# Impact of Integrating Information and Communication Technology into Teaching of Cellular Respiration at the Colleges of Education

Richard Koranteng Akpanglo-Nartey[1], Judith Kafui Kemetse[2] & Samuel Agyekum Darkwa[3]

[*1]*Department of Science, Mount Mary College of Education, P. O. Box 19, Somanya, Ghana*

[2]*Department of Science, E. P. College of Education, P. O. Box AM 12, Amedzofe, Ghana*

[3]*Department of Science, Mount Mary College of Education, P. O. Box 19, Somanya, Ghana*

***Abstract:*** **This study investigated the effectiveness of integrating Information and Communication Technology (ICT) into the teaching and the traditional approach of teaching cellular respiration at the Colleges of Education. Two intact science classes were randomly selected from the two Colleges of Education in the Central region of Ghana who offers the general science programme. The pretest-posttest non-equivalent group quasi-experimental design was used. The students in the experimental group learned cellular respiration using an ICT rich environment, whereas the students in the control group were taught the same cellular respiration using the traditional approach. The results indicated that students taught with the integration of ICT outperformed their counterparts taught with the traditional approach. It was also found that students in the experimental group had positive perceptions of using ICT in teaching and learning. It was recommended that tutors at the Colleges of Education should integrate ICT into their teaching.**

***Keywords:*** **academic achievement; ICT as an instructional tool; traditional teaching approach; perception of students and cellular respiration.**

## I. INTRODUCTION

In this 21st century, information and communication technology (ICT) has become an indispensable tool for economic growth and development and has permeated in virtually every sector such as medicine, banking, industrialization and education and has become part and parcel of every aspect of human endeavor [6]. Due to the rapid evolution of modern technology and industrialization across the globe, there is a massive demand for quality and meaningful education among developed countries as well as developing countries and Ghana in particular. This demand for quality education and science education, in particular, and has led to the introduction of computers into the classroom in the 19$^{th}$century [18]. In order to meet this 21$^{st}$-century demand for quality education which is rooted in discoveries and inventions, teaching and learning must be driven by computer integration [19]. It is based on the effectiveness of computers in education in general that drive a lot of developed countries to invest massively in incorporating computers in their educational system [2]. Findings from [31] indicated that almost all public schools in the United State of American have incorporated computers into the classroom for effective teaching and learning. Even though it could be argued that ICT cannot solve all the challenges in education and in the classroom, it is worth knowing that when it is strategically and effectively integrated into the classroom based on the context of concepts and the interest of the students, it could be a good motivational tool for engaging students in a meaningful learning experience for better academic achievement in biology.

Research conducted in the area of integrating ICT into classroom teaching proved that ICT integration in teaching is more effective than the traditional or deductive method of teaching ([14], [1], [34]). According to [22] the incorporation of ICT and its integration in classroom teaching and learning is no longer a challenge to developed countries such United States of American and the United Kingdom. However, the case is different in most African schools, especially in Ghana. Despite the incorporation of information and communication technology into the primary school, junior high school and senior high school curriculum in the current educational system of Ghana, there is little or no use of ICT as a tool for teaching in the primary, junior high and senior high schools and Colleges of Education in Ghana. This could be due to too much emphasis on teacher-centered approach in teaching in Ghana without viewing ICT as a tool that could serve as a complementary to the other teaching approaches for an effective and meaningful learning experience in biology by learners. Much concentration is on exposing junior high and senior high school students to basic technological knowledge but it should be noted that the integration of ICT into the curriculum of the educational system alone does not guarantee students 'academic achievement because the acquisition of technological knowledge is not sufficient for promoting effective teaching and learning in the classroom ([5], [12]). The essence of biology and education in general is to bring changes in the behavior of learners and this is achieved through appropriate learning experience which is rooted in teaching with appropriate methodologies [28].

Ref. [14] conducted a research to evaluate the effectiveness of ICT and lecture method of teaching in the classroom and stated that ICT is more effective than lecture method in terms of students' academic achievement in the

classroom. According to [16] the integration of ICT in teaching can enhance learning by making teaching less dependent on the teacher and by allowing students to search for most of the information in order to make learning meaningful thereby maximizing academic achievement in science**.** Research conducted by [15] indicated that the integration of ICT in classroom teaching has the ability to engage students in the learning process and subsequently improving their academic achievement. Ref. [20] conducted a comparative study on the effectiveness of computer-assisted instruction and conventional teaching methods in biology on senior high school students and indicated that ICT has the potential for improving students' academic achievement in biology. They selected two biology classes from randomly selected schools and administer a pretest-posttest using a nonequivalent quasi-experimental design. They taught one class using ICT and the other class conventional approach. They stated that students instructed by the conventional approach performed better on the posttest than those instructed by ICT. However, they indicated that the performance of students taught by ICT within the experimental group improved on the posttest. This seems to suggest that ICT has the potential for improving students' performance in biology. However, [7] was of the view that the use of ICT in teaching distracts students and does not permit them to stay focus on their learning. Contrary to the finding of other researchers which shows the effectiveness of ICT as an instructional tool over the conventional approach, [1] study proved that the traditional method of instruction is more effective when compared to ICT method. Thus, whereas some research found ICT to be effective in terms of students' academic achievement than the conventional approach, others found otherwise.

One of the complex topics in most biology curricula as reported in the literature is cellular respiration ([10], [32], [34]. Cellular respiration is considered to be one of the most complex and abstract concepts in the sciences. This is because concepts in cellular respiration are biological processes that consist of both macro and sub-microscopic levels of representation that are not visible to the naked eyes. Such processes consist of a sequence of sub-microscopic strands in the eukaryotic cell cytoplasm and mitochondria. It also involves glycolysis and Krebs cycle. The process begins with glucose and results in the production of adenosine triphosphate (ATP), which are molecular units for the transformation of energy in organisms [10]. In fact, the process of cell respiration goes on in all the cells of both animals and plants. This makes cellular respiration so important for students to study at all levels of education. However, researches [3] indicate that cellular respiration presents some difficulties in teaching and learning. Students are known to have challenges and low interest in understanding conceptually concepts in cellular respiration [3]. Both teachers and students, surprisingly complain of cellular respiration as one of the most complex and difficult topics in the biology curriculum [21]. A number of reasons have been proposed to be responsible for why cellular respiration is considered to complex. Firstly, the entire process of respiration is highly abstract simply because of its invisible nature and also because it contains many distinctive steps that function in a complex system making it confusing to comprehend [10]. Secondly, the processes involved make it difficult for students to relate the complex concepts to each other and to everyday life activities [3]. Thirdly, students are confronted with the challenge of having to learn too many detailed concepts and a number of complex vocabularies [21]. Finally, students develop some common misconceptions in the process of learning cellular respiration [3]. It is against this background that a robust teaching method is needed to help students overcome these problems.

Cellular respiration was chosen for investigation due to the following reasons. The first reason for choosing this concept is that it is considered as one of the core concepts in biology, which until recently has received a very little amount of attention in terms of research [29]. The second reason is that available research studies show several students' learning difficulties linked to this concept, which include confusion with the everyday usage of the terms respiration and breathing, everyday ideas about energy, the biochemical nature of the concept which implies that it requires understanding at the cellular, sub-cellular and molecular level and consequently the problem of connecting these levels of biological organization [32]. The final reason for selecting cellular respiration was that it refers to different processes: aerobic respiration and many variants of anaerobic respiration, such as lactic acid and alcoholic fermentation [32].

The question now is how can students be aided to overcome such difficulties? It requires the use of effective teaching methods to counter such difficulties. This study employed the use of ICT in teaching students to ascertain their effectiveness in helping them understand concepts in cellular respiration. The use of ICT in the context of this study involves the use of simulations and videos in teaching cellular respiration concepts like glycolysis and Krebs cycle which is considered to be one of the most difficult and abstract topics in biology [10]. Simulations and videos are widely used nowadays in science education. Simulations, in particular, are mostly used to study the outputs of complex systems resulting from certain input variables and by interactively changing conditions, variables, or courses of action (laws), the output can be adjusted. In biology education, however, complex systems are made up of a number of parts on many different, yet interwoven organizational levels ranging from microscopic to macroscopic levels and often without central control [10]. Videos on the other hand have also proven to be very effective in improving students' understanding of concepts. The attractiveness of videos in teaching comes from the combination of images and sounds. As such it will be able to generate an influential medium that can be used by teachers to help explain concepts while at the same time able to instruct students with content that provides multiple senses.

These would certainly assist teachers in making the explanation of abstract concepts and processes easy through the use of visualization that can be provided by videos [33].

This study, therefore, sought to determine the effectiveness of integrating ICT into the teaching of cellular respiration involving glycolysis and Krebs cycle at the Colleges of Education in Ghana. This study actually compared the integration of ICT into teaching and the traditional teaching approach on students' achievement in cellular respiration.

*Research Questions*

The study found answers to the following questions:

1. What is the difference in performance between students taught with ICT and those taught with the conventional approach of teaching cellular respiration?
2. What are the perceptions of students towards the use of ICT in teaching and learning biology?

*Theoretical framework*

The idea of using ICT as an instructional tool in the classroom dates back in the early 1960s [18]. The University of Illinois in the United State of American around the 1960s first made the attempt of integrating ICT into classroom teaching by producing Program Logic for Automatic Training Operations (PLATO) [17]. According to [4] there are various ways by which computers can be used in education to improve the quality of teaching, and for the technological development of learners. They believe teachers can assist students to develop technological skills by exposing them to basic computer skills which could be considered as teaching computers as a subject or teachers using ICT as a tool for effective delivering of content or subject matter to students. Ref. [30], also categorizes the uses of ICT and its associated technologies in education into three such as: Learning through information and communication technology where the computer becomes the whole learning environment by providing learning materials or assist the teacher in delivering lessons or transmitting the subject matter to the learners.

Using computers to support learning processes where the students use the computer to do homework, search for information online, and using spreadsheets to present reports which could be termed as learning with the computer as stated by [4]. Ref. [27], also coined this category as learning about the computer in which students are exposed to basic technical knowledge and skills thereby helping them to acquire computer literacy and its associated terminologies. This study, therefore, seeks to employ ICT as an instructional tool in delivering the subject matter to students.

It must also be pointed out that computerize teaching takes its root from the behaviorist theory of learning perspective [11]. Skinner's theory of learning provides the theoretical basis for the development of teaching machines and computer-assisted instruction [25]. He started by experimenting with teaching machines that made use of programmed learning and these teaching machines were one of the first forms of computer-based learning. Behaviorism's influence is still strong in some areas of science, engineering, and medical training. Skinner propounded the operant conditioning theory of learning. According to [24], operant conditioning is a method of learning that occurs through rewards and punishments for behavior. Through operant conditioning, an individual makes an association between a particular behavior and a consequence. Skinner's ideas of operant conditioning came after conducting experiments using animals which he placed in a 'Skinner Box' which was similar to Thorndike's puzzle box. He showed that pigeons could be trained in quite complex behavior by rewarding particular, desired responses that might initially occur at random, with appropriate stimuli, such as the provision of food pellets (reinforcement). Skinner believed that positive reinforcement strengthens a behavior by providing a consequence an individual finds rewarding. Because of the effectiveness of operant conditioning theory in training animals, Skinner was confident that his principles could be applied to the complex behavior of humans for effective learning especially with young people. According to [11], students become active in the learning process in an operant conditioning situation. This means that students take charge of their learning and it is the duty of the teacher to provide the right stimuli for the students to respond positively. According to [27], Skinner's reinforcement theory forms the basis for computerizes teaching and learning in the classroom. Students are motivated to engage in the learning process when audio-visual and pictures are used during teaching and learning. Behaviorism, with its emphasis on rewards and punishment as drivers of learning, is the basis of populist conceptions of learning among many parents and politicians. It should also be noted that computer scientists are interested in automating learning. It is not surprising then that there has also been a tendency, until recently, to see technology, and in particular computer-aided instruction, as being closely associated with behaviorist approaches. Basically, it could be argued that the integration of ICT in teaching and learning in our contemporary classroom takes its root mostly from the behaviorist theory of learning due to the principles of practice and reinforcement. Teachers, therefore, should endeavor to incorporate behaviorist learning theory in teaching to facilitate effective teaching and learning in the classroom for better academic achievement in cellular respiration which is considered as an abstract topic in Senior High School biology [26].

## II. RESEARCH METHODOLOGY

The quasi-experimental research design which followed a quantitative approach in data collection and analysis was employed in this study. The design was used to compare the effectiveness of ICT and the traditional methods of teaching in terms of students' academic achievement in cellular respiration. This research used a quasi-experimental

design since the participants in both the experimental and control groups were in their natural settings without randomization [9]. The pretest-posttest non-equivalent group design was used to collect data to determine whether there was a significant difference between the academic achievements of students taught using ICT as an instructional tool and those taught using the traditional approach. The experimental group (treatment) was taught with the aid of computer tools where videos, simulations, diagrams and pictures on each step of glycolysis and Krebs cycle were projected on the board followed by a discussion with the teacher serving as the facilitator of the discussion whiles the control group was taught by the traditional approach of teaching where the teacher was more or less on top of issues in the learning process while the students were more or less passive observers even though the content to be taught and learned was the same for the experimental and the control groups. Two lesson plans each was developed for both the experimental and control groups (i.e., glycolysis and Krebs cycle) based on what has been prescribed in the Colleges of Education biology syllabus. The students were taught the topic by the researchers based on the developed lesson plans for the two groups. Each group was taught between two hours' interval on the same day. This was due to the distance between the two selected schools. Posttest was conducted for both groups after teaching them the concept. After teaching the two lessons, the 10 item questionnaire on perceptions was later administered to the experimental group.

The participants for this research consisted of 82 second-year science students from two Colleges of Education in the Central Region of Ghana who offers the general science programme. The two schools have two science classes each and so one was randomly sampled to take part in the study. Before the intervention, a pre-test was administered to all students in the two classes from each selected school. There were 41 students each in both the experimental and control groups. The teaching methodologies (ICT and traditional approaches) were considered to be an independent variable while the academic achievement of students was considered to be the dependent variable.

Three research tools were constructed by the researchers and used for this study. They include pretest and posttest achievement test items, and a five-point Likert scale questionnaires. The pre-test was developed on the living cell which both selected classes were already taught in the first year. The pretest was administered to find out whether the two groups were performing at par. The posttest, on the other hand, was based on the topic of cellular respiration involving glycolysis, which was taught during the experiment. This topic was chosen because it is considered as one of the most difficult and abstract topics in biology and both teachers and students find it difficult to comprehend due to the enzymatic reaction involved [26]. Again, the aim of choosing this topic was to determine which of the two teaching strategies would be effective in teaching cellular respiration to maximal students' performance. Each of the tests consisted of 20-item multiple-choice questions. These tests were aimed at determining the performance of students before and after the experiment. For content validity, the table of specifications developed and used to construct the test items so that all the constructs are catered for in the instrument. The tests were also given to three experienced senior college tutors in biology and one biology lecturer for review. The achievement test items were pilot tested with final year students in one College of Education in the Greater Accra region. To determine the reliability of the tests, the Kuder-Richardson 20 formula was used because the items were scored dichotomously. The reliability coefficients of the pretest and posttest were found .75 and .84 respectively. The five-point Likert scale questionnaire consisted of 10 items that sought students' perceptions of the impact of ICT as an instructional tool on them. Students were asked to state their view on each item by ticking the extent to which they agree such as strongly agree, agree, undecided, disagree, and strongly disagree.

## III. RESULTS

*The difference in performance between students taught with ICT and those taught with the conventional approach of teaching cellular respiration*

To determine whether there were differences in performance between the control and experimental groups, initial assumption testing of the scores were determined. Assumption testing for normality, independence of observation, random sampling of schools, and Levene's test for equality of variance [$F = 1.018$, $p = .316$] were performed and no violations were detected. The two groups' pretest scores were analysed using the independent samples t-test to ascertain the level of performance of the groups because of its usefulness when comparing the mean scores of two different (independent) groups of people or conditions. The results of the independent samples t-test for the control and experimental groups are presented in Table 1. As shown in Table 1, there was no statistically significant differences in mean scores between the control [$M = 12.10$, $SD = 2.154$] and experimental [$M = 12.90$, $SD = 2.518$, $t(80) = 1.555$, $p = .124$] groups with respect to the pretest. This implies that students in the two groups started the treatment with similar levels of background knowledge of concepts in biology.

Table 1: Results of independent sample t-test on students' pretest scores for experimental and control groups

| Groups | N | Mean | SD | t | df | p-value |
|---|---|---|---|---|---|---|
| Control | 41 | 12.90 | 2.518 | | | |
| | | | | 1.555 | 80 | .124 |
| Experimental | 41 | 12.10 | 2.150 | | | |

Since the two groups pretest scores were similar statistically, one would have expected that the two groups' posttest scores are compared in a similar manner with the independent samples t-test. However, since the pretest and posttest items are not the same, analysis of covariance (ANCOVA) was

used. The posttest scores of the two groups were compared with the pretest scores used as covariates. The descriptive analysis of the control group is M = 14.90, SD = 1.998 and that of experimental group is M = 12.85, SD = 2.242. Table 2 shows the ANCOVA results of the control and experimental groups.

**Table 2: Results of analysis of covariance (ANCOVA) for the two groups**

| Source | Type III Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|
| Corrected Model | 89.303[a] | 2 | 44.651 | 9.868 | .000 |
| Intercept | 607.765 | 1 | 607.765 | 134.312 | .000 |
| Pretest | 3.254 | 1 | 3.254 | .719 | .399 |
| Posttest | 89.267 | 1 | 89.267 | 19.727 | .000 |
| Error | 357.478 | 79 | 4.525 | | |
| Total | 16240.000 | 82 | | | |
| Corrected Total | 446.780 | 81 | | | |

a. R Squared = .200 (Adjusted R Squared = .180)

As shown in Table 2, there was a statistically significant difference in mean score between the control and experimental groups [$F(1, 79) = 19.727$, $p < .001$]. The experimental group outperformed their counterparts in the control group on concepts in cellular respiration. This implies that teaching cellular respiration with the ICT method is more effective than the traditional method.

*Perceptions of students towards the use of ICT in teaching and learning biology*

Responses from the questionnaire were analysed using frequencies and percentages and finally concluded with the grand mean. As shown in Table 3, the majority of the students agree to the fact that using ICT in teaching and learning is very effective than the traditional methods of teaching used often by their tutors. A number of students were however not decided as to whether they prefer learning with ICT while minorities disagree with the assertion that ICT plays a key role in teaching and learning. It implies that students are of the view that teaching and learning with ICT is very effective (Grand mean = 4.13).

## IV. DISCUSSION

The results of this study showed that students who were instructed through the integration of ICT into teaching outperformed their counterparts who were instructed through the traditional method. This could be a result of students in the experimental group being exposed to videos and simulations which enabled them to see real processes involved in cellular respiration. This finding confirms the study by [14] who found the use of ICT to be more effective than the lecture method in terms of students' academic achievement in the classroom.

This finding, however, contradicts the study of [13] that the traditional method of instruction is more effective when compared to the ICT instructional approach. This study, therefore, suggests that ICT has the potential of improving students' academic performance when properly integrated into the classroom, an outcome similar to [15] that integration of ICT in the classroom teaching has the ability to engage students in the learning process and subsequently improving their academic achievement.

Table 3: Results of students' perceptions of the use of ICT in teaching and learning biology

| **Statement** | **SA** | **A** | **UN** | **D** | **SD** |
|---|---|---|---|---|---|
| 1. Using ICT in teaching biology is more effective than the traditional approach. | 6(14.6) | 16(39.0) | 9(22.0) | 7(17.1) | 3(7.3) |
| 2. I feel more motivated to learn when the teacher shows videos on the concept he is teaching. | 18(43.9) | 14(34.1) | 5(12.2) | 2(4.9) | 2(4.9) |
| 3. ICT helps me to understand abstract/difficult concepts in biology. | 23(56.1) | 13(31.7) | 3(7.3) | - | 2(4.9 |
| 4. ICT makes learning more interesting and enjoyable in biology. | 13(31.7) | 20(48.8) | 4(9.8) | 1(2.4) | 3(7.3) |
| 5. The use of ICT in teaching leads to greater student involvement in the teaching and learning process. | 14(34.1) | 20(48.8) | 5(12.2) | 1(2.4) | 1(2.4) |
| 6. I wish all the teachers should be using ICT in teaching. | 15(36.6) | 19(46.3) | 6(14.6) | - | 1(2.4) |
| 7. I usually use my mobile phone to search for information on the internet. | 22(53.7) | 13(31.7) | 5(12.2) | - | 1(2.4) |
| 8. I believe that ICT can really improve my understanding of biological concepts than the traditional teaching approach. | 20(48.8) | 16(39.0) | 1(2.4) | 2(4.9) | 2(4.9) |
| 9. The use of ICT resources stimulates students learning | 22(53.7) | 13(31.7) | 3(7.3) | 1(2.4) | 2(4.9) |
| 10. I pay less attention in class when ICT is used in teaching. | 25(61.0) | 12(29.3) | 3(7.3) | 1(2.4) | - |

*Grand mean = 4.13; Numbers in bracket are percentages*

Also, the outcome is similar to [20] that computer-assisted instruction has the potential for improving students' academic achievement in biology.

The results from this study also showed that students in the experimental group had a positive perception towards the use of ICT as an instructional tool. This finding is in agreement with [8] and [23] that computer-assisted instruction improves perception towards science positively. This finding is in sharp contrast to [7] that the use of ICT in teaching biology distracts students and does not permit them to stay focus on their learning. This is an indication that ICT has the potential of improving students' academic achievement when properly integrated into the classroom as a supplement to the other teaching approaches.

## V. CONCLUSIONS

From the findings of this study, it can be concluded that the use of ICT in teaching cellular respiration is more effective than the traditional approach of teaching. This implies that ICT has the ability to improve the performance of students within the classroom if properly and strategically integrated. Furthermore, it can be concluded that ICT has a positive effect on students learning and that students have shown positive perception towards the use of ICT in teaching and learning biology.

## VI. RECOMMENDATIONS AND IMPLICATIONS FOR TEACHING

Based on the findings of this study, it is recommended that tutors at the Colleges of Education should integrate ICT into the teaching concepts to aid easy understanding of concepts. ICT should always be integrated into teaching to serve as a supplement to the traditional teaching approaches. Again, students' perception of any method used for teaching should be sought to gain insight as to whether it is helping them or not. This will give tutors prompt feedback on any action they take in the classroom to promote learning.

This study recommended that a similar study should be conducted with at least five different schools since this study used only two different schools. This when done can properly as certain the effectiveness of the integration of ICT into teaching.

## REFERENCE


[1] Albirini, A. (2006). 'Teachers' attitudes toward information and communication technologies: The case of Syrian EFL teachers'. *Computers & Education, 47*, 373-398.

[2] Baggott La Velle, L., Wishart, J., McFarlane, R. B., & John, P. (2007). Technological and learning with ICT within the subject culture of secondary school science. *Research in Science & Technological Education, 25*(3), 339–349.

[3] Briggs, B.; Mitton, T.; Smith, R.; Magnusson, T. (2009). Teaching cellular respiration and alternate energy sources with a laboratory exercise developed by a scientist-teacher partnership. *Am. Biol. Teach, 71*, 164–167.

[4] Bybee, R. W., Poewll, J. C., & Trowbridge, L. W. (2008). *Teaching secondary school: Strategies for developing scientific literacy* (9th ed.). London: Pearson Prentice Hall.

[5] Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Journal of EducationalTechnology & Society, 13*(4), 63–73.

[6] Chalmers, P. A. (2000). User interface improvements in computer-assisted instruction, the challenge. *Computers in Human Behavior, 16*, 507–517.

[7] Cox, M. J. (1999). Motivating pupils through the use of ICT. In M. Leask, & N. Pachler,(Eds.), *Learning to teach using ICT in secondary school*. London: Routledge.

[8] Cotton, K. (1991). *Computer-assisted instruction (No. 10)*. The School Improvement ResearchSeries. Portland.

[9] Creswell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methodsapproaches (3rd ed.). London: Sage.

[10] Dam, M., Ottenhof, K., Boxtel, C. V., & Janssen, F. (2019). Understanding cellular respiration through simulation using Lego® as a concrete dynamic model. *Education Sciences, 9*(72), 1-21.

[11] Edwards, T. O. (1970). *Optimizing computer-assisted instruction by applying principles of learning theory*. Report available from ERIC. http://eric.ed.gov/ERICWebPortal/Record Detail? accno¼ED105899

[12] Hardy, M. (2010). Enhancing preservice mathematics teachers' TPCK. *Journal of Computers inMathematics and Science Teaching, 29*(1), 73–86.

[13] Imhanlahimi, O. E., & Imhanlahimi, R. E. (2008). An evaluation of the effectiveness of computer-assisted learning strategy and expository method of teaching biology: A case study of lumen Christi international high school, Uromi, Nigeria. Journal of Social Science, 16(3), 215–220.

[14] Kausar, T., Choudhry, B. N., & Gujjar, A. A. (2008). A comparative study to evaluate theeffectiveness of computer-assisted instruction (CAI) versus classroom lecture (CRL) for computer science at ICS level. *The Turkish Online Journal of Educational Technology,7*(4), 11–21.

[15] Kulik, J. A., & Bangert-Drowns, R. L. (1983). Effectiveness of technology in precollege mathematics and science teaching. *Journal of Educational Technology Research, 12*(2), 137–158.

[16] Mbwesa, J. (2014). Transactional distance as a predictor of perceived learner satisfaction in distance learning courses: A case of Bachelor of Arts program, University of Nairobi, Kenya. *Journal of Education and Training Studies, 2(2), 176-188.*

[17] Molnar, A. S. (1997). Computers in education: A brief history. *The Journal of Technological Horizons in Education, 24*(11), 63-68. Retrieved from http://thejournal.comCAI Effect on Rural Algebra I Students 35.

[18] Noor-Ul-Amin, S. (2013). Effective use of ICT for education and learning by drawing onworldwide knowledge, research, and experience: ICT as a change agent for education (A Literature review). *Scholarly Journal of Education, 2*(4), 38-45.

[19] Obanya, P. A. (2009). *Dreaming, living, and doing education*. Ibadan: Educational Research andStudy Group.

[20] Owusu, K. A., Monney, K. A., Appiah, J. Y., & Wilmot, E. M. (2010). Effects of computer-assisted instruction on the performance of senior high school biology students in Ghana. Computers & Education, 55,904–910.

[21] Patro, E. T. (2008). Teaching aerobic cell respiration using the 5 Es. Am. Biol. Teach, 70, 85–87.

[22] Salaway, G., Caruso, J. B., & Nelson, M. R. (2008). *The ECAR study of undergraduate students and information technology 2008 (Vol. Research study, 8)*. Boulder, CO, EDUCAUSE: Centre for Applied Research. Retrieved on 23/06/2019. Available from. http://www.educausd.edu/ecar.

[23] Selwyn, N. (1999). Students' attitudes towards computers in sixteen to nineteen education. *Education and Information Technologies, 4*(2), 129–141.

[24] Skinner, B. F. (1938). *The behavior of organisms: An experimental analysis*. New York: Appleton-Century-Crofts.

[25] Skinner, B. F. (1968). *The technology of teaching*. New York: Appleton-Century-Crofts.
[26] Songer, C. J. &Mintzes, J. J. (1994). Understanding cellular respiration: An analysis of conceptual change in college biology. Journal of Research in Science Teaching 31(6), 621–637. Wiley Periodicals, Inc.http://dx.doi.org/10.1002/tea.366031060
[27] Tabassum, R. (2004). Effect of computer-assisted instruction (CAI) on the secondary school student achievement in science. Ph.D. Thesis, Rawalpindi, Pakistan: University of Arid Agriculture. Retrieved on 23/06/19. Prr.hec.gov.pk/thesis/235.pdf
[28] Tebabal, A., & Kahssay, G. (2011). The Effects of a student-centered approach in improving students' graphical interpretation skills and conceptual understanding of kinematical motion. *Latin-American Journal of Physics Education, 5*(2), 374-381.
[29] Ummels, M. H. J., Kamp, M. J. A., de Kroon, H., & Boersma, K. Th. (2015). Designing and evaluating a context-based lesson sequence promoting conceptual coherence in biology. Journal of Biological Education, 49(1), 38–52.
[30] Webb, M. (2002). Pedagogical reasoning: Issues and solutions for the teaching and learning of ICT in secondary schools. *Education and Information Technologies, 7(*3), 237-255.
[31] Wells J, Lewis L, Greene B (2006) Internet access in U.S. public schools and classrooms: 1994-2005 (Highlights) (FRSS No. 2007-020). National Center for Education Statistics, Wash
[32] Wierdsma, M., Marie-Christine Knippels, M., van Oers, B., & Boersma, K. (2016). Recontextualizing cellular respiration in upper secondary biology education. Characteristics and practicability of learning and teaching strategy. *Journal of Biological Education, 50*(3), 239–250.
[33] Yousef, A. M. F., Chatti, M. A., & Schroeder, U. (2014). The state of video-based learning: A Review and future perspectives. *International Journal on Advances in Life Sciences, 6*(3 & 4), 122-135.
[34] Young, S. C. (2003). Integrating ICT into second language education in a vocational high school. *Journal of Computers Assisted Learning, 19*, 447-461.

.