The effects of 3D computer simulation on biology students' achievement and memory retention

***Tavasuria ELANGOVAN[1], Zurida ISMAIL[2]**

[1]Faculty of Applied Sciences, Universiti Teknologi MARA (Perak) Kampus Tapah, 35400

Tapah Road, Perak, MALAYSIA

[2]School of Educational Studies, Universiti Sains Malaysia, 11800 Penang, MALAYSIA

E-mail: tavasuria@perak.uitm.edu.my, tavasuria@yahoo.com

Received 8 Nov., 2013
Revised 18 Dec., 2014

Contents

Abstract

A quasi experimental study was conducted for six weeks to determine the effectiveness of two different 3D computer simulation based teaching methods, that is, realistic simulation and non-realistic simulation on Form Four Biology students' achievement and memory retention in Perak, Malaysia. A sample of 136 Form Four Biology students in Perak, Malaysia were involved in this study. Students from two Form Four Biology classes were randomly selected for this study. One class was randomly assigned as the treatment group (68 students) while the second Biology class was the control group (68 students). Pre-test was given to all students before they underwent the teaching and learning process for the topic on Cell Division. The students in the treatment group were taught Cell Division using realistic simulation while the control group students learnt using non-realistic simulation for three weeks. All students were given post achievement test during the third week after they have learnt the Cell Division topic. Post memory retention test was given to all students on the sixth week that is three weeks after the post achievement test. Data of the present study was collected and analyzed using descriptive statistics and inferential statistics such as paired samples t-test and one way ANCOVA. The results show that realistic simulation is a more effective 3D computer simulation based teaching method than the non-realistic simulation and it improves Biology students' achievement and memory retention.

Keywords: 3D Computer Simulation, Realistic Simulation, Non-Realistic Simulation, Biology, Cell Division, Form Four Students, Malaysia

Introduction

Biology is a program offered for two years to Malaysian secondary school students in years four (Form Four) and five (Form Five). The concepts included in Biology generally are abstract and students failed to understand the concepts. Cell Division is one of the most problematic and difficult concepts that students need to learn (Atilboz, 2004; Kablan, 2004; Knippels, Waarlo, & Boersma, 2005; Lazarowitz & Lieb, 2006; Saka et al., 2006; Baser, 2007; Kara & Yesilyurt, 2008; She & Chen, 2009; Murniza Muhamad, Halimah Badioze Zaman & Azlina Ahmad, 2010). Questions on Cell Cycle, Mitosis and Meiosis concepts in Cell Division are very

popular and asked every year in the Malaysian Certificate of Education examination (*SPM*) for Biology subject (Jabatan Pelajaran Negeri Perak, 2012).

Analysis of the *SPM* Biology paper from the years 2007 until 2011 showed that students have yet to master the concepts on Cell Division well because they are unable to understand the Cell Division topic clearly and have misconceptions about the main concepts of Cell division topic such as mitosis and meiosis (Atilboz, 2004; Kablan, 2004; Knippels, Waarlo & Boersma, 2005; Aziz Nordin & Ami Norliyana Shamsu Kamar, 2011; Chattopadhyay, 2012; Ozcan, Yildirim & Ozgur, 2012). These learning problems in Cell Division arise from improper teaching and learning (Wekesa, 2003) method that emphasized mainly on teacher centered learning (Kiboss, 2002) and encourage rote learning among students (Ozcan, Yildirim & Ozgur, 2012). Students' roles become very less in teacher centered learning method. Therefore, the Ministry of Education (2006) suggested that teaching and learning strategies in Biology curriculum should emphasize learning that stimulates and enhance students' ability in thinking. There are various learning strategies that stimulate thinking ability among students such as inquiry, constructivism, contextual learning, mastery learning, experiments, discussions, simulations, projects and visits (Ministry of Education Malaysia, 2006).

Computer simulation is one of the effective teaching methods and has positive impacts in teaching science subjects (Wellington, 2004). Otero (2001) and Olele (2008) reported that most of the research findings showed a positive impact on computer simulation based teaching and learning method. This is because of its features that consist of movement and color which bring real learning environment into Biology classroom. Computer simulation is ICT based teaching and learning methods (Clark, Nelson, Sengupta, & D'Angelo, 2009).

Simulation help students to learn and understand Cell Division process through visualization. Students build their own mental model based on the observation to be recorded in the form of schemas in their long term memory (Ali & Zamzuri, 2007). Recorded visual form information is retained in the memory structure for a longer period. Otero (2001), Lindgren and Schwartz (2009) emphasized that the visual forms of learning encourage students to develop an understanding of learnt concepts and support their memory retention which improve their achievement (Kiboss, Ndirangu, & Wekesa, 2004). Students' achievement in Biology depends on students' level of understandings and memory retention. Students' understandings and memory retention depend on the teaching and learning strategy.

Hence, the effectiveness of selected teaching and learning method will be determined by the students' achievement in Biology subject.

Therefore, this study was conducted to identify the effectiveness of two different forms of three dimensional (3D) computer simulations, that are, realistic simulation and non-realistic simulation on Form Four Biology students from Perak, Malaysia. There are various terms used by researchers to refer to the 3D multimedia simulation and virtual reality simulation in their studies. 3D multimedia simulation is known as computer based instruction simulation program (Kiboss, Wekesa & Ndirangu's, 2006). Similarly, virtual reality simulation is also known as educational virtual environment (Mikropoulos, Katsikis, Nikolou & Tsakalis, 2003), virtual reality technology (Shim, Park, Kim, Kim, Park & Ryu, 2003), inquiry based simulated labs called 'OsmoBeaker' (Meir, Perry, Stal, Maruca & Klopfer, 2005), virtual learning environment, VLE (Pan, Cheok, Yang, Zhu, & Shi, 2006) and technology-enhanced curriculum module called Global Warming: Virtual Earth (Varma & Linn, 2012). However, in this study, realistic simulation refers to a 3D multimedia simulation while non-realistic simulation refers to a desktop virtual reality simulation.

Although both realistic and non-realistic simulations are 3D simulation, they differ from desktop virtual reality simulation. 3D multimedia simulation consists of multimedia elements such as illustrations, static pictures, graphics, animation, simulation, photos or video, text on the computer screen and narration (Mayer, 2001). Realistic simulation brings actual learning environment that is more toward realistic learning environment (Laurillard, 2002). Akpan (2002) said that students' motivation level increase when they receive lesson content in a realistic learning environment. In contrast, desktop virtual reality simulation is semi-immersive and less interactive than the virtual reality simulation (Shin, 2002) and does not create realistic learning environment (Mikropoulos, Katsikis, Nikolou & Tsakalis, 2003). Virtual reality simulation creates immersive and interactive learning environment (Burdea, 1999; Winn & Windschitl, 2000; Pan et al., 2006; Jimoyiannis, 2011). Both desktop virtual reality and virtual reality use different scenarios (Shim et al., 2003). Desktop virtual reality allows users to interact with virtual environment using keyboard, joystick and touch screen (Chen & Teh, 2000; Zhang & Yang, 2009) which need to be run and play in the computer desktop. Meanwhile, virtual reality simulation shows real user images on the computer screen and also allows users to see their own image on the computer screen. Users need to use head-mounted display when they use virtual reality simulation whereas in a desktop

virtual reality environment, users need to use the CRT monitors or computer monitor (Shim et al., 2003).

Studies have shown that both realistic and non-realistic simulations have positive effects in learning Biology. Several research findings showed that the realistic simulation increase students' understandings and achievement (Kiboss, Wekesa & Ndirangu, 2006) whereas non-realistic simulations enhance students' understandings, reduce their misconceptions about learned Biology concepts (Meir, Perry, Stal, Maruca, & Klopfer, 2005) and improve students' performance and their achievement (Varma & Linn, 2012).

Students' learning problem in biology subject

Studies have shown that students have poor understandings and misconceptions about the Cell Division process (Lewis, Leach & Wood-Robinson, 2000a; Atilboz, 2004; Knippels, Waarlo & Boersma, 2005; She & Chen, 2009; Aziz & Ami Norliyana, 2011; Chattopadhyay, 2012; Ozcan, Yildirim & Ozgur, 2012) due to the use of traditional teaching and learning methods that require memorization of learned concepts (Ozcan, Yildirim & Ozgur, 2012). Yenilmez and Tekkaya (2006) said that students' misconceptions cannot be reduced if teachers use traditional teaching methods alone and it will affect the students' Biology achievement. Students' misconceptions can be reduced or avoided through the interactive based teaching and learning method that uses educational software programs (Karamusta-faog ˘ lu, Sevim, Mustafaog ˘ lu & C¸epni, 2003).

Purpose and research questions of the study

The purpose of this study was to determine the effectiveness of realistic simulation and non-realistic simulation on Form Four Biology students' achievement before and after the teaching and learning process and their memory retention for Cell Division topic. The study aimed to answer the following research questions:

1. Is there any difference in treatment group students' achievement between the pre-test and post achievement test after learning Cell Division topic with realistic simulation?

2. Is there any difference between the pre-test and post achievement test scores of the control group students after learning Cell Division topic with non-realistic simulation?
3. Are there any differences in the post achievement test scores between the treatment group students who learnt with realistic simulation and control group students who learnt with non-realistic simulation?
4. Is there any difference in the memory retention between treatment group students and control group students for Cell Division topic?

Methodology

Research sample

A sample of 136 Form Four Biology students were divided into two groups: experimental/treatment group (68 students) and the control group (68 students). Two Form four Biology classes were randomly selected from two different secondary schools of Perak, Malaysia. Two Biology classes from the first school were assigned as treatment group while the other two Biology classes from the second school were assigned the control group.

Teaching and learning in experimental and control groups

The control group was taught Cell Division topic using non-realistic simulation while the treatment group was taught using realistic simulation for three weeks. Realistic simulation (3D multimedia simulation) and non-realistic simulation (3D desktop virtual reality simulation) were chosen from existing and freely accessible computer simulation software from the website. Both realistic and non-realistic simulations consisted of four main concepts on Cell Division: Cell Cycle, Mitosis, Meiosis I and Meiosis II. Snapshots of realistic simulation and non-realistic simulations are shown in Figure 1:

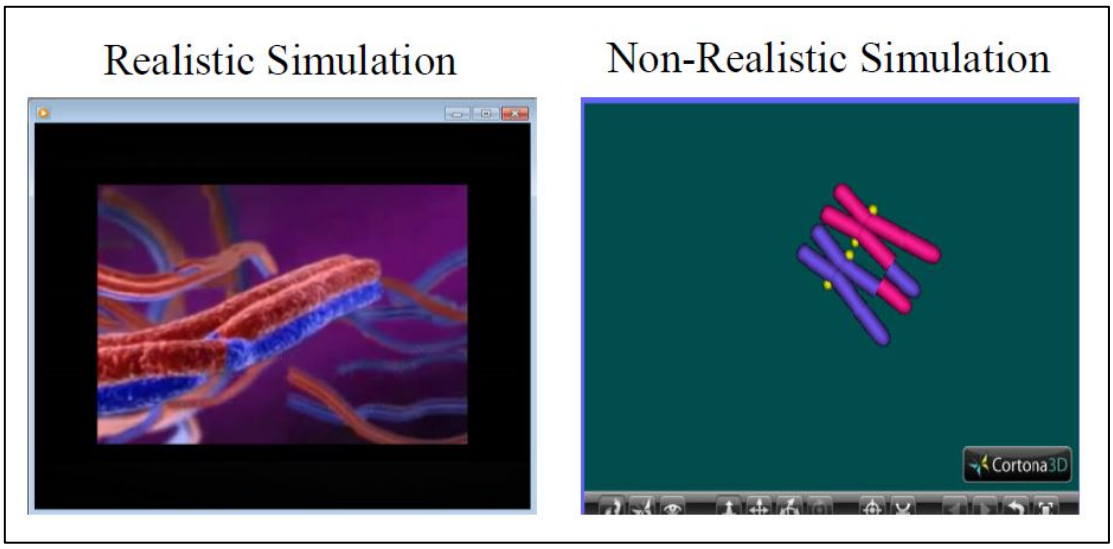

Figure 1. Snapshot of realistic and non-realistic simulation for meiosis concept.

The pre-test was given to students of both control and treatment groups before they were taught the topic of Cell Division with realistic simulation and non-realistic simulation. The post achievement test was given immediately to both control group and treatment group students on the third week after they finished three weeks of learning using realistic simulation and non-realistic simulations. Post memory retention test was given on the sixth week, that is, three weeks later after the post achievement test. The framework of teaching and learning process involved in this study is summarized in Figure 2:

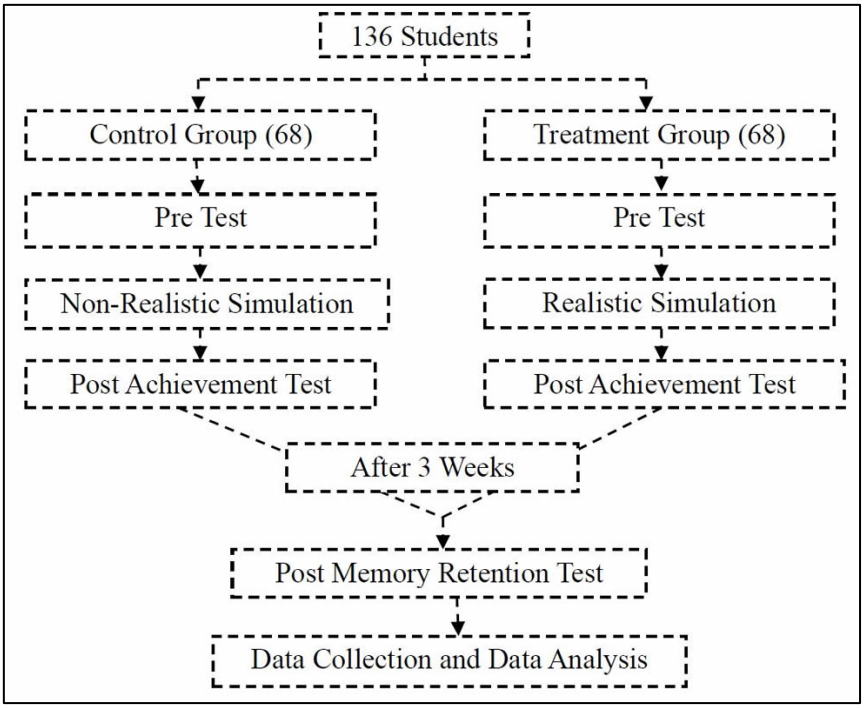

Figure 2. The framework of teaching and learning process.

Research instruments

Measurement was carried out through a set of pre-test and post-test (post achievement test and post memory retention test). Both pre-test and post-test consisted of 18 objective questions regarding Cell Division based on the Form Four Biology Syllabus. Both pre-test and post memory retention test were validated by experienced Biology teachers and modified based on the comments and suggestions given.

Pilot study

A pilot study was conducted to determine the validity and reliability of the research instruments (post achievement test and post memory retention questions). Both post achievement test and post memory retention test were administered to 61 Form Four Biology students who were not involved in the research. The students were given 20 minutes to complete each test. The post achievement test was given on day one while the post memory retention test was given on the following day.

Reliability is defined as the consistency of the measurement (Hartas, 2010). The reliability of the post achievement test and post memory retention test was determined using the Kuder-Richardson Formula 20 (K-R 20) method. The index of discrimination (ID) and the difficulty index (CI) were also determined for both the post achievement test and post memory retention test. Analysis of the pilot study showed that the post achievement test yielded a reliability coefficient of 0.57 while the post memory retention test yielded a reliability coefficient of 0.65. This result shows that the post memory retention test is reliable and accepted. The reliability coefficient of the post achievement test, 0.57 is lesser than the suggested cutoff value of 0.60. However, the post achievement test is still valid, reliable and acceptable since the value obtained was close to the suggested reliability coefficient of 0.60 (Gliner & Morgan, 2000; Lyles, 2008; Menard, 2008).

Study design

This study was a quasi-experimental study using a quantitative approach and involves measurement and variables such as the dependent and independent variable. The dependent variable for this study is the Biology students' achievement and memory retention while, the independent variable is the 3D computer simulation based teaching and learning method (realistic simulation and

non-realistic simulation). Measurement is carried out through a set research instruments.

Data analysis

Descriptive statistics and inferential statistics such as paired samples t-test and one way ANCOVA were used to analyzed the data in this study. The significance level was set at the suggested $p < 0.05$ for inferential statistics such as paired samples t-test and one way ANCOVA. Results obtained are reliable by 95% if the p value is less than .05. Table I shows the type of analysis that was used to answer each research questions in this study.

Table I. Summary of scientific methods used for analysis

No	Research Questions	Scientific Methods
1	Is there any difference in treatment group students' achievement between the pre-test and post achievement test after learning Cell Division topic with realistic simulation?	Paired Samples t-test
2	Is there any difference between the pre-test and post achievement test scores of the control group students after learning Cell Division topic with non-realistic simulation?	Paired Samples t-test
3	Are there any differences in the post achievement test scores between the treatment group students who learnt with realistic simulation and control group students who learnt with non-realistic simulation?	One Way ANCOVA
4	Is there any difference in the memory retention between treatment group students and control group students for Cell Division topic?	One Way ANCOVA

Preliminary check such as normality of the distribution of data in each scale have been checked to ensure that the basic assumptions for parametric tests such as paired samples t-test and one way ANCOVA method were not violated. The basic assumptions of one way ANCOVA method such as the linearity, homogeneity of regression slopes and homogeneity of variances were also checked before running the one way ANCOVA analysis. Pre-test and post-test (post achievement test and post memory retention test) data were analyzed using SPSS 16.0 software.

Results

Findings of this study were presented based on the analysis using descriptive statistics and inferential statistics such as paired samples t-test and one way ANCOVA for each research question:

Research Question 1: Is there any difference in treatment group students' achievement between the pre-test and post achievement test after learning Cell Division topic with realistic simulation?

Paired sample t-test was used to answer the first research question. Results of the paired sample t-test showed that there was a significant difference in treatment group students' achievement between the pre-test and post achievement test. Table II shows the results of paired sample t-test for treatment group students taught with realistic simulation.

Table II. Results of paired samples t-test for treatment group

		n	M	SD	t	df	*Sig. (2-tailed)
Realistic Simulation	**Pre test**	68	9.32	1.86	-19.74	67	.000
	Post achievement test	68	12.60	1.90			

Table II shows that the treatment group students who learnt with realistic simulation had significantly higher mean scores in the post achievement test (M = 12.60, SD = 1.89) than the pre-test scores (M = 9:32, SD = 1.86), t(67) = -19.74; p <.001 (two-tailed). Figure 3 also showed the results of descriptive statistics for the treatment group students who learnt Cell Division topic with realistic simulation. The descriptive statistic results showed that the mean scores of the treatment group students have increased by 3.28 in the post achievement test as compared to the pre-test. The mean score differences between the pre-test and the post achievement test of treatment group students is presented in the Figure 3. Both descriptive and inferential statistics results show that the realistic simulation had improved the students' understanding, performance and their achievement in Biology.

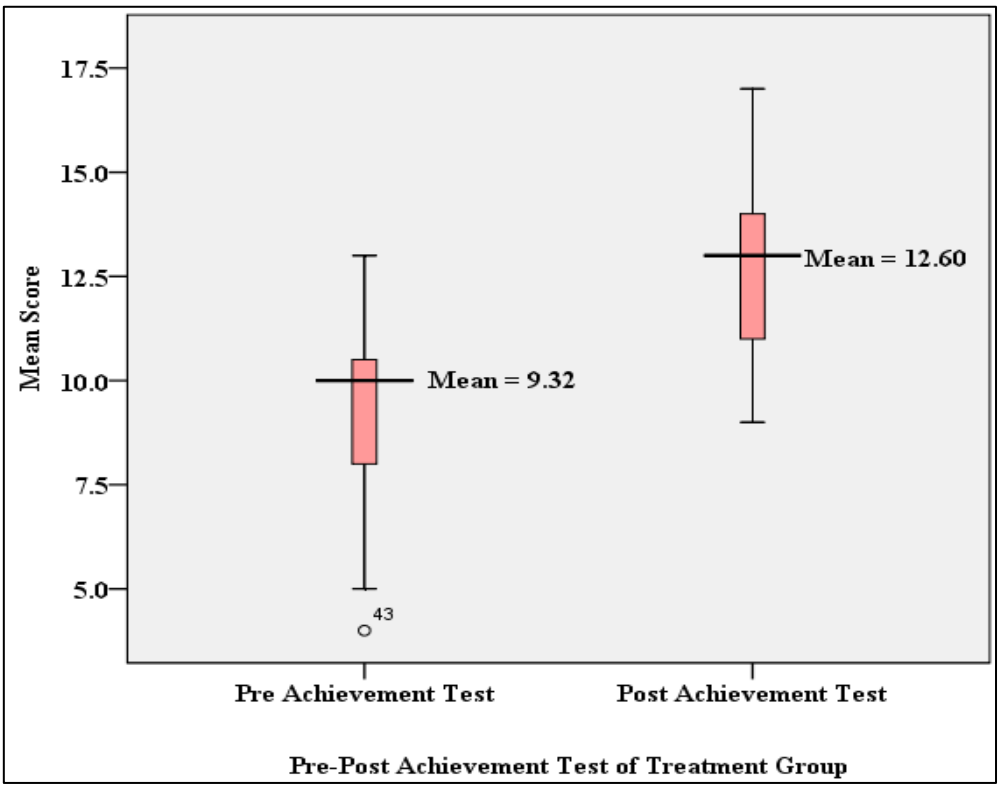

Figure 3. Difference in treatment group students' achievement between pre test and post achievement test.

Research Question 2: Is there any difference between the pre-test and post achievement test scores of the control group students after learning Cell Division topic with non-realistic simulation?

Inferential statistics such as paired samples t-test was used to test the second research question. Results of the paired sample t-test showed that there was a significant difference in the control group students' achievement for Cell Division topic between the pre-test and post achievement test. Results of the paired sample t-test for the group of students who learnt with non-realistic simulation is presented in Table III.

Table III. Results of paired samples t-test for control group

		n	M	SD	t	df	*Sig. (2-tailed)
Non-Realistic Simulation	**Pre test**	68	8.09	1.92	-12.65	67	.00
	Post achievement test	68	10.79	1.85			

Table III shows that the control group students who learnt Cell Division topic using non-realistic simulation had significantly higher mean scores in the post achievement test (M = 10.79, SD = 1.85) than the pre-test (M = 8.09, SD = 1.92), t(67) = -12.15; p < .001 (two-tailed). The descriptive statistics also showed that the control group students' mean scores have increased by 2.70 in the post achievement test as compared to the pre-test. Mean scores differences between pre test and post achievement test of control group is presented in Figure 4. Both descriptive statistics and inferential statistics results indicate that non-realistic simulation based teaching method had improved students' understanding, performance and their achievement.

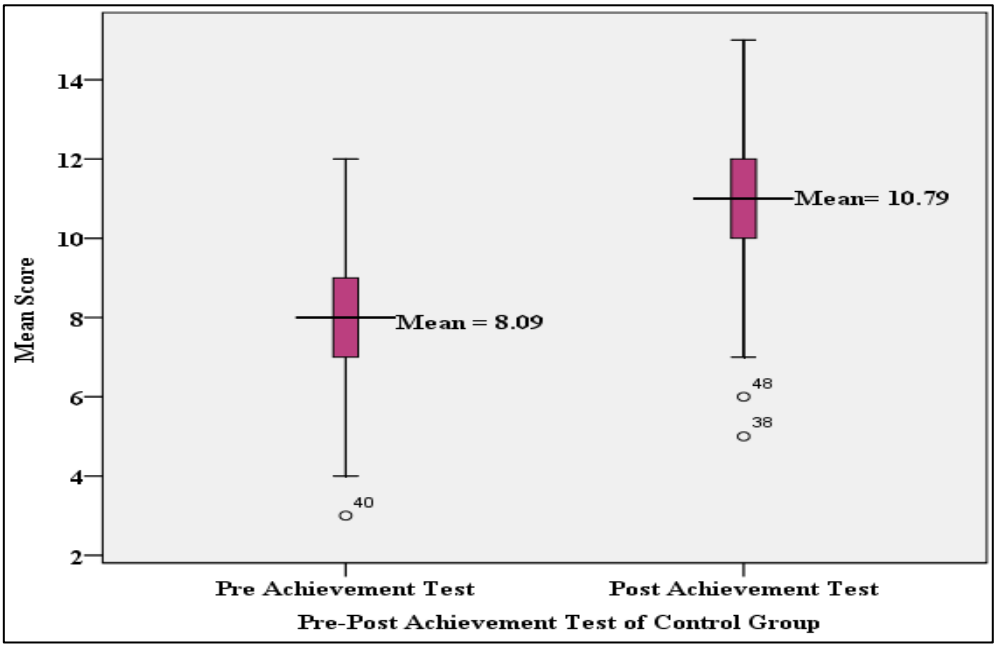

Figure 4. Difference in control group students' achievement between pre achievement test and post achievement test.

Research Question 3: Are there any differences in the post achievement test scores between the treatment group students who learnt with realistic simulation and control group students who learnt with non-realistic simulation?

The third research question was analyzed with inferential statistics such as one way analysis of covariance (ANCOVA). One way ANCOVA method was used to compare the effectiveness of realistic simulations with non-realistic simulations on students' post achievement test scores. Basic assumptions underlying one way ANCOVA such as homogeneity of variances, homogeneity of regression slopes

and linearity were checked before running the main analysis of one way ANCOVA. Findings of preliminary analyses showed that these basic assumptions for analysis of covariance (ANCOVA) are not violated and can therefore proceed with ANCOVA analysis.

The pre-test was used as a covariate to control the effects of covariate (pre-test) on the dependent variable (students' post achievement scores). The results of the main analysis (test between subject effects on students' post achievement scores) are shown in Table IV after controlling the effects of covariates (pre-test scores).

Table IV. Tests of between-subjects effects for dependent variable: post achievement test scores

Source	Type III sum of squares	*df*	Mean square	F	Sig.
Corrected model	296.851a	2	148.426	69.561	.000
Intercept	237.534	1	237.534	111.323	.000
Pre test (Covariate)	185.609	1	185.609	86.987	.000
Groups	33.134	1	33.134	15.529	.000
Error	283.788	133	2.134		
Total	19193.000	136			
Corrected total	580.640	135			
a. R squared = .511 (Adjusted R squared = .504)					

The results (F(1, 133) = 15.529; p = .00) showed that there is a significant difference in post achievement test scores between control group and treatment group students after adjusting the effects of pre test scores (Table IV). Furthermore, the estimated marginal means (adjusted mean which is controlling for the effects of covariate) for the post achievement test also showed that the treatment group students (M = 12.22) had improved significantly by 1.04 more than the control group students (M= 11.18). The estimated marginal means for dependent variable: post achievement test scores is shown in Table V and Figure 5.

Table V. Estimated marginal means for dependent variable: post achievement test scores

Groups	Mean	Std. Error	95% confidence interval	
			Lower bound	Upper bound
Realistic simulation	12.218a	.182	11.858	12.578
Non-Realistic simulation	11.179a	.182	10.819	11.539

a. Covariates appearing in the model are evaluated at the following values: post achievement test scores

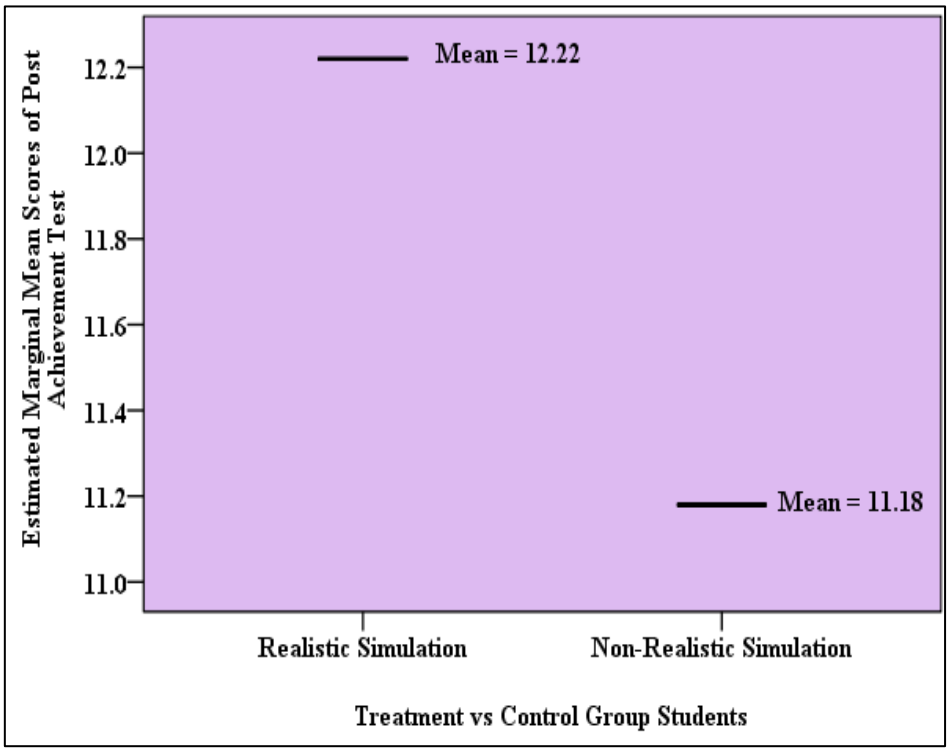

Figure 5. Difference in estimated marginal mean scores for post achievement test between control group and treatment group students.

These results indicate that realistic simulation based teaching method is more effective for learning Cell Division topic in Biology than the non-realistic simulation. Realistic simulation is shown to improve students' performance and achievement for the Cell Division topic.

Research Question 4: Is there any difference in the memory retention between treatment group students and control group students for Cell Division topic?

One way analysis of covariance (ANCOVA) method was used to compare the effectiveness of realistic simulations with non-realistic simulations on students' post memory retention. The basic assumptions underlying one way analysis of covariance (ANCOVA) such as homogeneity of variances, homogeneity of regression slopes and linearity assumptions were tested before conducting the ANCOVA. Findings of preliminary analysis showed that the basic assumptions for one way analysis of covariance (ANCOVA) were met and therefore can proceed with one way ANCOVA.

The pre-test was used as a covariate to control the effects of covariate (pre-test) on the dependent variable (students' post memory retention). The results of the main analysis (test between subject effects on students' post memory retention) are shown in Table VI after controlling the effects of covariates (pre-test scores).

Table VI. Tests of between-subjects effects for dependent variable: post memory retention test scores

Source	Type III sum of squares	*df*	Mean square	F	Sig.
Corrected model	322.537a	2	161.268	62.884	.000
Intercept	121.604	1	121.604	47.418	.000
Pre test (Covariate)	182.507	1	182.507	71.166	.000
Groups	49.192	1	49.192	19.182	.000
Error	341.081	133	2.565		
Total	13906.000	136			
Corrected total	663.618	135			
a. R squared = .486 (Adjusted R squared = .478)					

The findings showed that there is a significant difference in students' post memory retention test scores between control group and treatment group after controlling the effects of pre test scores ($F(1, 133) = 19.182$; p=.00). Furthermore, the estimated marginal means (adjusted mean which is controlling for the effects of covariate) scores for the post memory retention test also showed that the treatment group students (M = 10.50) had gained significantly by 1.27 more than the control

group students (M= 9.23). The estimated marginal means for dependent variable: post memory retention test scores is shown in Table VII and Figure 6.

Table VII. Estimated marginal means for dependent variable: post memory retention test scores

Groups	Mean	Std. Error	95% confidence interval	
			Lower bound	Upper bound
Realistic simulation	10.501a	.199	10.106	10.895
Non-Realistic simulation	9.234a	.199	8.840	9.629

a. Covariates appearing in the model are evaluated at the following values: post memory retention test scores = 8.71.

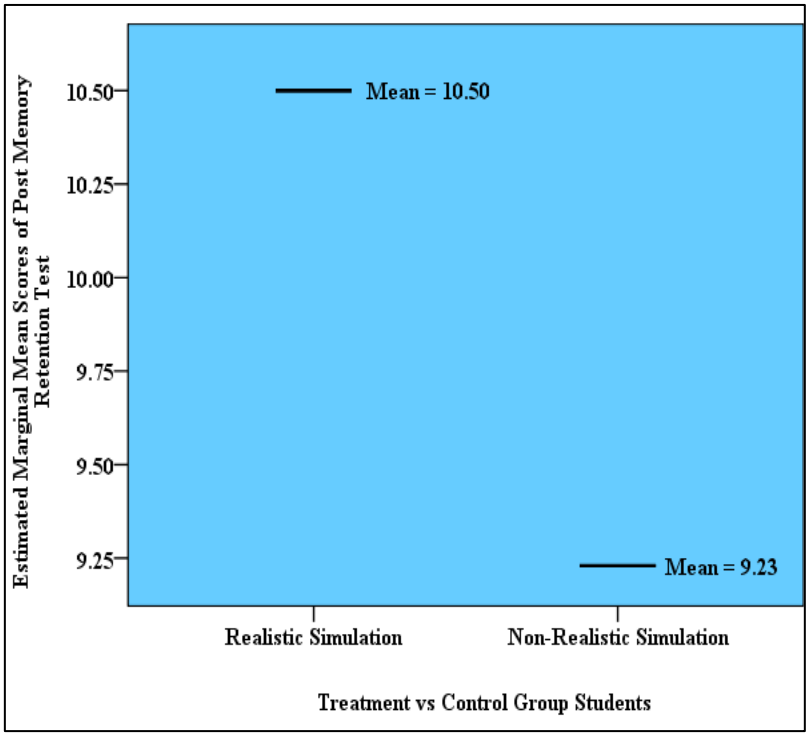

Figure 6. Difference in estimated marginal mean scores for post memory retention test between control group and treatment group students.

Table VII and Figure 7 showed that the realistic simulation is an effective teaching method for learning Cell Division topic in Biology compared to the non-realistic simulation. Teaching and learning that uses realistic simulation enhanced students'

understanding and improved F(1, 133) = 19.182their memory retention for Cell Division topic.

Discussion

Realistic simulation (3D multimedia simulation) and non-realistic simulation (desktop virtual reality simulation) have positive impacts on Biology students' learning outcomes such as students' achievement and memory retention. Effectiveness of realistic simulation and non-realistic simulation on students' post achievement and post memory retention has been shown statistically in this study. Analysis of the descriptive and inferential statistics such as one way analysis of covariance (ANCOVA) showed that both the treatment and control group students had gained high scores in their post achievement test and post memory retention test than the pre-test. These results indicate that both realistic simulation and non-realistic simulation had improved students' understanding, performance, achievement and memory retention in Cell Division topic. However, analysis of descriptive statistics and one way analysis of covariance (ANCOVA) showed that there is a significant difference in students' achievement and memory retention between the group who learnt with realistic simulation and the group who learnt with non-realistic simulation. The realistic simulation group of students attained significantly higher scores in the post achievement test and post memory retention test compared to the non-realistic group.

Findings of this study supported the findings of previous studies that showed that realistic simulation (3D multimedia simulation) has positive impacts on students' performance, achievement and understandings compared to students who learnt using traditional teaching method (Kiboss, 2002; Kiboss & Ogunniyi, 2003; Tanui, 2003; Kiboss, Ndirangu & Wekesa, 2006).

Non-Realistic simulation (virtual reality simulation) based teaching and learning method widens students' knowledge, improves Biology students' understandings and their achievement (Mikropoulos, Katsikis, Nikolou & Tsakalis; 2003; Meir, Perry, Stal, Maruca & Klopfer, 2005; Varma & Linn, 2012). Non-realistic simulation not only improves students' understandings through visualization but also reduces their misconceptions about the abstract Biology concepts (Meir, Perry, Stal, Maruca & Klopfer, 2005), encourage them to actively participate in Biology

learning environment and enhance their concentration toward Biology lesson (Buckley, 2000; Mikropoulos, Katsikis, Nikolou & Tsakalis, 2003).

However, realistic simulation (3D multimedia simulation) is shown to be more effective than the non-realistic simulation (desktop virtual reality simulation). Findings from several including this study had shown the effectiveness of realistic simulation in learning abstract concepts of Biology subject. Findings from a study by Shim, Park, Kim, Kim, Park, & Ryu (2003) reported that students have more interest in virtual reality simulations-based learning than the two dimensional (2D) multimedia teaching and learning method and the students said that virtual reality simulations are very helpful in learning abstract concepts of science subjects especially Biology subject. Findings of this study showed that the group of students who learnt with realistic simulation (3D multimedia simulation) had gained high scores and improved their achievement in Cell Division topic than the control group students who learnt using non-realistic simulation.

Realistic simulation and non-realistic simulation not only enhances students' understandings and achievement but also improve students' memory retention (Otero, 2001). This is because of the nature of the Realistic simulation and non-realistic simulations that encourage students to visualize the simulation played on the computer screen. Both realistic simulation and non-realistic simulation as educational software consist of multimedia elements such as text, animation, video and audio. These multimedia elements play vital role in enhancing students' interest in learning and improve their memory retention (Plass, Homer, & Hayward, 2009; Jonid, Muslim & Mat Junos @ Siti Jamaliah, 2010).

Students' poor understandings and misconceptions in Cell Division process and Biology are inter-related to the teaching and learning methods used by teachers which mainly require students to memorize the learned concepts (Ozcan, Yildirim & Ozgur, 2012). Hence, students faced difficulty in learning and tended to memorize the Biology concepts including Mitosis and Meiosis concepts to score in the Biology exam.

Students' understandings for Mitosis and Meiosis concepts mainly rely on the visual processing skills (Scheiter et al., 2008). Students create their own mental model about the learned concepts while learning through visualization and recorded in the form of visual in their long-term memory (Eichinger, Nakhleh & Auberry, 2000; Flick & Bell, 2000; Ali & Zamzuri, 2007). Visual form learned concepts

enhance their understandings and retained in their memory for a longer period (Lindgren & Schwartz, 2009) and they easily recall back when needed. Hence, high quality visual displays such as 3D computer simulations (realistic simulation and non-realistic simulation) are more effective in increasing students' understanding, memory retention and achievement.

Findings of Scheiter et al. (2008) showed that 83.8% of the students who learned the Cell Division topic using low quality display under the microscope claimed that they remember the concepts of Cell Division process by Mitosis only. Findings of this study showed that treatment group students who learnt with realistic simulation and control group students who learnt with non-realistic simulation had gained high scores in post memory retention test that the pre-test. These results showed that realistic simulation and non-realistic simulation improved students' memory retention. The group of students who learnt Cell Division topic using realistic simulation (3D multimedia simulation) had high memory retention level compared to the group students who learnt with non-realistic simulation (desktop virtual reality simulation). Thus, in this study realistic simulation is shown to be more effective in enhancing students' understanding, memory retention and their achievement in Biology than the non-realistic simulation.

Conclusions and recommendations

The integration of realistic simulation (3D multimedia simulation) and non-realistic simulation (desktop virtual reality simulation) in Biology teaching and learning have positive impacts on students. However, the findings of this study showed that realistic simulation (3D multimedia simulation) is more effective in learning Biology than the non-realistic simulation (desktop virtual reality simulation). Realistic simulation (3D multimedia simulation) in Cell Division topic helped students to visualize and understand the abstract and difficult concepts such as mitosis and meiosis through the simulation.

It is suggested that future studies investigate the use of realistic simulation (3D multimedia simulation) and non-realistic simulation (desktop virtual reality) in teaching and learning process for a longer period to see the longitudinal impact students' learning. Other factors that might be affect students' achievement and memory retention such as gender differences, students' ability level and students' spatial level should also be considered. It is also suggested that future studies

should adopt both quantitative and qualitative research methods to provide insights into the process of teaching and learning.

Acknowledgements

I would like to thank Prof. Dr. Zurida Ismail and also Dr. Mageswary Karpudewan (School of Educational Studies, Universiti Sains Malaysia, Malaysia) for their guidance and also for reading the manuscript.

References

Akpan, J. P. (2002). Which comes first: Computer simulation of dissection or a traditional laboratory practical method of dissection. *Electronic Journal of Science Education* [Online serial], *6*(4). Available:http://ejse.southwestern.edu/article/view/7686/5453. (August 20, 2012)

Ali, M., & Zamzuri, A. (2007). *Kesan koswer strategi animasi pelbagai kawalan penggunaan terhadap prestasi kognitif dan ketekalan pelajar*. Tesis ijazah Doktor Falsafah, Universiti Sains Malaysia, Pulau Pinang.

Atilboz, N. G. (2004). Lise 1. Sinif ogrencilerinin mitoz ve mayoz bolunme konulari ile ilgili anlama düzeyleri ve kavram yanilgilari. *G. Ü. Gazi Egitim Fakultesi Dergisi* [Online serial], *24*(3), 147-157. Available:http://www.gefad.gazi.edu.tr/window/dosyapdf/2004/3/2004-3-147-157-9-n.gckbenatiboz.pdf. (August 20, 2012)

Aziz Nordin & Ami Norliyana Shamsu Kamar (2011). Tahap pemahaman pelajar terhadap konsep Pembahagian Sel dalam mata pelajaran Biologi KBSM tingkatan empat. [Online]. Tidak diterbitkan. Dipetik daripada: http://eprints.utm.my/11220/. (June 18, 2013)

Başer, M. (2007). *The contribution of learning motivation, reasoning ability and learning orientation to ninth grade international baccalaurate and national program students' understanding of Mitosis and Meiosis*. [Online]. Master of Science Thesis, Middle East Technical University, Ankara.
Available: http://etd.lib.metu.edu.tr/upload/12608544/index.pdf. (June18, 2013)

Buckley, B. C. (2000). Interactive multimedia and model-based learning in Biology. *International Journal of Science Education* [Online serial], *22*(9), 895–935. Available: http://dx.doi.org/10.1080/095006900416848. (May 18, 2013)

Burdea, G. C. (1999, May). Keynote address: Haptic feedback for virtual reality. [Online]. *Proceedings of International Workshop on Virtual Prototyping* (pp. 87-96).

Laval: France. Available:http://ti.rutgers.edu/publications/papers/1999_laval.pdf. (April 20, 2013)

Chattopadhyay, A. (2012). Understanding of Mitosis and Meiosis in higher secondary students of Northeast India and the implications for Genetics education. *Education* [Online serial], *2*(3), 41-47. Available:http://article.sapub.org/10.5923.j.edu.20120203.04.html. (February 20, 2013)

Chen, C. J., & Teh, C. S. (2000). An affordable virtual reality technology for constructivist learning environments. *Proceeding of the 4th Global Chinese Conference on Computers in Education* (pp. 414-421). Singapore.

Clark, D.B., Nelson, B., Sengupta, P., & D'Angelo, C. (2009). *Rethinking Science learning through digital games and simulations: Genres, examples, and evidence.* [Online]. Paper Commissioned for the National Research Council Workshop on Gaming and Simulations, October 6-7, Washington, DC. Available:http://www.academia.edu/493598/Rethinking_science_learning_through_digital_games_and_simulations_Genres_examples_and_evidence. (March 21, 2013)

Eichinger, D. C., Nakhleh, M. B., & Auberry, D. L. (2000). Evaluating computer lab modules for large Biology courses. *The Journal of Computers in Mathematics and Science Teaching*, *19*(3), 253–275.

Flick, L., & Bell, R. (2000). Preparing tomorrow's Science teachers to use technology: Guidelines for Science educators. *Contemporary Issues in Technology and Teacher Education* [Online serial], *1*(1), 39–60. Available: http://www.citejournal.org/vol1/iss1/currentissues/science/article1.htm. (December 18, 2012)

Gliner, J. A., & Morgan, G. A. (2000). *Research methods in applied settings: An integrated approach to design and analysis*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Hartas, Dimitra (2010). *Educational research and inquiry: Qualitative and quantitative approaches*. London: Continuum.

Jabatan Pelajaran Negeri Perak (2012). *Analisis keputusan SPM bagi mata pelajaran Biologi mengikut sekolah tahun 2007-2011*. Perak, Malaysia: Sektor Pengurusan Penilaian dan Peperiksaan.

Jimoyiannis, A. (2011). Computer simulations and scientific knowledge construction. In I. R. M. Association (Ed.), *Gaming and simulations: Concepts, methodologies, tools and applications* (pp. 57-74). Hershey, PA: Information Science Reference.

Jonid, Muslim & Mat Junos @ Yunus, Siti Jamaliah (2010). *Pembangunan perisian alat bantu mengajar (ABM) berasaskan komputer bertajuk Cell division: Meiosis dalam matapelajaran Biologi KBSM tingkatan empat*. [Online]. Tidak diterbitkan. Dipetik daripada: http://eprints.utm.my/11164/. (November 23, 2012)

Kablan, H. (2004). *An analysis of high school students' learning difficulties in Biology*. Master Thesis, Middle East Technical University, Ankara.

Kara, Y., & Yesilyurt, S. (2008). Comparing the impacts of tutorial and edutainment software programs on students' achievements, misconceptions, and attitudes towards Biology. *Journal of Science Education and Technology* [Online serial], *17*(1), 32-41. Available: http://dx.doi.org/ 10.1007/s10956-007-9077-z. (February 12, 2013)

Karamustafaog˘lu, S., Sevim, S., Mustafaog˘lu, O., & C¸ epni, S. (2003). Analysis Turkish high school Chemistry examination questions according to bloom's taxonomy. *Chemistry Education Research And Practice*[Online serial], *4*(1): 25–30. Available: http://dx.doi.org/10.1039/b2rp90034c. (December 18, 2012)

Kiboss, J. K. (2002). Impact of a computer based physics instruction program on pupil's understanding of measurement concepts and methods associated with school Science. *Journal of Science Education and Technology* [Online serial], *11*(2), 193-198. Availabe: http://dx.doi.org/10.1023/A:1014673615275. (February 18, 2013)

Kiboss, J. K., Ndirangu, M., & Wekesa, E. W. (2004). Effectiveness of a computer mediated simulations program in school Biology on pupils' learning outcomes in Cell Theory. *Journal of Science Education and Technology* [Online serial], *13*(2), 207-213. Available: http://dx.doi.org/ 10.1023/B:JOST.0000031259.76872.f1. (December 18, 2012)

Kiboss, J. K., & Ogunniyi, M. B. (2003). Influence of a computer based intervention on student's conceptions of measurement in secondary school Physics in Kenya. *Themes in Education, 4*, 203-217.

Kiboss, J., Wekesa, E., & Ndirangu, M. (2006). Improving students' understanding and perception of Cell Theory in school Biology using a computer based instruction simulation program. *Journal of Educational Multimedia and Hypermedia, 15*(4), 397-410.

Knippels, M. C. P. J., Waarlo, A. J. & Boersma, K. T. (2005). Design criteria for learning and teaching Genetics. *Journal of Biological Education* [Online serial], *39*(3), 108-112. Available:http://dx.doi.org/10.1080/00219266.2005.9655976. (January 12, 2013)

Laurillard, D. (2002). *Rethinking university teaching: A conversational framework for the effective use of learning technologies* (2nd Ed.), London: Routledge Falmer.

Lazarowitz, R. & Lieb, C. (2006). Formative assessment pre-test to identify college students' prior knowledge, misconceptions and learning difficulties in Biology. *International Journal of Science and Mathematics Education* [Online serial], *4*(4), 741–762. Available: http://dx.doi.org/10.1007/s10763-005-9024-5. (January 18, 2013]

Lewis, J., Leach, J. & Wood-Robinson, C. (2000a). Chromosomes: The missing link-young people's understanding of Mitosis, Meiosis and Fertilization. *Journal of Biological Education* [Online serial], *34*(4), 189-199.

Available: http://dx.doi.org/10.1080/00219266.2000.9655717. (January 18, 2013)

Lindgren, R., & Schwartz, D. L. (2009). Spatial learning and computer simulations in Science. *International Journal of Science Education* [Online serial], *31*(3), 419-438. Available:http://dx.doi.org/10.1080/09500690802595813. (January 18, 2013)

Lyles, A. N. (2008). *Development of an instrument to assess how Health education professional preparation programs prepare students to address health disparities*. [Online]. Published PhD Thesis, Southern Illinois University Carbondale, United States. Available: http://search.proquest.com/docview/304474891#. (January 21, 2013)

Mayer, R. E. (2001). *Multimedia learning*. New York, NY: Cambridge University Press.

Meir, E., Perry, J., Stal, D., Maruca, S., & Klopfer, E. (2005). How effective are simulated molecular-level experiments for teaching Diffusion and Osmosis? *Cell Biology Education* [Online serial], *4*(3), 235–248.
Available: http://dx.doi.org/10.1187/cbe.04-09-0049. (January 21, 2013)

Menard, S. W. (2008). *Handbook of longitudinal research: Design, measurement, and analysis*. Amsterdam: Elsvier/Academic Press.

Mikropoulos,T. A., Katsikis, A., Nikolou, E., & Tsakalis, P. (2003). Virtual environments in Biology teaching. *Journal of Biological Education* [Online serial], *37*(4), 176-181. Available:http://dx.doi.org/10.1080/00219266.2003.9655879. (January 21, 2013)

Murniza, M., Halimah, B. Z., & Azlina, A. (2010). Virtual laboratory for learning Biology: A preliminary investigation. *World Academy of Science, Engineering and Technology*, *6*(71), 775-778.

Olele, C. N. (2008). Emerging issues for computers in schools: A bridge for digital divide phenomenon in Nigeria. In N. Udofia (Ed.), *Proceedings of 49th annual conference of Science Teachers Association of Nigeria (STAN) Ibadan* (pp. 195-199). Ibadan: HEBN Publishers Plc.

Otero, V. (2001). *The role of computer simulators in students' construction of explanatory models of Static Electricity*. A Paper Presented at NARST Conference at St Louis, Missouri.

Ozcan, T., Yildirim, O., & Ozgur, S. (2012). Determining of the university freshmen students' misconceptions and alternative conceptions about Mitosis and Meiosis. *Procedia Social and Behavioral Sciences* [Online serial], *46*, 3677-3680.
Available: http://dx.doi.org/10.1016/j.sbspro.2012.06.126. (April 3, 2013)

Pan, Z., Cheok, A. D., Yang, H., Zhu, J., & Shi, J. (2006). Virtual reality and mixed reality for virtual learning environments. *Computers and Graphics* [Online serial], *30*(1), 20–28. Available:http://dx.doi.org/10.1016/j.cag.2005.10.004. (March 3, 2013)

Plass, J., Homer, B., & Hayward, E. (2009). Design factors for educationally effective animations and simulations. Journal of Computing in Higher Education [Online

Serial], 21(1), 31-61. Available: http://dx.doi.org/10.1007/s12528-009-9011-x. (March 3, 2013)

Saka, A., Cerrah, L., Akdeniz, A. R. & Ayas, A. (2006). A cross age study of the understanding of three Genetic concepts: How do they image the Gene, DNA and Chromosome? *Journal of Science Education and Technology* [Online serial], *15*(2), 192–202. Available: http://dx.doi.org/10.1007/s10956-006-9006-6. (December 21, 2013)

Scheiter, K., Gerjets, P., Huk, T., Imhof, B., & Kammerer, Y. (2008). The effects of realism in learning with dynamic visualizations. *Learning and Instruction* [Online serial], 19(6), 481-494. Available:http://dx.doi.org/10.1016/j.learninstruc.2008.08.001. (February 21, 2013)

She, H.-C. & Chen, Y.-Z. (2009). The impact of multimedia effect on Science learning: Evidence from eye movements. *Computers & Education* [Online serial], *53*(4), 1297-1307. Available:http://dx.doi.org/10.1016/j.compedu.2009.06.012. (August 3, 2013)

Shim, K.-C., Park, J.-S., Kim, H.-S., Kim, J.-H., Park, Y.-C., & Ryu, H.-I. (2003). Application of virtual reality technology in Biology education. *Journal of Biological Education* [Online serial], *37*(2), 71-74.
Available: http://dx.doi.org/10.1080/00219266.2003.9655854. (March 12, 2013)

Slavin, R. E. (2006). *Educational psychology: Theory and practice* (8th Ed.), Boston: Pearson Education.

Tanui, E. K. (2003). *Relative effects of computer based instruction in Accounting on students' achievement, perception of the classroom environment and motivation in secondary schools in Kenya*. Unpublished Doctoral Thesis, Egerton University, Njoro, Kenya.

Varma, K., & Linn, M. (2012). Using interactive technology to support students' understanding of the Greenhouse Effect and Global Warming. *Journal of Science Education and Technology* [Online serial], *21*(4), 453-464.
Available: http://dx.doi.org/ 10.1007/s10956-011-9337-9. (May 28, 2013)

Wekesa, E. (2003). *Effects of a computer based instruction module on student's achievement, perception of the classroom environment and attitude towards school Biology in Nakuru District, Kenya*. Unpublished Master's Thesis, Egerton University, Njoro, Kenya.

Wellington, J. (2004). Using ICT in teaching and learning in Science. In R. Holliman & E. Scanlon (Eds.), *Mediating Science Learning through Information and Communication Technology* (pp. 51-78). London: Routledge Falmer.

Winn, W. D., & Windschitl, M. (2000). Learning Science in virtual environments: The interplay of theory and experience. *Themes in Education, 1*(4): 373–389.

Yenilmez, A., & Tekkaya, C. (2006). Enhancing students' understanding of Photosynthesis and Respiration in plant through conceptual change approach. *Journal of Science Education and Technology* [Online serial],*15*(1), 81–87. Available: http://dx.doi.org/10.1007/s10956-006-0358-8. (December 27, 2012)

Zhang, J. P., & Yang, Y. H. (2009). Design and implementation of virtual museum based on Web3D. In Z. Pan, A. D. Cheok & W. Muller (Eds.), *Transactions on Edutainment III* (pp. 154-165). Germany: Springer-Verlag Berlin Heidelberg. Available: http://link.springer.com/chapter/10.1007%2F978-3-642-11245-4_14. (January 12, 2013)