them to the students (Jimoyiannis & Komis, 2001). An additional, this method is a teacher-centered classroom and it makes students perceive that learning physics is a textbook-based learning since it is like to reread materials or transmitted by teachers (Siorenta &Jimoyiannis, 2008). Therefore, many research were conducted to find new teaching methodologies which can draw students' interests in physics and improve students' understanding both of verbal and nonverbal abilities.

Paper Focus

In this modernisation era, both of teachers and students have been familiar with technology in their daily life. To introduce Information and Communication Technology (ICT) in the classroom, many researchers constructed their research by involving ICT in teaching physics courses. The results showed that ICT gives positive influences for senior high school students' understanding in physics courses. In this paper, I focus on the involvement of ICT in physics courses to prove that ICT can help physics teachers transferring the materials easier without reducing their meaning. Therefore, this paper concerns on the discussion of three stuctured questions which broaden the description about how ICT influences high school students' understanding in learning physics. They are:

1. What methods are used in implementation of ICT in physics learning?
2. How does ICT improve students understanding in physics?
3. What factors help ICT effective in physics learning?

The discussion begins with the methodology, followed by the discussion about three structured questions, and then closed by conclusion.

Methodology in selecting references

All further analysed references were collecting through ERIC and Monash Google Scholar. The chosen references were searched using four key words relate to the research; ICT, physics, students, understanding. In this paper, ICT stands for every form of ICT from the simple one to the sophisticated one, such as PowerPoint to the certain software related physics concept. Moreover, students' understanding embraces both of students' performance and students' achievement.

Discussion

1. What methods are used in the implementation of ICT in physics learning?

Numerous research were conducted to examine the influences of ICT in physics courses. Researchers used a variety of methodologies when applied ICT in their investigation to make them easier to analyse the influences of ICT. I classify those methodologies into three categories:

1.1 ICT vs traditional instruction

The studies compared two or more groups to see the differences between students who were taught using ICT (experiment group) and those who were taught using traditional instruction (control group). In this method, ICT has role as a teaching methodology because it dominates the learning processes. ICT plays as the core of information while teachers supervise the learning processes. It shows the materials, illustrates the phenomena and demonstrates the procedure of activities. Students observe the visualization and gain information through ICT. Meanwhile, teachers control the condition of class environment and add the needed information or the unclear information.

Studies, which used this method, usually utilize sophisticated forms of ICT such as a certain software which is intentionally invented to facilitate physics learning processes. There are several studies focusing on this methodology; (1) Ajredini et al., (2013) investigated the effectiveness of Phet Simulation on students' understanding in electrostatic charging. The participants were divided into experimental (implemented ICT) and control group (implemented real experiment). The results showed that there is no significant differences between ICT class and real experiment class; (2) Thiong'o et al., (2013) investigated the differences of depth understanding in magnetism effect of electric current between class which was facilitated by computer-based simulation module and control class; (3) Kiboss and Ogunniyi (2005) applied computer-augment physics (CAP) module to investigate students' understanding in measurement concept; (4) Kiboss (2002) used computer-based physics instruction (CBPI) program to improve measurement concept; (5) Kiboss (2011) developed electronic learning environment program (ELEP) contains basic lessons of instrument concept which were presented on the computer.

1.2 ICT + Regular teaching method

ICT is instrument of teaching methods. Many studies investigated how ICT supports the teaching processes by combining ICT and regular teaching methods. In these cases, teachers give the information of materials dominantly and lead the learning processes. They use ICT as a complement of teaching to support their teaching activities. ICT is used to provide an additional information or to help them demonstrate how to operate physics instruments and describe the steps of physics processes.

Zacharia has conducted a series of investigation regarding of the effectiveness of real experiment (RE) and virtual experiment (VE) (Zacharia & Anderson, 2003; Zacharia, 2005, 2007). Zacharia (2007) conducted experiments which compared RE and VE to examine which one is better for developing students understanding. Furthermore, Zacharia combined both of experiments to see the different effects of using ICT alone or combined ICT and regular instruction. The results show that the simulation can promote students' scientific conception either alone or in combination with real experiment. However, the combination of both real and virtual experiment showed the best results of students' understanding. Therefore, Zacharia believed that the best method to promote students' understanding in physics is when ICT supports the real experiment. In addition, Borghi et al., (1987) emphasized that the proper balance of simulation and real experiment activities in delivering physics concept will help students engage with physics theories and reality.

1.3 Ranking of ICT

There are numerous kinds of ICT used in education. The experts had constructed research to investigate the most effective implementation of ICT in learning system. For example, Adegoke (2011) compared three kind of multimedia; combination of on-screen text + animation, animation + narration, and on-screen text + animation + narration. This study found that the best performance was students in animation + on-screen text + narration class by obtaining the highest mean score. In addition, this result was also supported by the evidence that students in this class took the best quality of notes. Taking notes is important for learners to remember information about materials. The researcher suggested that the combination of on-screen text + narration + animation enables students to catch the missing information of teachers' explanation through both on-screen text and narration.

2. How does ICT improve students understanding in physics?

According to the evidences, ICT enhances students' understanding in physics in several ways:

2.1 Bring abstract phenomena, high-cost apparatus and hazardous activities into classroom

Simulations are effective to develop knowledge about abstract physics concepts because simulations provide those concepts become more visible and concrete experiences (Zacharia & Anderson, 2003; Zacharia, 2007). Students use to imagined those abstract phenomena in physics and it complicated them to understand the materials. They only relied on the teachers' explanation and textbook, though textbooks usually make them confuse of its limited explanation and drive students' misconception on physics concepts. The existence of illustration of those physics materials helps both teachers and students in learning processes; it helps teachers to explain and demonstrate the materials easier and enables students to watch those phenomena as the real one. Therefore, computer simulation seems able to bridge the gap between students' pre-conception (imagination) with teachers' explanation. Thereby, computer simulation helps students achieve conceptual change and deepen understanding in physics (Jimoyiannis & Komis, 2001; Thiong'o et al., 2013; Smentana & Bell 2012). Furthermore, ICT enables high school students observe the hazardous activities and expensive apparatuses in physics experiment because ICT can manipulate the dangerous physics processes and high-cost apparatus into classroom hence students are able to see them in the more real ways.

2.2 Encourage students use complexity learning activities

Computer simulation brings multi learning sensor in their implementation. ICT enables students learn through their visual and auditory. Although recently textbooks have been more attractive to draw students' interest to read textbooks, the combination of visual and verbal learning are more effective than ranges of passages in textbooks in helping students' understanding physics concept (Stelzer et al., 2009; Adegoke, 2011). A finding of research showed that the best kind of ICT to implement in physics courses is the combination of on-screen text, animation and narration (Adegoke, 2011). The reason is that students use both of their visual and auditory ability to get the information. Through their visual, they get information from text and animation, while their auditory acquires the narration. In addition, they can catch up the missing information on on-screen text through narration, or vise versa.

The computer simulation encourages students use complexity learning activities. The use of computer simulation in learning activities helps students promote their scientific skills development because the computer simulation facilitates learning by linking learners to information sources and virtual learning tools. Therefore, the involvement of the computer simulation in classroom environment increases students' abilities in visualisation, critical thinking, classification, identification, data interpretation, problem solving and practice skills (Smetana & Bell, 2012; Zacharia, 2003).

2.3 Create students-centered classroom

ICT can change the condition and situation in classrooms. It seems that using ICT in classroom changes the ways of teachers deliver the materials (Achimugu et al, 2010). Comparing to traditional environment classes, ICT helps teachers to more concern on monitoring during learning processes rather than instructing (Chandra et al, 2008). It will surely help teachers embrace whole students in strict time rather than use the laboratory work and approach students one by one to explain how to operate those instruments.

ICT enhances students' understanding both verbally and nonverbally. Students do not only gain better score in physics tests but also be able to explain the reasons behind their answers. The implementation of ICT in learning processes enhances students' ability to communicate scientifically regarding the physics phenomena. This was found by Kiboss (2000) how CBI (computer-based instruction) influences senior secondary school students in Kenya towards the understanding of physics concept especially in measurement courses. The findings showed that pupils were more active in asking questions about unclear materials, discussing with peers, and transferring their opinions in CBI class than those who are in the conventional class.

Moreover, the using of ICT enriches the classroom environment because it relates to learning variables such as teachers, pupils, and instructional (Kiboss, 2002). The researchers suggested that ICT provides information which makes students less rely on their teachers (Kiboss, 2011). It makes students more actively look for the information in order to solve the problems and/or asked to their teachers to get further explanation.

2.4 Draw students' interest

The implementation of ICT in physics learning provides an enjoyable simulation yet educational (Kiboss & Ogunniyi, 2005; Smetana & Bell, 2012). Visualization of physics phenomena raises students' interest in studying physics. Comparing with listening to teachers' talk and textbook passages, the unfamiliar and interest simulation more encourage the curiosity of students so that they will give more attention to the simulation. The more students are interested in physics the more they engage with physics, because students tend to learn what they are interested in (Chandra et al., 2008; Smentana & Bell, 2012). The heighten engagement will increase students' attention in learning processes and enhance students' understanding as well.

2.5 Give quick feedback

Previous studies found that ICT promotes conceptual change. One of the reasons is that ICT provides automatic error steps. Automatic error steps is a multimedia program which gives the automatically feedback if students make the wrong steps during experiment. One of experiments used this program was conducted by Zacharia (2007) who combined VE (virtual experiment and RE (real experiment) on the electric current concept. This program enables students to reflect their wrong step or misunderstanding because students get feedback immediately. Through this program, students will be able to construct their own understanding on a certain physics process, since they can analyze the causes of the mistake and repeat the steps until they get the right one.

3. What factors help ICT effective in physics learning?

Physics is a sophisticated subject so that complex learning skills are needed to master it. Students should be trained to engage with complexity studies in terms of research approach, critical thinking, collaboration, making decision and conclusion (Ajredini et al., 2013). To achieve the goals of education, all educational stakeholders need to cooperate because the quality of education cannot be relied only on teachers. This part will describe several factors which are important to be considered in order to optimize the benefit of ICT.

3.1 Students' own motivation

Visualization of ICT indeed draws students' attention to learn but it does not derive students' motivation as well. Motivation, as the crucial role in term of learning, is the main factor to begin the phase of learning. It is true that the essence of teachers' role and curriculum management is important, but the fully comprehension of students in learning is depended on the willingness of students themselves to make it happen (Hopkins et al., 2011). Therefore, students' motivation to learn physics is a must to help them immerse during physics learning. Here is a study examined how motivation is a key to achieve success in learning.

Gynnild et al. (2007) measured how extent the use of visualization deepen students' conceptual understanding related to their daily experiences. They predicted that each student has their own pre-conception based on their life experiences. By dividing the participants into small groups, they expected that the students would work cooperatively through the visualization instruction, and then they discuss the situation with their peers even try to understand it. Consequently, it can change or enrich their pre-conception. The results showed that although all students received the implementation of visualization and fostered their interest in learning physics, however there was no significant increase toward students' understanding in physics courses. They said that the fully conception understanding can only be gained for those who commit to deep learning. It shows that students' personal desire on physics more encourages them to consider visualization as their facilitator in reaching their goals, understanding physics.

3.2 Create supported classroom situation

Ajredini et al. (2013) compared the advantages and disadvantages of real experiment and virtual experiment. Findings showed that students in the real experiment class engaged with the real apparatuses and were more capable in procedural skills. However, the real experiment is time-consuming activities because they have to prepare the laboratory needs and usually confront with technical problems during experiment. On the other hand, students in virtual experiment did not need to spend time for organizing activities related to laboratory work, hence they could use much more time for thinking the topics and discussing them with their group members. However, they were lack of procedural skills. Similar findings were found by Stamenkovski and Zajkov (2014). They suggested that these results were caused by two main reasons; shortage of time for real experiment class and number of students per group. They added proper number of group members is essential for a meaning discussion.

ICT will optimize in supporting classroom learning if it is prepared well. As the guide of learning, teachers should highly consider about the time proportion of ICT implementation, problem solving and discussion so that they are not running out of time. In addition, in creating classroom activities, teachers need to reflect on the number of students in the classroom, what activities will be held, and which concepts should be mastered. Thus, I believe that teachers need to more consider about an appropriate learning plan which engages with the time and proper group number for discussion. In addition, teachers ensure the heterogeneity of each group regarding skills, abilities, and existing knowledge, to maximize students' participation in learning.

3.3 Improve teachers' awareness on ICT

Both of teachers and ICT are complementary in learning activities. However, many teachers still do not apply ICT in their classroom. Two main reasons are; firstly, ICT consumes much time in preparation (Mumtaz, 2000); and secondly, they are not familiar with ICT. Regarding teachers' belief on time consuming of ICT seems contrary to the studies of Jimoyiannis and Komis (2001) and Ajredini et al. (2013) which found that the computer simulation saves a lot of the learning time because it is able to bring time-consuming activities into classroom such as laboratory work. It shows that the wasting time of ICT preparation in learning emerges because teachers are not used to operate ICT in their learning activities.

The diffusion of ICT implementation in education does not spread evenly on the world. It rarely finds schools with integrated computer availability in rural area, especially in developing country. Operating ICT is a difficult thing for teachers, implementing it in their teaching activities is even worse. Yet, the needs of master in ICT are inevitable because of the globalisation and technology advancement. Globalisation encourages teachers to give their best teaching performance in order to make their students can compete globally. Moreover, technology advancement makes most students have been familiar with technology so they will adapt easier with ICT involvement in education. Therefore, teacher's training development is needed to help teacher enhance their teaching performance and engage with both ICT and classroom situation (Smentana & Bell, 2012).

3.4 Integrate with proper curriculum

Visualization has two sides of coin. On the one side, it does attract students' attention in learning and help demonstrating abstract physics phenomena and complex physics processes. On the other side, it does disturb students' concentration. A simulation with interesting features grows students' interest, but it may make students focus only on the feature's point not the purpose of the simulation. To minimize it, teachers need to consider the content of virtual materials. The content must be relevant to the concept that wants to be mastered and be able to support teachers' explanation. The combination of teachers' explanation and virtual explanation will deepen the engagement of students in learning.

However, as a noted earlier, improving education quality is not only teachers' responsibility. It needs the cooperation among government, educators, and education policy makers. Henceforth, the supports from government and education policy maker are needed to create the preparation programs which help teachers arise their awareness of technology advanced and globalisation. The programs can be training programs, include how to operate computer or laptop in the classroom, what the contents should be provided in the simulation, and how to link between the simulation and oral explanation, and between visualization and their existing knowledge. It will surely help teachers increase their confidence regarding ICT operation and the capability in teaching activities since ICT will only maximize its potential in helping learning processes when it properly integrates with essential physics curriculum and class situation (Zacharia & Anderson, 2003).

Conclusion

Numerous studies with varied purposes and methods had been conducted to measure the effectiveness of ICT in physics learning. They compared ICT with traditional instruction to examine how significant ICT improves students' understanding in physics; combined ICT and regular teaching method to elaborate how ICT supports conventional instruction in teaching physics; and ranked types of ICT to measure which ICT performs the best performance in developing students' understanding in physics. From these studies, I believe that there are two main roles of ICT in learning process; ICT as a teaching methodology and ICT as a complement teaching. As a teaching methodology, ICT is a core of teaching processes. It plays a fundamental role in display both of the materials and the explanation, while teachers monitor and mentor the learning processes. Meanwhile, ICT as a complement teaching is considered as a tool or instrument of teaching. Teachers are the main actors of teaching while ICT only supports their activities. Teachers manage the materials and the classrooms along with observe the processes of learning. Furthermore, teachers give feedback for students' questions about unclear materials. The evidences show that ICT is better implemented as a complement in teaching activities rather than as teaching methodology.

According to evidences, findings and explanations above, it seems that the use of information and communication technology (ICT) improves the conceptual understanding in physics courses. The reasons are; ICT enables to bring visible and real phenomena of abstract phenomena in classroom; ICT is designed entertaining yet educational so that enhance students' interest; and ICT changes teaching methodology into student-centered classroom. ICT provides meaningful learning experiences and enhances peers interaction (Thiong'o et al, 2013).

ICT classes outperform conventional classes because ICT brings multi learning sensor in their implementation. ICT enables students to learn through their visual and auditory (Stelzer et al, 2008; Adegoke, 2011. p.547). Furthermore, ICT uses a range of learning skills such as visualisation, manipulation, classification, identification, data interpretation, problem solving and practice skills which improves their quality of learning and thinking (Smetana & Bell, 2012). ICT not only enrich students' knowledge about physics but also can apply them to solve the physics problems and to communicate the results as well.

Acknowledgement

I would like to show my gratitude to Indonesia Endowment Fund for Education (lpdp) for supporting my expenses for a conference.

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