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Assessing the Impact of Integrating Information and Communication Technology on Senior High School Students' Achievement in Genetics

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SUMMARY

The use of digital technologies in teaching and learning has proven to be effective in aiding students' understanding of difficult concepts. Hence this study sought to find the effectiveness of ICT in teaching concepts of genetics which have been indicated as one of the biology concepts Ghanaian senior high school students find challenging. The study used two groups: the experimental group and the control group. The instrument used for data collection is an achievement test. A pre-test was administered to both groups to ascertain their level of achievement. The groups were then taught genetics, followed by the post-test. The experimental group was taught using ICT tools, while the control group was taught using the traditional teaching method. The research findings revealed that students taught using ICT performed better than those taught by the traditional teaching method. Based on the findings, it was concluded that using ICT tools in teaching genetics could serve as an appropriate means for teaching genetics since it aided in improving students' understanding of genetic concepts. Hence, it is recommended that teachers adopt ICT in their teaching methods rather than the traditional method. Also, school leaders and policymakers should also provide the needed support systems to enhance ICT integration practices.

Keywords: Genetics, Senior high school, ICT integration, Technology in education, Students' achievement

INTRODUCTION

In the 21st century, genetics is applied in almost every aspect of life to make the world better (Thörne, 2012). The principle in gene technology is applied in a wide range of industries such as agriculture, health, mining, textile production, and environmental protection sectors that are key to the sustainability of life on earth. Hence, there simply cannot be any meaningful development in virtually any area of life without knowledge of genetics. It is, therefore, crucial to prepare the public for the increasing accessibility of genetic information and education (Collins et al., 2003; Whitley et al., 2020).

Among the science subjects studied by students in senior high schools, biology is one of the popular choices of students (Ahmed & Abimbola, 2011). Though most students find biology to be a more interesting science subject, some topics are perceived to be challenging for students to learn. A key among them is molecular genetics. Tekkaya et al. (2001) found that Turkish secondary school students considered genes, chromosomes, mitosis, and meiosis difficult concepts. A study by Johnstone & Mahmoud (1980) revealed that the topics found to be difficult by most students are related to genetics (DNA and RNA, gametes, and genes). First-year undergraduate biology major students in Indonesia have indicated that genetics was one of the most difficult topics they studied in their senior high school biology curriculum (Fauzi & Mitalistiani, 2018). In Zambia and Barbados, both teachers and students have classified genetics as one of the difficult topics in the secondary school biology curriculum (Haambokoma, 2007; Ogunkola & Samuel, 2011). Across all contexts, the reoccurring causes of this difficulty are the abstract and complex molecular concepts (Fauzi & Mitalistiani, 2018; Ogunkola & Samuel, 2011; Tekkaya et al., 2001). Thus, most of these concepts need practical and visual presentation for better understanding.

In the Ghanaian education system, senior high school (SHS) biology consists of several topics like anatomy, physiology, genetics, and ecology. While all SHS students are introduced to genetics, science students who select elective biology as one of their major subjects learn genetics in detail. Regardless of the need for the advancement of the application of the concept of genetics in our contemporary world, our future scientists and senior high school students find it difficult to understand such concepts (Quainoo et al., 2021). Reports on the annual senior high school biology have indicated that there is a level of difficulty in some biology concepts for students. The chief

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Examiners' reports on biology in the past decade have always revealed the poor performance of students in answering questions on genetics that form part of the assessment process (West African Examination Council WAEC, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020). Analysis of the WAEC chief examiners' report from 2011 to 2020 revealed that concepts of genetics have consistently been classified among students' weaknesses and poor performance. From 2011 to 2016, Chief examiners' reports have featured concepts such as the genetic makeup of cells such as DNA, RNA, and chromosomes as well as genetic crossing, polygenic inheritance, sex-linked characters, and molecular basis of blood transfusion, which are concepts of genetics were reported as difficult for students. In the same sequence, 2017 Chief Examiners reported that candidates showed a lack of adequate knowledge of the subject of genetic diagram construction in the biology examination. The 2018 report highlighted variations among concepts that marked students' weaknesses and unsatisfactory performance in the biology examination. In 2019, the chief examiner categorically stated that students performed poorly in questions on genetic crossing and that few were able to provide accurate standard genetic diagrams. The 2020 report featured students' inability to explain the concept of crossbreeding. Thus, both research from students' perspectives and students performance in examinations have confirmed genetics as one of the biological concepts students fin challenging.

With these present-day benefits and prospects of genetics in our society, it is therefore important to act quickly to prepare our students to have a broader understanding and mastery over genetics as a topic to enable them to make incisive decisions. Worldwide research has shown that information and communication technology (ICT) can lead to improving students' learning as well as better pedagogical practices and has the potential to prepare students for life, including biology education.

ICT in Education

The emergence of the internet as an educational tool has given rise to the quality of education experienced in many parts of the world, with many more countries still catching up with current trends in education and schooling (Fu, 2013). According to Wakhaya (2010), ICT is not a separate entity but a resource in pedagogical instruction. Integration, therefore, goes beyond computer literacy to include the preparation, use, selection, and operation of appropriate ICT materials. Therefore, schools and other educational institutions which are supposed to prepare students to live in "a knowledge society" need to consider ICT integration in their curriculum (Ghavifekr et al., 2012). Pedagogical integration of ICT in education is "a use that permits either enhanced learning or enhanced teaching" (Mostafa et al., 2017). Mahmud et al. (2008)define ICT integration as the process of determining where and how technology fits in the teaching and learning scenario.

Integrating ICT in the teaching and learning process is a pedagogical practice of constructivists, especially in science classrooms (Hughes, 2013). Through ICT, new educational approaches can be applied and can also provide speedy dissemination of education to target groups. Several studies on integrating ICT in science, as well as biology teaching and learning, have been guided by the social constructivist theory due to the collaborative teaching and learning environment due to the opportunity ICT gives both teachers and students to interact with each other (Mwanda et al., 2017).

The student and teacher interaction with ICT tools to facilitate teaching and learning is characterized by the constructivist approach to teaching and learning. ICT tools in teaching allow the learner to take individual initiative for learning through the interacting process as it provides a collaborative environment for teaching and learning(Chand, 2018). The process of retrieving information online, preparing lessons and disseminating it in a variety of modes for students to interact in the classroom infers a constructivist teaching approach (Mwanda et al., 2017). Teaching and learning with ICT specific to internet accessibility will make the teaching and learning knowledge borderless and create a virtual learning environment for both teachers and students (Ghavifekr et al., 2014). Thus, teaching with the aid of virtual ICT tools allows easy teaching and learning of concepts without abstraction. In sum, ICT integration facilitates cooperative learning among students and makes concepts simple and real to them.

Integration of ICT in Teaching Sciences

Knowing what ICT tools and what ICT tools to adopt for teaching a particular concept creates a conducive environment for learning to take place. For some time now, science education reforms have emphasized the need for integrating computer technologies into learning and teaching (Jang, 2008). Application program instructions are usually used in a computer during ICT integration to accomplish tasks and a properly crafted ICT Integrated lesson ICT and pedagogy are molded into one entity. As a result, the quality of the lesson realizes improved in pedagogy (Ong'amo et al., 2015). Technology in science teaching and learning has the potential to bridge the gap between theory and practice (Polly & Binns, 2018). Thus, integrating ICT in teaching sciences enables students to have experience of the scientific concepts.

Several research findings in the literature show how useful ICT have become to science teaching and learning. Research by Ong'amo et al. (2015) revealed that biology, a component of scientific discipline, is best taught by incorporating teaching and learning resources, including ICT as a media resource. According to Çığrık & Ergül

(2009), using computers in teaching has led to an improved teaching quality which in turn leads to better learner achievement. The potential value of ICT in enhancing quality learning experiences and transformation of pedagogy are some of the factors driving ICT integration in teaching Biology (McNair & Galanouli, 2002). The integration of ICT tools in teaching makes it easier to learn biology by creating a conducive instructional process that facilitates learning (Senthilkumar et al., 2014). Hence, researchers and education specialists have recommended that teachers teach difficult and complex concepts using computer-assisted instruction.

ICT in Senior High School Education in Ghana

Ghana has taken proactive steps to enhance teaching and learning in schools, including ICT integration in education policy. As such, educational institutions have alluded to adopting ICT to facilitate as a teaching aid in teaching various subjects (Boahen & Atuahene, 2020). The Ministry of Education, in collaboration with the Ghana Education Service, is also providing support systems to ensure ICT integration in schools. Secondary schools in Ghana have been resourced with access to an open internet that helps teachers to explore the internet for different forms of information and technological teaching aids such as videos, images, and simulations to facilitate teaching and learning. In addition, the has been the provision of laptops to all pre-tertiary educators as one of the initiatives to enhance ICT integration in Ghanaian schools. This one-teacher, one laptop initiative is aimed at helping teachers with ICT integration, from lesson planning to the assessment of students learning experiences.

Aligning with the changing trends in teaching and learning and the provision of support systems for ICT integration in Ghana, some senior high schools have refurbished science laboratories and installed technological devices that facilitate science teaching and learning. As such, science teachers can utilize ICT tools to aid their teaching activities. Also, some science teachers in Ghana have alluded to the significance of ICT in their teaching process (Buabeng-Andoh, 2019). In a study by Boahen & Atuahene (2020) on the perception of students and teachers in senior high schools in the Kumasi-Ashanti region on how ICT impacts teaching and learning, both students and teachers responded positively to the impact of ICT. Students responded that ICT improves their learning. This is because the use of ICT allows them to explore information in different forms to enhance their understanding of various concepts. Teachers also affirmed that the use of ICT as instructional aid facilitates the teaching and learning process. The teacher's integration of ICT gives them access to rich information and helps them teach in an interactive and cooperative way. This means the integration of ICT I not only beneficial to students but also teachers. Bayuo et al. (2022) also assessed Chemistry teachers' usage of ICT in their teaching. The authors found that teachers have positive attitude towards ICT integration and reported high frequency of technology usage among the senior high school chemistry teachers. Thus, thus there is high technology acceptance among senior high school science teachers in Ghana.

ICT-integrated Teaching and Students' Academic Achievements in Sciences

The integration of ICT has proven to enhance students achievement in secondary school sciences (physics, Biology and Chemistry) since it facilitates the teaching and learning process. Çığrık and Ergül (2009) explored the effect of simulation-based learning on Turkish students success in electrostatic induction (physics) through quasi experimental study. The findings of the study indicated an improvement and high achievement of students in the simulation-based classroom than those in traditional classrooms. Chemistry students in Nigeria who are taught with the aid of ICT tools have higher academic achievement than when taught without any ICT tools (Wallace et al., 2019). Samuel & Ikwuka (2017) also used computer animations as a treatment in an experimental study to teach secondary school chemistry. The findings of the study did not only reveal high achievement among students in the simulations class than those in traditional classrooms but also an improvement in their understanding of the chemistry concepts. Thus, the use of ICT has proven to have positive impact on students' learning of science.

The achievement of students taught with ICT tools have consistently shown to have significant impact on students' achievement in different biology concepts including those perceived to be difficult. Eyo (2018) studied the impact of using computer-assisted multimedia in teaching senior high school biology students in two educational zones in Nigeria. Using the quasi-experimental approach, the study included two experimental groups and a control group from the two educational zones. The findings indicated a strong significant difference between each of the two experimental groups and the control group. Also, in the Northwestern states of Nigeria, students taught ecological concepts with computer-assisted multimedia instruction also performed better than their colleagues taught with traditional expository method (Bello et al., 2022). A similar study was conducted by Bilesanmi-Awoderu (2006) to find out the impact technology on students learning of biology. In this study one experimental group learnt biological concepts with computer-assisted instruction, the other experimental learnt with digital biology simulated games and the control group learnt biology traditional through traditional teaching. Both experimental groups in this study also performed better than students taught with traditional method without any ICT tool. Another study by Yusuf & Afolabi (2010) which compared individualized computer-assisted instruction, cooperative computer-assisted instruction and conventional (traditional) found that students who were taught biology with individualized or cooperative computer assisted instructions have high achievement than those who had the conventional lessons.

A couple of experimental studies have also indicated the significance of ICT in teaching some science concepts in the senior high school curriculum. An experimental study by Entsie (2015) with senior high school students in Korle Klottey Municipality in Ghana showed integrating ICT in Biology teaching resulted in high performance in glycolysis lessons than their peers taught by the traditional method. Hanson et al. (2017) conducted a study in the Keta Municipality of Volta region on how adopting ICT impacts students learning of chemical bonding of the Ghanaian senior high school integrated science curriculum. The findings indicated a significant difference in the performance of students of ICT when taught with the traditional teaching approach. Students reiterated in a post-experiment study that; the use of ICT positively impacted their learning process. A study by Owusu et al. (2010) found an improvement in the performance the students taught with computer-assisted instruction when their pre-test and post-test biology achievement tests were analyzed. This means ICT has the potential to improve students learning of difficult science concepts in the science curricula including genetics in the biology curriculum.

Problem and Purpose of the Study

In a situation like ours where the dominant method of teaching science in general and biology is the lecture method because of the lack of equipped laboratories and relevant resources, it becomes necessary to look for alternative methods of instruction which will guarantee effective learning of challenging concepts like genetics. The integration of ICT has been proven to useful in teaching some science concepts (biology, physics, and chemistry) in the senior high school curriculum (both in Ghana and international context). However, there is no empirical literature on the usage of ICT for teaching genetics which has been enlisted among the difficult biology concepts in the senior high school biology concepts. Hence, the purpose of this study is to find out if these ICT tools in teaching genetics in the Ghanaian context will have any impact on student understanding of genetics since it is considered to enhance students learning of difficult concepts.

Hypothesis

H0: There will be no significant difference between the achievement of students who will be taught genetics using ICT and those who will be taught using the traditional method.

Ha: Students who will be taught genetics using ICT will have significantly higher achievement than the students who will be taught with the traditional method.

METHODS

Research design

The study adopted a quantitative research approach was used in the study. As shown in figure 1, quasi-experimental research design that employed pre-test and post-test equivalent group study (White & Sabarwal, 2014).

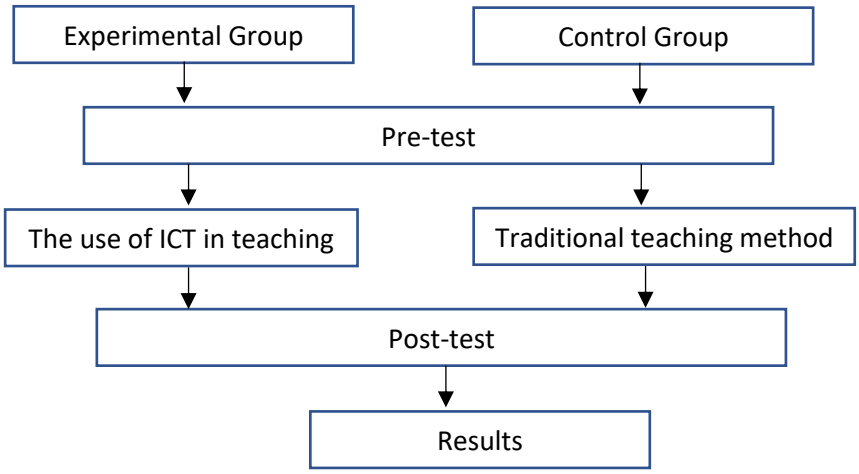

Figure 1: Flow chart of research design

Participants and Sampling

The population for this study is science students at Senior High Schools in Cape Coast, Central Region of Ghana. The study focused on students who have enrolled in biology as one of their electives. One senior High school was selected for this study. Permission to include students in this stud was sought and approved by the head of science department and the biology coordinator. Two classes comprising 30 students each were used. The two classes were randomly assigned as control and experimental groups. All students voluntarily participated in the study after reading and signing consent forms which explained the purpose and methods that was used in this study.

Research Instruments

Pre- and post-achievement tests were used as a means of collecting data. A set of standardized and validated WAEC senior high school biology questions were adopted as Pretest and post-test achievement items. Each test was made up of twenty (20) items. The pre-test was used to affirm the equivalency of the two groups. The pre-test items covered cell biology, which is a foundational concept for understanding genetics. This topic was selected because enabled the researchers to also confirm the students have the relevant previous knowledge to learn and understand concepts of genetics. The post-test comprised items also covered genetics, the concept for the study. The reliability of the items to the population was tested by piloting the instrument with non-participant science students of the same level for three consecutive weeks. In all cases, over 80% of the students had the same responses.

Experimental Process

The experimental process spanned 10 weeks. This included 8 weeks of intervention and days for pre-test and post-test. The pre-test was administered to students a week before the intervention. The one-week gap enabled researchers to mark and analyze the results to ascertain the level of achievement of the two groups. Also, students were given a week to for revision before the administration of the post-test.

During the 8-week period of teaching, the experimental group had to technology-enhanced teaching, while the control group was taught with the traditional method of teaching. One of the authors taught both the experimental and control group over the 8-week period. Each of the groups had 4-period lessons (4 hours) each week. The content of the lessons were units 5 and 6 of the senior High school biology which covers introduction to genetics, the concept of inheritance and genetic variation.

The experimental group had all lessons in a biology lab where ICT devices such as teacher desktop, Liquid crystal display (LCD) projector, projector screen and audio devices were set-up. All lessons for the experimental group were aided by simulations multimedia (videos and digital images) on genetics. The simulations and multimedia used for teaching specific concepts were pre-downloaded during the planning of each lesson and verted by the authors before usage. During each of these lessons, the teacher through lessons through power point presentations. The genetic concepts were explained with the aid of the downloaded resources. The power point presentation, simulations, videos, and digital images were displayed to students with the aid of the teacher desktop set-up and the LCF projector. Students sometimes watched simulations on concepts to initiate small group discussions. Thus, the experimental group had ICT-integrated learning.

The control group on the other hand were taught with traditional method where the teacher taught the lessons without any digital support but with some diagrammatic illustrations on the whiteboard. Unlike the experimental group, students in the control group on had small group discussions based on a question or printed image or drawing on the whiteboard. Thus, control group had the traditional learning where there is no use of any digital device.

Data analysis

The data was analyzed using Statistical Package for the Social Science (SPSS), version 26.0. To find out the impact of the experimental process, descriptive group statistics and independent sample t-test analysis were used to analyze results to ascertain the difference in students' achievement in levels in both pre-test and post-test scores (Lakens, 2013; Siegel, 1957). The Pre-test conducted was scored to examine the level of achievement of each group before the instructional session and post-test. The post-test of students was also marked, and test scores were organized for analysis. Both pre-test and post-tests were analyzed and interpretated at 95% confidence level and the hypothesis was tested with 0.05 significance level (Hespanhol et al., 2019).

RESULTS

The results for both pre-and post-tests have been presented in tables alongside interpretations.

Pre-test results

This aspect of the research was to test the level of achievements of each of the groups, research, and control groups, for the study.

Table 1: Group Statistics for Pre-test Scores

Group	N	Mean	Std. Deviation	Std. Error Mean
Control group (Traditional teaching method)	30	14.13	1.358	.248

Research group (Teaching with ICT)	30	14.10	2.893	.528

Table 2: Pre-Test Score Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	9.563	.003	.057	58.000	.955	.033	.583	-1.135	1.201
Equal variances not assumed			.057	41.186	.955	.033	.583	-1.145	1.211

As shown in table 1, descriptive statistics of the control group (M =14.13, S = 1.36) and the research group (M =14.10, S = 2.89) mean score for the pre-test shows a close performance by both groups. As shown in table 2, the p = 0.003< 0.005, so the variances are not equal; hence values at the base row were used to ascertain the equality of achievement of the two groups. This means there is no significant difference between the levels of achievement of the two groups. Thus, the level of achievement of the two groups is the same.

Post-test results

This aspect of the research was to find out whether there is a significant difference between those taught using ICT and the traditional method. Thus, to find out if the use of ICT has any effect on students' achievement. The hypotheses stated for the study were used to direct the findings of these results.

Table 3: Post-Test Score Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.001	.981	-3.904	58.000	.000	-2.467	.632	-3.731	-1.202
Equal variances not assumed			-3.904	57.733	.000	-2.467	.632	-3.732	-1.202

Table 4*:* Group statistics for Post-test Scores

Group	N	Mean	Std. Deviation	Std. Error Mean
Control group (Traditional teaching method)	30	13.07	2.363	.431
Research group (Teaching with ICT)	30	15.53	2.529	.462

As shown in table 3, the results show the analysis of the post-test; from the results, the $p > 0.005$ hence there are equal variances. As a result, the values in the values corresponding to equal variances assumed were used to determine which of the hypothesis to accept or reject. As shown in table 4, there is a significant difference between the performance of students taught genetics with ICT (M =15.53, S = 2.53) and their peers who were taught by the traditional method (M = 13.07, S = 2.36), t (58) =3.90, p = .000, d = 2.47. Hence, the null hypothesis, which states that there is no significant difference between the performance of students that are taught genetics using ICT and those taught using the traditional method, was rejected since the significant difference was established.

DISCUSSION OF RESULTS

The findings of the study showed that there is a significant difference between the performance of student that was taught genetics using ICT and those taught using the traditional method. This means students taught using ICT performed better than those taught with the traditional method. Also, there was an improvement in the performance of the experimental group based on the pre-test and post-test group descriptive statistics.

The high performance of the experimental group that received teaching with ICT affirms the findings of Entsie (2015) that ICT integration in biology classrooms enhances students' understanding and, for that matter, their performance in Ghanaian schools. Similarly, the finding is in line with Ong'amo et al. (2015)study that Integration focuses on how ICT is used and how computers and the internet can be harnessed to improve the efficiency and effectiveness of teaching difficult topics in Biology. Also, Çığrık & Ergül (2009) reported that using computers in teaching improves teaching quality which in turn leads to better learner achievement. Thus, the findings of this study have confirmed the potential of ICT integration to provide conducive teaching and learning experiences to bridge the gap between theory and practice in student learning of scientific concepts (Buabeng-Andoh, 2019; Jang, 2008; Polly & Binns, 2018). The findings also align with the studies of Bello et al. (2022) and Eyo (2018) that also assessed the effect of computer-assisted multimedia instruction on students' learning and found a higher achievement than their colleagues who learnt the biology concepts without the use of ICT. Along the same lines of teaching with simulations, Bilesanmi-Awoderu (2006) found that simulation-based biology learners perform better than students who learn biology by traditional teaching.

Moreover, the improvement of the experimental group's achievement in the post-test as compared to the pre-test results for both groups affirms the findings of Owusu et al. (2010) who found an improvement in the performance of students in computer-assisted biology instructions. This improvement in the achievement of the students taught with ICT tools also reiterates the findings of Samuel & Ikwuka (2017) that revealed an improvement in students understanding of chemistry when taught with computer simulations. This means the findings of this study concur with studies conducted in difference contexts about the impact integration of ICT integration on students' academic achievement in learning secondary school biology.

CONCLUSION AND RECOMMENDATIONS

The results from the study indicate that the use of ICT in teaching genetics has a positive impact on students understanding and hence high academic achievement. This means the potential of ICT to make difficult and complex concepts easy for the student to learn is applicable to teaching and learning genetics. It is therefore concluded that the study of genetics in senior high schools can be enhanced by integrating information and communication tools in teaching.

Based on the findings it was recommended that,

1. There should be collaborative efforts by curriculum developers and school administrators to organize seminars and workshops for in-service teachers on new trends and development in the curriculum to help them improve upon their teaching methodologies and align the content with suitable ICT-integrated teaching.
2. Teachers should also be ready to adopt the use of ICT in their teaching methods rather than the teacher-centered traditional method to allow students to understand the concepts without abstraction. Thus, teachers should commit time to plan and acquire resources for teaching.
3. A similar study should be conducted in other parts of Ghana since this study is limited to the Cape Coast metropolis of the Central Region of Ghana.
4. Future studies should be long-term to enable the recruitment of participants from different to produce findings that could be more generalizable. This is because the participants of this study were delimited to students from only one school due to limited resources and time constrain.

REFERENCES

Ahmed, M. A., & Abimbola, I. O. (2011). Influence of teaching experience and school location on biology teachers' rating of the difficulty levels of nutrition concepts in Ilorin, Nigeria. *Journal of Science,*

Technology, Mathematics and Education, *7*(2), 52–61. https://jostmed.futminna.edu.ng/images/jostmed/volume_72_aprıl_2011/1.-jostmed-7_2_-april-2011.pdf#page=63

Bayuo, J., Abukari, M. A., Bornaa, C. S., Samari, J. A., & Alagbela, A. A. (2022). Utilization of Information and Communication Technology in Teaching and Learning of Chemistry at Senior High Schools in Ghana. *Contemporary Mathematics and Science Education*, *3*(2), ep22018. https://doi.org/10.30935/conmaths/12364

Bello, S., Kamar, Y. M., Yusha'u, M. A., & Abubakar, H. S. (2022). Efficacy of Computer Assisted Multimedia Instruction on students' academic performance and retention of ecology in some northwestern states, Nigeria. *Journal of Educational Research in Developing Areas*, *3*(2), Article 2. https://doi.org/10.47434/JEREDA.3.2.2022.127

Bilesanmi-Awoderu, J. B. (2006). Effect of Computer-assısted Instructıon and Sımulatıon/games on the Academıc Achıevement of Secondary School Students ın Bıology. *Sokoto Educational Review*, *8*(1), Article 1. https://doi.org/10.35386/ser.v8i1.417

Boahen, E., & Atuahene, E. (2020). Effects of ICT Integration in Kumasi High Schools, Ghana:Teachers' and students' perspective. *European Journal of Education Studies*, *7*(12), Article 12. https://doi.org/10.46827/ejes.v7i12.3534

Buabeng-Andoh, C. (2019). Factors that Influence Teachers' Pedagogical Use of ICT in Secondary Schools: A Case of Ghana. *Contemporary Educational Technology*, *10*(3), Article 3. https://doi.org/10.30935/cet.590099

Chand, B. (2018). A Constructivism Approach Towards Integration of ICT for Collaborative Learning. *Scholarly Research Journal for Humanity Science & English Language*, *6*(26). https://doi.org/10.21922/srjhsel.v6i26.11432

Çığrık, E., & Ergül, R. (2009). The investigation of the effect of simulation based teaching on the student achievement and attitude in electrostatic induction. *Procedia - Social and Behavioral Sciences*, *1*(1), 2470–2474. https://doi.org/10.1016/j.sbspro.2009.01.434

Collins, F. S., Green, E. D., Guttmacher, A. E., & Guyer, M. S. (2003). A vision for the future of genomics research. *Nature*, *422*(6934), Article 6934. https://doi.org/10.1038/nature01626

Entsie, G. (2021). *The impact of integrating information and communication technology into the teaching and learning of biology in Ghanaian Senior High Schools* [University of Education, Winneba]. https://afribary.com/works/the-impact-of-integrating-information-and-communication-technology-into-the-teaching-and-learning-of-biology-in-ghanaian-senior-high-schools

Eyo, U. E. (2018). Effects of Computer Assisted Multimedia Instruction on Senior Secondary School Students' Achievement In Biology In Two Educational Zones of Niger State, Nigeria, West Africa. *IOSR Journal of Research & Method in Education*, *8*(2), 53–59. http://www.doi.org/10.9790/7388-0802065359

Fauzi, A., & Mitalistiani, M. (2018). High School Biology Topics Perceived Difficult by Undergraduate Students. *Didaktika Biologi: Jurnal Penelitian Pendidikan Biologi*, *2*(2), Article 2. https://doi.org/10.32502/dikbio.v2i2.1242

Fu, J. (2013). Complexity of ICT in education: A critical literature review and its implications. *International Journal of Education and Development Using ICT*, *9*(1), 112–125. https://www.learntechlib.org/p/111900/

Ghavifekr, S., Afshari, M., & Amla, S. (2012). Management strategies for E-Learning system as the core component of systemic change: A qualitative analysis. *Life Science Journal*, *9*(3), 2190–2196. http://www.lifesciencesite.com

Ghavifekr, S., Razak, A. Z. A., Ghani, M. F. A., Yan, N., Meixi, Y., & Tengyue, Z. (2014). *ICT Integration In Education: Incorporation for Teaching & Learning Improvement*. *2*(2), 22. https://eric.ed.gov/?id=EJ1086419

Haambokoma, C. (2007). Nature and causes of learning difficulties in genetics at high school level in Zambia. *Journal of International Development and Cooperation*, *13*(1), 1–9.

Hanson, R., Antwi, V., & Ayim, G. (2017). The Potential of integrating ICT into the Teaching and Learning of Chemical Bonds in Senior High Schools in Ghana – A Case study. *International Journal of Scientific Research in Science and Technology*, *3*(3), 198–210. https://cir.nii.ac.jp/crid/1390290699831249408

Hespanhol, L., Vallio, C. S., Costa, L. M., & Saragiotto, B. T. (2019). Understanding and interpreting confidence and credible intervals around effect estimates. *Brazilian Journal of Physical Therapy*, *23*(4), 290–301. https://doi.org/10.1016/j.bjpt.2018.12.006

Hughes, J. E. (2013). Descriptive Indicators of Future Teachers' Technology Integration in the PK-12 Classroom: Trends from a Laptop-Infused Teacher Education Program. *Journal of Educational Computing Research*, *48*(4), 491–516. https://doi.org/10.2190/EC.48.4.e

Jang, S.-J. (2008). Innovations in science teacher education: Effects of integrating technology and team-teaching strategies. *Computers & Education*, *51*(2), 646–659. https://doi.org/10.1016/j.compedu.2007.07.001

Johnstone, A. H., & Mahmoud, N. A. (1980). Isolating topics of high perceived difficulty school biology. *Journal of Biological Education*, *14*(2), 163–166. https://doi.org/10.1080/00219266.1980.10668983

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00863

Mahmud, R., Ismail, M. A. H., Ali, W. Z. W., Nawawi, M. D. H., & Luan, W. S. (2008). ICT integration of novice and experienced teachers: Differences and similarities. *Malaysian Journal Of Education Technology*, *1*. http://merr.utm.my/id/eprint/4580

McNair, V., & Galanouli, D. (2002). Information and communications technology in teacher education: Can a reflective portfolio enhance reflective practice? *Journal of Information Technology for Teacher Education*, *11*(2), 181–196. https://doi.org/10.1080/14759390200200131

Mostafa, J., Hashemi, S. A., Sosahabi, P., & Berahman, M. (2017). *The role of ICT in learning – teaching process*. 12. http://www.worldscientificnews.com/wp-content/uploads/2017/01/WSN-72-2017-680-691.pdf

Mwanda, G., Mwanda, S., Midigo, R., & Maundu, J. (2017). Integrating ICT into Teaching and Learning Biology: A Case for Rachuonyo South Sub-County, Kenya. *International Journal of Education, Culture and Society*, *2*(6), Article 6. https://doi.org/10.11648/j.ijecs.20170206.12

Ogunkola, B., & Samuel, D. (2011). Science Teachers' and Students' Perceived Difficult Topics in the Integrated Science Curriculum of Lower Secondary Schools in Barbados. *World Journal of Education*, *1*(2), 17–29. https://doi.org/10.5430/wje.v1n2p17

Ong'amo, B., Ondigi, S., & Maundu, J. (2015). Integration of ICT in the Teaching of Biology – A Case of Selected Secondary Schools in Mumias Sub County. *Proceedings of the 4th International Conference on Education*, 391–415. http://ir-library.ku.ac.ke/handle/123456789/18315

Owusu, K. A., Monney, K. A., Appiah, J. Y., & Wilmot, E. M. (2010). Effects of computer-assisted instruction on performance of senior high school biology students in Ghana. *Computers & Education*, *55*(2), 904–910. https://doi.org/10.1016/j.compedu.2010.04.001

Polly, D., & Binns, I. (2018). Elementary Education Candidates' Integration of Technology in Science Units. *Contemporary Issues in Technology and Teacher Education*, *18*(4), 631–647. https://www.learntechlib.org/primary/p/181127/

Quainoo, B. A., Otami, C. D., & Owusu, K. A. (2021). Effect of the REACT strategy on senior high school students' achievement in molecular genetics. *LUMAT: International Journal on Math, Science and Technology Education*, *9*(1), Article 1. https://doi.org/10.31129/LUMAT.9.1.1418

Samuel, N. N. C., & Ikwuka, O. I. (2017). Effect of computer animation on chemistry academic achievement of secondary school students in Anambra State, Nigeria. *Journal of Emerging Trends in Educational Research and Policy Studies*, *8*(2), 98–102. https://doi.org/10.10520/EJC-9b95fd597

Senthilkumar, R., Sivapragasam, C., & Senthamaraikannan, B. (2014). Role of ICT In Teaching Biology. *International Journal of Research*, *1*(9), Article 9. https://journals.pen2print.org/index.php/ijr/article/view/701

Siegel, S. (1957). Nonparametric Statistics. *The American Statistician*, *11*(3), 13–19. https://doi.org/10.1080/00031305.1957.10501091

Tekkaya, C., Özkan, Ö., & Sungur, S. (2001). Biology concepts perceived as difficult by Turkish high school students. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *21*(21).

Thörne, K. (2012). *Teaching genetics - a linguistic challenge: A classroom study of secondary teachers' talk about genes, traits and proteins*. http://urn.kb.se/resolve?urn=urn:nbn:se:kau:diva-15311

Wakhaya, M. N. (2010). *Influence of the use of Information and Communication Technology on teaching and learning mathematics in secondary schools: A case of Nairobi Province, Kenya* [Thesis, University of Nairobi, Kenya]. http://erepository.uonbi.ac.ke/handle/11295/5039

Wallace, I., Ode, E. J., & Oada, I. (2019). Effects of ICT on Students' Academic Performance in Science Education. *International Journal of Science and Research Methodology*, *14*(2), 66–75. https://ijsrm.humanjournals.com/effects-of-ict-on-students-academic-performance-in-science-education/

West African Examination Council. (2011). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2012). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2013). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2014). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2015). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2016). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2017). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2018). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2019). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

West African Examination Council. (2020). *Science Resumé of the Chief Examiners' Reports for the West African Senior School Certificate Examination for School Candidates* (May/June). WAEC.

White, H., & Sabarwal, S. (2014). Quasi-experimental design and methods- Impact evaluation. *Methodological Briefs*, *8*(2014), 1–16. https://ideas.repec.org/p/ucf/metbri/innpub753.html

Whitley, K. V., Tueller, J. A., & Weber, K. S. (2020). Genomics Education in the Era of Personal Genomics: Academic, Professional, and Public Considerations. *International Journal of Molecular Sciences*, *21*(3), Article 3. https://doi.org/10.3390/ijms21030768

Yusuf, M. O., & Afolabi, A. O. (2010). Effects of Computer Assısted Instructıon (CAI) on Secondary School Students' Performance in Bıology. *The Turkish Online Journal of Educational Technology*, *9*(1), 62–69. http://files.eric.ed.gov/fulltext/EJ875764.pdf