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Effect of computer simulation on academic performance and experiences of year two science students in the concept, circulatory system in humans

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Abstract
The study was conducted to determine the effect of computer simulation on academic performance and experiences of second year science students in the concept, circulatory system in humans at Presbyterian Senior High School, Tema. Quasi-experimental research design and survey of students' opinion were used. The target population was all students of the school (800 students). The accessible population was year two science (80) students. The sample size was 80 students. Purposive sampling was used to select two intact classes A and B. Class A was assigned the experimental group and was exposed to the computer simulation and class B was assigned the control group and was exposed to the lecture method. Each group consisted of 40 students. Tests and Questionnaires were used for the collection of data. The data were analyzed using weighted means, effect size, and t-tests. The findings revealed that students of the control and experimental groups were all of the same academic standard before the treatments ($t = 1.209$; $df = 78$; $P \geq 0.05$). Students in the experimental group performed better in the post test than the control group ($t = 3.542$; $df = 78$; $P < 0.05$). The experiences of the students in the experimental group were significantly positive compared to the control group ($t = 6.9584$; $df = 78$; $P < 0.05$). It is recommended that teachers of Presbyterian Senior High School should use computer-based instructions that may cater for the different learning styles of the students to enhance their academic performance.

Keywords: Computer simulation, academic performance, circulatory system in humans, experiences, effects

Introduction

Biology is one of the science subjects very important for development and the subject is fundamental for individual well-being, development of good living environment and acquisition of functional scientific attitudes (Matazu, 2022) [34]. In Ghana, though Biology has remained the most popular subject in the Senior High Schools where it has a high enrolment figures annually compared to Chemistry, Physics and other science subjects, the enrolment figures do not reflect students' achievement in the subject (Anamuah Mensah, 1995) [3].

Salaudin, Mohammed and Jubrin (2020) [50] observed that secondary school biology students cannot fully understand most of the concepts of biology when taught without instructional materials. Thus, there is the need for biology teachers to make it major part of their professional practice to use instructional materials to promote the teaching and learning of biology. Similarly, Ajemba, Ahmed, Ogunode and Olatunde-Aiyedun (2021) [2] stated that the quality of education a student receives largely depends on the quality of teaching/learning resources provided. This implies that students learn well when instructional materials are applied in the implementation of the teaching-learning process.

Therefore, the onus lies on the teachers involved in the implementation of a given curriculum to use a wide range of quality instructional materials for effective and efficient teaching and learning (Matazu, 2022) [34]. The learning process is enhanced when the learner is participating in the learning process (Noel, Daniels & Martins, 2015) [41]. Therefore, the ability of a learner to comprehend and the ability to internalize fundamental concepts and appreciate biological principles as a science subject depends to a large extend on the teaching methods employed by the classroom teacher (Ogunleye, 2014) [42].

One of the several ways identified for human learning is how sophisticated form of information is processed. This view of learning was inspired by advances in computer science by theorists who hypothesized that human minds perform mental operations like computers. Slavin (2015) [51] described a model of information processing proposed by Atkinson and Shiffrin as a model of information processing with three components focusing on how individuals register sensory information taken in from the environment (sensory register), how they process information (working memory) and how that information is stored and retrieved (long-term memory). For learning to take place among learners, Bandura (1986) [6] believes that people are neither driven by inner forces nor automatically shaped by external forces; rather, they are creative, active participants in shaping their lives. In other words, people are proactive rather than reactive; they have some control over how they live their lives (Bandura, 1986, 2001) [6]. This relates to the social cognitive learning. Some of the general principles that support the social cognitive view of learning (Slavin, 2015; Ormrod 2012) [51, 43] are that:

- People learn through a process of modelling and observing others' behaviour.
- People learn vicariously from others' successes and failures.
- Learning may or may not result in an observable change of behaviour,
- Cognition is important in learning such as awareness, attention, expectations, and retention.
- People can actively exert control over their actions and environments.

In effect, it can also be said that one other important way of learning is making observation. Bandura's theory of observational learning involves four phases and processes: attention, retention, reproduction, and motivation (Bandura, 1986; Olsen & Hergenhahn, 2013) [6]. The first phase, attention, occurs when the individual actively pays attention to the behaviour of others. In the second phase, retention, the individual must have an opportunity to practice imitating the behaviour of others. In the third phase, reproduction, the individual tries to match the behaviour of others. This depends on the person's ability to actually perform what has been learned. The last phase, motivation, the individual finds satisfying reasons to imitate the behaviour of others. Bandura's social cognitive theory states that people learn from observing others in a social setting (Bandura, 1986) [6]. By observing others, people acquire knowledge and skills, learn social rules and norms, and develop beliefs and attitudes.

In similar vein, Farombi (1998) [23] intimates that materials such as books, audio visual aids (computers, projectors), software and hardware of educational technology facilitate learning among students. He further opines that the availability, adequacy and relevance of instructional materials in classrooms can influence quality teaching, which can have positive effect on students‟ learning and academic performance. Relevant and appropriate instructional materials help to arouse and sustain interest and help to concretize ideas and stimulate the imaginations of the students, thus enhances achievement of students in a subject (Mustapha, Aminu, Abdul & Dauda, 2022) [40]. Instructional materials are considered important in teaching and learning in all levels of education because textbooks and other resource materials are basic tools. For example, textbooks, charts, maps, audio-visual and electronic instructional materials such as radio, computers, tape recorders, television and video and tape recorders contribute much in making learning more interesting (Atkinson, 2000) [5].

For several years, the use of the convectional approach in teaching has been widely used in senior high schools, colleges and universities. For instance, nearly 80 percent of all U.S college classrooms in the late 1970 were reported using some form of the lecture method to teach students (Cashin, 1990) [13]. In Sub-Sahara Africa including Ghana, most universities and second cycle institutions have been using the traditional lecture approach (Antwi, 2013) [4]. Meanwhile, the lecture method of teaching encourages one-way communication only (Kumar, Saxena & Kapor, 2015) [29] instead of the teacher blending lecture method with other interactive method to meet set goals.

According to Waldeck and Weimer (2017) [58], it is not surprising that many students are unable to apply information from lecture in a meaningful way. Active learning increases student's retention of information, improves performance on course assessments and increases standardized test scores (Styers, Van, & Hayden, 2018: Ulrich, Kryscynski & Brockbank, 2017) [52, 55]. Results from a study by Matsuda, Azaiza and Salani (2017) [35] support the concept that when students are connected with course content, learning outcomes improve overall. Active learning also improves students' perceptions of inclusiveness in the classroom and their self-efficacy (Lumpkin, Achen & Dodd, 2015) [32].

A meta-analysis of science, technology, engineering and mathematics (STEM) courses demonstrated that students in the lecture classroom were 1.5 times more likely to fail when compared with those in active learning courses, hence the average examination scores of the active learning course participants were 6 percent higher than lecture course participants. With active learning, students are the primary knowledge creators and focus of the teaching-learning process (Cattaneo, 2017) [14]. From this view, learners construct meaning from what they interact with making the teaching and learning process an interactive learning environment. Therefore, the use of computer technologies in teaching and learning will tend to improve interaction among students and the effective use of it will equip the students to perform exceptionally in their final exams. Using computer technology in instruction gives alternatives to students. These alternatives include:

- Computer-based instruction provides an atmosphere like laboratories where students are active (Perkins, Adams, Dubson, Finkelstein, Reid, Wieman & LeMaster 2006), observe and interpret results (Holec, Spodniakova, Pfefferova & Raganova (2004) [26].
- Computer-based instruction encourages students to carry out activities such as ask questions, predict and hypothesize.

- Computer-based instruction enables visualization of abstract concepts that will foster students' understanding and interest (Meltzer & Manivannan 2002) [38].
- Computer-based instruction makes concepts more visible that are otherwise invisible to students (Finnkelstein, Adams, Keller, Kohl, Perkins, Podolefsky, Reid & LeMaster 2005) [1].

The above submissions point to the fact that one most important means for students to participate actively in class is by employing computer-based teaching.

The problem statement

The performance of the science students in Biology at Presbyterian Senior High School, Tema has been poor. This problem has persisted for some years and has affected the good image of the school. For instance, in the year 2019, out of 71 candidates presented for Biology in West African Senior Secondary Certificate Examinations (WASSCE) at Presbyterian Senior High School, Tema, one student representing 1.4% obtained grade A1, six students representing 8.5% obtained grades between C4 and C6, 61 students representing 85.9% obtained grades between D7 and F9 whilst 3 students representing 4.2% were absent. Also, in 2020, four students representing 5.6% obtained grades between A1 and B3, 21 students representing 29.6% obtained grades between C4 and C6 and 46 students representing 64.8% obtained grades between D7 and F9. Similarly, in 2021, the school's percentage pass for Biology was 8.4% whilst 65.2% failed. These statistics indicated low students' performance in Biology in the school. The problem was further revealed after the researcher marked the exercises, assignments and project works of the students. The results of exercises conducted by the researcher after teaching the form two students Biology for two weeks indicated that, out of 80 students, only 22.23% of them obtained pass mark in class exercise, 21.24% passed in assignments and 23.12 passed in project works. The situation looked grave and had to be looked at to prevent massive failure of the students in WASSCE in subsequent years. Therefore, the teaching strategy that would arouse the interest of the students to improve upon class participation and subsequently affect the academic performance of the students positively needed to be adopted and used. Hence, the researcher decided to determine the effect of computer simulation on academic performance and experiences of year two science students in an abstract concept such as circulatory system in humans at Presbyterian Senior High School, Tema.

Objectives, research questions and hypotheses of the study

The specific objectives of the study were to

1. Ascertain the level of academic performance of control and experimental groups of year two science students of Presbyterian Senior High School, Tema in the concept

Circulatory system in humans before the treatment

2. Determine the effects of computer simulation on academic performance in the concept circulatory system in humans of year two science students at Presbyterian Senior High School, Tema.
3. Examine the impact of computer simulation on year two science students' experiences from the study of circulatory system in humans at Presbyterian Senior High School, Tema.

The research questions answered by the study were as follows

1. What was the difference between the control and experimental groups in terms of academic performance of year two science students of Presbyterian Senior High School, Tema in the concept circulatory system in humans before the treatment?
2. What is the effect of computer simulation on academic performance of year two science students at Presbyterian Senior High School, Tema in the concept circulatory system in humans?
3. To what extent does the use of computer simulation influence the experiences of year two science students in the study of circulatory system in humans at Presbyterian Senior High School, Tema?

Research Hypotheses

The following hypotheses were formulated and tested;

Ho_1: There is no statistically significant difference in the mean performance of the control and experimental groups before the treatment.

H_1: There is statistically significant difference in the mean performance of the control and experimental groups before the treatment.

Ho_2: There is no statistically significant difference in the mean performance between the control and experimental groups after the treatment.

H_2: There is statistically significant difference in the mean performance between the control and experimental groups after the treatment

Ho_3: There is no statistically significant difference in the experiences of students in the control and experimental groups after the treatment.

H_3: There is statistically significant difference in the experiences of students in the control and experimental groups after the treatment.

Conceptual framework

The study was based on the cognitivists and the constructivists learning theories. According to these theories, an interactive strategy (such as computer simulation) that encourages learners' active interactions and ends in building learners' schema would improve upon their academic performance (Mayer & Chandler, 2001) [36]. Also, a cooperative environment that enables learners to interact with one another encourages students to engage in dialogue both with the teacher and with one another improving upon learners' interactions in class (Brooks & Brooks, 1993; Vygotsky, 1978) [56] and lastly, the use of effective audio-visual aids and interactive graphics and multimedia arouse learners' curiosity and interest to learn abstract concepts with ease. This would affect the experiences of learners positively and in turn affect their academic performance (Mayer & Chandler, 2001) [36] as illustrated in Figure 1.

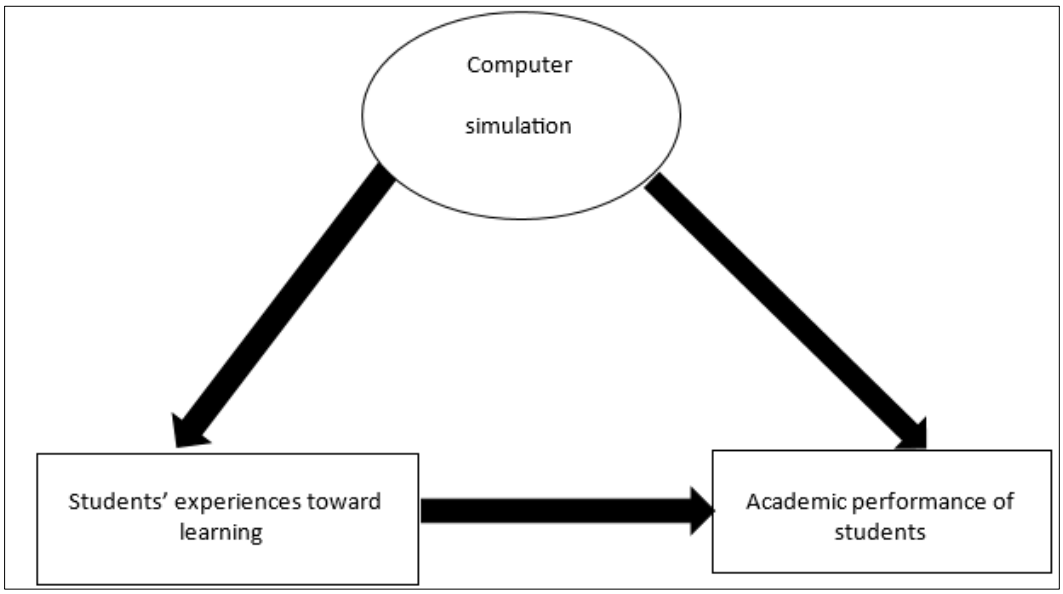

Fig 1: Conceptual Framework (Source: Researcher's own construct, 2023)

Methodology

Study Design

The study employed quasi-experimental research and survey designs. Quasi-experimental design is used to examine causal relationship in education (Campbell & Stanley, 1963; Cook & Campbell, 1979) [12, 18]. The researcher used this design because two intact classes (A and B) were used. Mackey and Gass (2005) [33] stated that intact classes are commonly and often by necessity used in research for the sake of convenience. Intact classes reflect real world classrooms, where students are in class units to learn. Again, this design was used because students were not randomly assigned to the treatment or the control group. In this study the samples were not chosen randomly because of logistical constraints. Class A was assigned the experimental group and class B was assigned the control group. The assigning was done by using non-randomized sampling technique. Survey method employing five item questionnaire was used to determine the influence of the two teaching approaches on participants' learning of circulatory system in humans.

Population

The target population for this study was all students of Presbyterian Senior High School, Tema. The number of students at the time of the study was 800. The accessible population was all year two science students of the school at the time. There were 80 of them during 2022/2023 academic year.

Sample and sampling

The 80 year two science students constituted the sample for the study. Forty students were for the experimental group (Class A) and the other forty for the control group (Class B). Purposive sampling technique was used in the choosing of the respondents. The school was conveniently and purposively chosen due to proximity to the researcher and willingness of the students to participate in the study respectively. This was established since the researcher is a teacher in the school. Purposive sampling stresses on the fact that it is important to select samples which are likely to be knowledgeable and informative about the phenomenon the researcher is investigating (McMillan & Schumacher, 2001) [37]. The year two science students were purposively selected because the concept/topic circulatory system of humans is treated at that level and the students were free from examination stress during the time of the study.

Instrumentation

The research instruments used for this study were tests and questionnaire. The tests consisted of twenty (20) items and were used as pre-test and post-test to determine the prior knowledge of the students and what they have learnt after the treatment respectively. The scope of the test included coronary circulation, pulmonary circulation and systemic circulation. The questions for the pre-test and post-test were different but covered the same sub-concepts and were of equal standard. The pre-test was named by the researcher as Biological Performance Test of Circulatory System (BIOPETCS) and the post-test as Biological Student Achievement Test of Circulatory System (BIOSATCS). Each test consisted of three (3) sections, A, B and C of which section-A consisted of 10 multiple choice questions, Section B made up of 5-item True/False questions and Section C made up of 5-item essay test. The Content validity of the instruments was done by employing Lawshe's method to analyze the items for accurateness. The Content validity ratios obtained for the tests was 0.80. The researcher employed Cronbach Alpha to determine the reliability coefficient of the tests and a value of 0.74 was obtained and 0.78 in the questionnaires and test respectively.

The questionnaire which comprised 5 items was named post-treatment questionnaire (PTQ) and was administered to the student respondents after the treatment in both control and experimental groups. This was to determine the influence of the teaching approaches on the control and experimental groups of students in teaching and learning of circulatory system of Human after the treatment. The items were five level Likert scale types. The Content validity ratios obtained for the questionnaires was 0.79. The researcher employed Cronbach Alpha to determine the reliability coefficient of the questionnaire and a value of 0.78 was obtained.

Treatment

The treatments under this study were the use of computer

simulation approach used to teach the experimental group (Class A) and the use of conventional lecture method to teach the control group (Class B). A pre-test was administered to both groups at the beginning of the study. This allowed the researcher to determine if the two groups were equal in performance at the beginning of the instructional programme (Tuckman, 1999) [54]. Post-test teaching questionnaire was administered to all the participants after the treatment.

Data Collection and Analysis

Pre-test (BIOPETCS) was administered to both the control group and the experimental group. The test results were collated. After the teaching, post-test (BIOSATCS) was administered to both groups. The post-teaching questionnaires (PTQ) was administered and retrieved thereafter. The researcher served as the teacher for the two groups. Therefore, the respondents were treated with the same environmental conditions. The collated data were analyzed using weighted means, frequencies, effect size and t-test. Appropriate conclusions and recommendations were given.

Results and discussion

Research question 1

What was the difference between the control and experimental groups in terms of academic performance of year two science students of Presbyterian Senior High School, Tema in the concept circulatory system in humans before the treatment? The results answering research question 1 and objective one are presented in Table 1.

Table 1: Performance of control and experimental groups before the treatments

Score range	Control Group	Experimental Group
	Frequency	Frequency
1– 5	9	9
6 – 10	27	30
11 – 15	3	1
16 – 20	1	0
21 – 25	0	0
26 – 30	0	0
Total	40	40

***Source*:** Field work (2023)

The students' performance in pretest for both groups were generally the same. However, most of the students in both groups obtained scores from 1 to 15 (Table 1). In the control group, only one student scored between 16 and 30 whilst no student scored between 16 and 30 in the experimental group. The t-test results have been presented in Table 2.

Table 2: T-test results of pre-test scores of control and experimental groups

Groups Compared	Mean Test Scores	t – stat	p- value
Control	7.725	1.2090	0.230
Experimental	7.025		

The differences between the mean scores for the control and experimental groups were not statistically significant ($t = 1.209$; $df = 78$; $P \geq 0.05$). Thus, the null hypothesis has been accepted, suggesting that the differences were due to chance. This means that, students in both groups were having the same knowledge level in the concept circulatory system of humans before the treatment. This might probably be due to the fact that circulatory system in humans might have been introduced to the students at Junior High School. This result is consistent with the findings of conducted research on simulation using control and experimental groups and found out that the mean scores in the pre-test in both groups were the same.

Research question 2

What is the effect of computer simulation on academic performance of year two science students at Presbyterian Senior High School, Tema in the concept circulatory system in humans?

Table 3: Post-treatment results for control and experimental groups

Score range	Control Group	Experimental Group
	Frequency	Frequency
1 – 5	1	0
6 – 10	4	1
11 – 15	19	13
16 – 20	12	10
21 – 25	3	12
26 – 30	1	4
Total	40	40

***Source*:** Field work (2023)

The results have been presented in Table 3. Indications are that students in the experimental group performed better than the students in the control group after the treatments (Table 3). It can be seen that 24 students representing 60% scored between 1 and 15 marks in the control group whilst 14 students representing 35% scored within that range in the experimental group. Similarly, 16 students representing 40% scored between 16 and 30 marks in the control group whilst 26 of them representing 65% scored within the same range for the experimental group. The mean score of the experimental group (18.45) was higher than the mean score of the control group (14.80). Similarly, an effect size of 0.7926 was obtained which points to large difference in post-test scores between the control and experimental groups. Hence the experimental treatment had a substantial impact on the post-test scores compared to the control group according to Cohen (1988) [17]. The t-value indicated that there were statistically significant differences between the mean scores for the control and experimental groups ($t = 3.542$; $df = 78$; $p < 0.05$) as in Table 4. This means that the null hypothesis was rejected and the alternate hypothesis accepted. A further implication is that the differences were not due to chance but real, meaning that students in the experimental group performed better than students in the control group. Hence, it can be said that use of computer simulation promoted better understanding of the concepts than use of the traditional method.

Table 4: t-test results of post-test scores of control and experimental groups

Groups Compared	Mean Test Scores	t – stats	p- value
Control	14.800	3.5423	0.000673*
Experimental	18.450		

This result corroborates the findings of Kiboss *et al*. (2006) [28] and Adams *et al.* (2005) [1]. Kiboss *et al*. (2006) [28] assessed the effects of computer simulation on students and discovered that it positively improved the performance of the students. Similarly, Adams *et al*. (2005) [1] used computer

simulation to model electron flow and found out that, the group of students who used the simulation performed better than the other group exposed to the traditional approach. This finding contradicts that of Ybarrondo (1984) [59] where there was no significant difference between students taught using computer simulations and those taught using conventional instruction.

Research question 3

To what extent does the use of computer simulation affect the experiences of year two science students in the study of circulatory system in humans at Presbyterian Senior High School, Tema?

The weighted means covering students' experiences with the treatments have been presented in Table 5.

Table 5: Weighted means of students' experiences with regard to the treatments

Item No	Experience	Control group	Exper. group	Effect size
1	I am motivated to learn circulatory system of human	3.73	4.13	0.4
2	Concepts in circulatory system of human seems confusing	3.23	1.68	-1.55
3	I am able to relate concepts in circulatory system of human with each other	3.025	3.88	0.86
4	I am motivated to come to class for Biology lessons.	3.43	4.08	0.65
5	I am able to relate concepts in circulatory system of humans to real life situations.	3.20	4.00	0.80

Key: 1 - 1.4 = strongly Disagreed 3.5 - 4.4 = agree
1.5 - 2.4 = Disagreed 4.5 - 5.0 = strongly agree
2.5 - 3.4 = Neutral

Results from Table 5 show that, most of the students in both groups chose agree (3.73 for control and 4.13 for experimental group) for statement 1. This indicates that they were motivated to learn circulatory system of humans. The fact that students in the experimental group obtained a higher weighted mean (4.13) than the control group (3.73) signifies that they were highly motivated to learn the concept after the use of computer simulation. The effect size between these groups obtained was 0.4. This means that the difference between the performance of students in the experimental group and control group was 40% of the standard deviation or variability within the data. This suggests that a small difference between the control and experimental groups existed (Cohen, 1988) [17].

For statement 2, the students in the control group were neutral in their response to the fact that they neither agreed nor disagreed that concepts in circulatory system of humans seems confusing. In the experimental group they strongly disagreed to the statement which indicates that the concept was not confusing. The effect size measured was -1.55 which means a large difference exist between the control and experimental groups. Thus, the experimental group has a significantly lower weighted mean (1.68) than the control group (3.23) (Cohen, 1988) [17].

Considering statement 3, the students in the control were neither able nor unable to relate concepts in circulatory system to each other (3.025) whist those in the experimental group agreed to that statement (3.88) showing their ability in relating the concepts with each other. This suggests that the computer simulation approach helped them to relate concepts to each other. A large difference existed between the control and experimental groups with effect size of 0.86. According to Cohen (1988) [17], this indicates the experimental group tends to have a higher weighted mean than the control group, with 86% of the standard deviation or variability within the data.

Students in the control group were neutral in their response about statement 4 and 5. They were neither motivated nor interested to come to class and were unable to relate the concept of circulatory system to real life (3.43 and 3.20 respectively). On the other hand students in the experimental group agreed to statements 4 and 5, (4.08 and 4.00 respectively). This clearly indicates that they were motivated to come to class and also able to relate the concepts to real life situations with an effect sizes of 0.65 and 0.8 respectively. Thus, large differences between the control and experimental groups indicating the experimental group tends to have a slightly higher weighted mean than the control group representing 65% and 80% of the standard deviation or variability within the data respectively as stated by Cohen (1988) [17].

In general terms, the weighted means of the control group indicated that on average, students stated opinions that leaned slightly towards agreement or neutral. This was a distinct indication that the students' experiences from learning the circulatory system in humans was neither negative nor positive. On the other hand, responses from the experimental group suggest that students had positive experiences towards the learning of circulatory system of humans. This shows that the treatment provided to the experimental group had a favourable impact on them and influenced them to develop positive attitudes toward the approach

The differences between the means for control and experimental groups were significantly significant ($t = 6.9584$; $df = 78$; $P < 0.05$) as in Table 6. Thus, the null hypothesis (H_{O2}) was rejected, meaning the differences between the means were not due to chance but real.

Table 6: Results of t-test analysis of students' experiences

Groups Compared	Mean Test Scores	t – stat	p- value
Control	3.320	6.9584	1.424 E-11*
Experimental	3.995		

The overall effect size measured was 0.6958. According to Cohen (1988) [17], this indicates a large difference in their experiences after the treatment. The positive value suggests higher scores in the experimental group. This result is in consonant with the findings of Brasell (1987) [11]. They are all of the view that, using computer simulation in various classrooms result in positive students' attitude and students are able to apply the learned material. Similarly, according to Kusar, Chowdhry and Gujjar (2008) computer simulation proved to be significantly superior to class room lecture in terms of achievements in knowledge, analysis and synthesis of the Bloom's taxonomy when they conducted a comparative study to evaluate the effectiveness of simulations versus classroom lecture for computer science students. The study seems to suggest that simulations are able to improve student achievement and thus affects the experiences of students toward a particular subject of study.

Conclusions

It can be said that before the lecture and computer simulation approaches were used in teaching, students, members of both control and experimental groups were at the same level of academic standard. It was evident from the study that computer simulation was more effective in teaching and learning circulatory system in humans. It enhanced the academic performance of the students and positively influenced the experiences of the experimental group towards learning of circulatory system and Biology. Therefore, it is possible that exposure of students to computer simulations can arouse their interest which can also enhance their performance in Biology.

Recommendations

Teachers of Presbyterian Senior High School, Tema should use computer-based instructions that may cater for the different learning styles of students to enhance their academic performance. Computer simulation should be used for instruction of complex and abstract concepts in science to enable learners to relate concepts to real life situations and this will enhance their experiences and attitude toward learning. The study can also be replicated with other subjects to further validate the effectiveness of computer simulation in the teaching and learning process.

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