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Instructional Strategies for Promoting Genetics Literacy for Sustainable Science Education in The Twenty-First Century

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Abstract

This paper investigated instructional strategies for effective teaching and learning of genetics for promoting genetics literacy for sustainable science education in the 21st century. The study adopted a descriptive survey design. The participants were Senior Secondary 3 biology students in Enugu Education Zone, Enugu State, Nigeria. Two research questions were answered using mean and standard deviation and two null hypotheses tested at 0.05 level of significance guided the study. The population consists of 1,986 students and 50 Biology teachers. 200 students and 20 biology teachers selected through multistage sampling constituted the sample. A 12-item structured questionnaire titled Promoting Genetics Literacy for Sustainable Science Education (PGLSS) was used for data collection. The reliability coefficient of the instrument was 0.89 obtained using Cronbach Alpha. The findings of the study showed that the use of creative critical thinking, communication, constructivist and collaborative instructional strategies were effective strategies for promoting genetics literacy needed for sustainable science (biology) education. There is no significant difference between the mean responses of teachers and students on the instructional strategies needed for promoting genetics literacy. It was recommended among others that biology teachers should adopt instructional strategies that would offer students the opportunity to participate actively in the teaching and learning process for sustainable development through science education, thereby promoting the acquisition of 21st-century skills.

Keywords: Genetics Literacy, Instructional Strategies, Science Education, 21st-century skills

Introduction

Genetic literacy plays an important role in achieving sustainable science education for the nation, Nigeria in the 21st century. The advancement of science education has become an important tool in sustainable development in Nigeria. Science is a body of knowledge that is continuously built up and revised as new evidence evolves. Science education can be viewed as the field of study that ensures the effective acquisition of knowledge of content as well as skills for practical application (Samba, Imoko & Muluku, 2020). Science occupies an important position in the school curriculum and has been studied under different subjects one of which is biology.

Biology has been recognized as a science subject that helps students understand things around them and offers them the opportunity to live healthy and rewarding life.

Ose-Aigbekaen (2020) stated that biology is the science that studies plants and animals and this involve the structure, distribution, origin, and interaction with the environment. To effectively participate in a civilized society, biology finds answers to problems related to our daily lives for instance health and environmental problems (Jose & Benjamin, 2022). It has been equally realized that biology serves as a preparatory ground for advanced learning of professional courses in fields such as medicine, pharmacy, and genetic engineering. One of the biology topics that strongly impact the nation's scientific advancement is genetics.

The 21st-century concept of genetics encourages students to understand the problems of genetics as well as learn accurate ways of explaining genetics principles. Samuel and Oka (2020) posited that genetics is the study of heredity and variation in living organisms. To have a meaningful understanding of genetics there is a need to examine the genes as well as the transmission and expression in living organisms. This can be achieved through the proper teaching of genetics using the curriculum which includes how characters are passed from generation to generation and the application of principles of heredity in medicine and agriculture. Genetics has developed into an integral part of most biological research whose findings provide a significant impact on human lives, plant breeding, and uncovering new species and new diseases. For instance, during the COVID -19 pandemic unprecedented times, there have been a lot of genetic methods applied to study the virus (Ahmad, Muhammad, Evi, Widi & Nurita, 2021). The purpose of teaching genetics is to bring a fundamental change in the behavior of students to the point of solving real-world problems and this can only be tagged as genetics literacy.

Literacy has risen over recent years to empower students in activities that facilitate the development of knowledge. It has been recognized that the concept of genetics literacy provides an opportunity for students to read, write and make informed decisions concerning socio-scientific issues that affect society (Guliz & Gaye, 2016). Genetics literacy has two outstanding components, one is related to the topics traditionally taught in the classroom such as knowledge of genes and chromosomes (Duda, 2016) while the other component of genetics deals with questions that students may encounter as citizens such as ethical questions related to genetic testing, genetic engineering and genetics modified organisms (Bernado, 2020). Genetic literacy can be viewed as the acquisition of knowledge and the application of genetics concepts to our lives. A genetics-literate student should have enough knowledge for continual informed learning about genetics and for intelligent reading of genetics articles. Therefore, it seems that the content of genetics taught in schools and the methods adopted by teachers in the teaching of the contents do not accurately represent the knowledge that is relevant to understand current socio-scientific issues.

Teaching and learning have shifted from what is happening in the classroom to students' developing solutions to problems they encounter in daily life. For the nation to flourish in this century, there is a strategic priority to emphasize technologically enhanced teaching and learning in the educational system (Ugwuanyi, 2022). This could equip

students with basic skills that enhance participatory learning by making decisions, conducting research, and promoting future career choices (Nwagbo, 2022). Incidentally, these interactive instructional strategies fall into the first category of 21st-century known as learning skills (4Cs). These learning skills include critical thinking, creativity, collaboration, and communication. To be literate in this modern world, students need to integrate innovative and technological advances to achieve digital literacy. Digital literacy is a continuous acquisition of learning and training using 21st-century skills such as collaboration, communication, creativity, critical thinking, and others (Dare, Keratithamkul, Hiwatig & Li, 2021).

Teaching for the promotion of genetics literacy using interactive instructional strategies would prepare and enable students to learn effectively and meaningfully thereby acquiring 21st-century skills. These skills are required for the adaptability and sustainability of individuals or groups in the modern work environment. A brief of some of the interactive instructional activities such as guided inquiry, problem-solving, constructivist, cooperative, and collaborative instructional strategies as well as the use of creativity, project, discussion, critical thinking, and communication that would help to promote genetics literacy are highlighted below.

The teacher uses communication skills verbally and non-verbally in a classroom activity to discuss, converse and express his ideas to the students. According to Nurul and Ixora, (2021) acquisition of communication skills implies that students develop their potential creatively, collaboratively, and critically in biology. Critical thinking is used to make a serious approval or disapproval of an important decision to solve a problem. Palavan (2020) mentioned that critical thinking can ease students' learning and play a significant role in the student's cognitive development. The use of a guided inquiry instructional strategy enables the students to engage in hands-on activities. This supports the view of Azubuike and Mumuni (2018) that guided inquiry instructional strategy directs students through a problem-solving approach to develop their inquiry abilities and enable them to conduct their investigations. Rahmawati, Sajidana, and Ashadi (2018) remarked that problem-solving skill is needed in the learning process of genetics to identify problems and direct students to critically succeed in life.

The constructivist instructional strategy focuses on critical thinking, problem-solving, collaboration, and creativity for students to build their knowledge and express their ideas. Nwagbo and Aham (2015) posited that constructivist instructional strategy focuses on the acquisition and application of scientific knowledge that is gained outside the classroom setting. In both collaborative and cooperative instructional strategies, students are divided into small heterogeneous groups so that they work together and maximize their own and each other's learning. Rabgay (2018) mentioned that in a cooperative instructional strategy teacher assesses the group based on the achievement of a common goal while in collaboration, according to Onu, Anyaegbunam, and Uzoigwe (2020) every student work hard and may not be competing because each student emerges in his / her uniqueness.

Students are more attentive to acquiring knowledge of genetics in a meaningful manner by making use of projects. Snezana and Domnica (2017) reported that in using projects, students are actively involved in selection and planning. Students are engaged in writing, solving problems, and reaching conclusions individually or in groups. Discussion strategy enables students to stimulate their critical thinking, create a good rapport, and contribute to their learning and creativity (Khalid, Muhamad, Asmaa & Wafa, 2018). Creativity occurs when one is engaged with new ideas that may be useful in solving problems. Bakac (2018) refer to creativity as the ability to think about new ways of doing things to have a unique solution to the problems in genetics. Inviting outside experts like doctors, medical counselors and public health specialists is suitable for creating excitement and is useful in igniting learning for genetics literacy. The process of accessing scientific information in this dimension is a sine qua non for sustainable science education.

There is a need for promoting genetics literacy through the use of interactive instructional strategies for promoting 21st-century skills acquisition. According to Carlie and Andrea (2020), sustainability is the ability of people to meet the present needs to improve environmental and developmental issues. Lindsey (2019) posited that the introduction of some of the basic concepts of sustainable science such as stem cell research, cloning, and twinning will enable students to bring in their knowledge and skills of solving sustainability problems, especially in genetics and this could be applied in real-life problems.

Previous studies have shown that promoting genetics literacy using appropriate instructional strategies is necessary for sustainable science education. The result of the study by Mareike and Eilks (2013) showed that many science teachers do not use discussion, project-based learning, and cooperative learning strategies that have positive impacts on achieving sustainable science education. Ormond, McClaren, Zandvliet, Robertson, Leddy, Mayer, and Metcalfe (2015) investigated pre-service teachers' experiences in a module designed to address sustainability and found that sustainability provided new sets of competencies such as problem-solving skills, critical thinking skills, and collaboration to the pre-service science teachers. The present study is set to determine instructional strategies suitable for promoting genetics literacy for sustainable science education in this 21st century.

Statement of the Problem

Previous studies on students' performance in genetics show that students find it difficult to apply the knowledge they gain in the study of genetics in making informed decisions in marriages, blood transfusion, disputed parentage, and agricultural application. Researchers have shown that among the factors militating against genetics literacy for sustainable science education to be achieved by science teachers is the use of inappropriate instructional strategies in teaching genetics. The use of student-centered instructional strategies such as guided inquiry, problem-solving, constructivist,

cooperative, and collaborative instructional strategies as well as critical thinking may enhance literacy in genetics amongst students. The use of communication skills and creativity that concretizes abstract and difficult areas of genetics concepts may also promote genetics literacy. Therefore, the problem of this study posed in question form is: what are the instructional strategies suitable for promoting genetics literacy for sustainable science education in the 21st century?

Research Questions

The study is guided by two research questions

1. What are the instructional strategies employed by biology teachers for promoting genetics literacy in the learner for sustainable science education in the 21st century?
2. What is the influence of gender on the instructional strategies for promoting genetics literacy for sustainable science education in the 21st century?

Hypotheses

Two null hypotheses tested at 0.05 level of significance guided the study

Ho_1: There is no significant difference between the mean response scores of teachers and students on instructional strategies for promoting genetics literacy for sustainable science education in the 21st century.

Ho_2: There is no significant difference between the mean response scores of male and female teachers and students on instructional strategies for promoting genetics literacy for sustainable science education in the 21st century.

Method

This study employed a descriptive survey research design in identifying instructional strategies used by secondary school biology teachers for promoting genetics literacy for sustainable science education in the 21st century. Descriptive survey design according to Nworgu (2015) is one in which a group of people or items are studied by collecting and analyzing data from a few people or items considered to be representative of the entire group. The study was carried out using Senior Secondary III biology students and teachers in the Enugu Education Zone of Enugu State. The population of the study comprises 1,986 SS III biology students and 50 biology teachers in the Enugu Education Zone of Enugu State. A multi-stage sampling technique was used to select 200 SSIII biology students and 10 biology teachers. A 12-item-structured questionnaire titled 'Promoting Genetics Literacy for Sustainable Science Education (PGLSSE)" designed on a 4-point scale of strongly agree to have 4 points, agree, 3 points, disagree 2 points, and strongly disagree 1 point was used for the study.

The instrument was subjected to face and content validation by three experts two from the Biology unit and one from the Measurement and Evaluation unit from the Department of Science Education, University of Nigeria, Nsukka. Cronbach alpha reliability test was used and this yielded 0.88. Two research questions and two hypotheses guided the study. Data relating to the research questions were analyzed using mean and standard deviation while the hypotheses were tested at a 0.05 level of significance using an independent sample t-test. Any mean score lower than 2.50 implies disagreement while equal to or higher than 2.50 implies agreement with the items. Similarly, for testing the null hypotheses, if the t-calculated values are less than the critical t-value null hypothesis was accepted, but if the t-calculated values are more than the critical t-value, the null hypothesis was rejected.

Results

Research question 1: what are the instructional strategies employed in promoting genetics literacy for sustainable science education in the 21st century?

Table 1: Mean and standard deviation ratings of teachers and students on the strategies for promoting sustainable science education in the 21st century

S/N	Item Description	Biology Students N= 200			Biology Teachers N= 20		
		$\bar{X}$	SD	Decision	$\bar{X}$	SD	Decision
1.	Application of creativity in genetics	3.20	0.98	Agree	3.10	0.99	Agree
2.	Use of constructivist strategies	2.90	0.44	Agree	2.80	0.42	Agree
3.	Use of cooperative learning groups	2.75	0.70	Agree	2.90	0.74	Agree
4.	Use of collaborative strategies	3.05	0.74	Agree	3.00	0.47	Agree
5.	Inviting outside health specialists example doctors	2.80	0.51	Agree	2.80	0.42	Agree
6.	Use of guided inquiry in genetics	2.60	0.92	Agree	2.90	0.74	Agree
7.	Emphasize problem-solving	2.55	1.07	Agree	2.80	1.14	Agree
8.	Engage in meaningful discussion	2.50	0.74	Agree	2.50	0.71	Agree
9.	Use of project method in genetics	3.20	0.81	Agree	2.90	0.74	Agree
10.	Use of communication in genetics	3.30	0.90	Agree	3.00	0.82	Agree
11.	Encourage critical thinking	3.11	0.64	Agree	3.11	0.89	Agree
12.	Linking genetics to other fields of study	3.02	0.48	Agree	2.18	0.24	Agree
	Grand mean	2.92	0.74	Agree	2.83	0.69	Agree

The result in Table 1 showed that both biology students and teachers agreed on all the items with mean values greater than 2.50. The grand mean value for students is (N = 2.92, SD = 0.70) and the grand mean value for teachers is (N = 2.83, SD = 0.69). The result which is higher than 2.50 for students and teachers respectively, indicated that the respondents agreed that all the items were the instructional strategies biology teachers employed for promoting genetics literacy in sustainable science education among secondary school biology students. The standard deviation of biology students and teachers' responses were 0.74 and 0.69 respectively.

Hypothesis 1: There is no significant difference between the mean response scores of teachers and students on instructional strategies for promoting genetics literacy for sustainable science education in the 21st century.

Table 2: An independent sample t-test analysis of the difference between biology students and teachers on the strategies for promoting sustainable science education in the 21st century

Groups	N	Mean	SD	Df	t value	Sig. (2-tailed)
Students	200	39.60	6.17	218	0.36	0.73
Teachers	20	40.10	4.03			

Table 2 shows that the mean ratings of students on teaching strategies adopted by teachers for promoting sustainable science education in the 21st century ($M = 39.60, SD = 6.17$) are not significantly higher ($t = 0.36, df = 218, p = 0.73$) than teachers' ratings ($M = 40.10, SD = 4.03$). Hence, the null hypothesis which states that there is no significant difference in the mean ratings of teachers and students on the instructional strategies was not rejected. Thus, there is no significant difference in the mean responses of biology students and teachers on the instructional strategies for promoting sustainable science education in the 21st century.

Research question 2: What is the influence of gender on the instructional strategies for promoting genetics literacy for sustainable science education in the 21st century?

Table 3: Mean and standard deviation ratings of teachers and students on the strategies for promoting sustainable science education in the 21st century

S/N	Item Description	Male (N= 98)			Female (N= 122)		
		$\bar{X}$	SD	Decision	$\bar{X}$	SD	Decision
1.	Application of creativity in genetics	3.23	0.98	Agree	3.11	0.99	Agree
2.	Use of constructivist strategies	2.94	0.44	Agree	2.85	0.46	Agree
3.	Use of cooperative learning groups	2.77	0.76	Agree	2.80	0.74	Agree
4.	Use of collaborative strategies	3.04	0.76	Agree	3.03	0.48	Agree

5.	Inviting outside health specialists example doctors	2.78	0.63	Agree	2.80	0.43	Agree
6.	Use of guided inquiry in genetics	2.68	0.92	Agree	2.70	0.94	Agree
7.	Emphasize problem-solving	2.53	1.00	Agree	2.63	1.14	Agree
8.	Engage in meaningful discussion	2.52	0.77	Agree	2.50	0.78	Agree
9.	Use of project method in genetics	3.24	0.84	Agree	2.93	0.88	Agree
10.	Use of communication in genetics	3.29	0.78	Agree	3.00	0.80	Agree
11.	Encourage critical thinking	3.14	0.57	Agree	3.16	0.89	Agree
12.	Linking genetics to other fields of study	3.15	0.67	Agree	2.17	0.69	Agree
	Grand mean	2.94	0.76	Agree	2.81	0.77	Agree

The result in Table 3 showed that both male and female respondents on all the items with the had mean values greater than 2.50. The grand mean value for a male is (X = 2.94, SD = 0.76) and the grand mean value for a female is (X = 2.81, SD = 0.77). Since all the responses are higher than 2.50 for both male and female respondents, it implies that the respondents agreed that all the items were the instructional strategies biology teachers employed for promoting genetics literacy in sustainable science education among secondary school biology students.

Hypothesis Two: There is no significant difference between the mean response scores of male and female teachers and students on instructional strategies for promoting genetics literacy for sustainable science education in the 21st century.

Table 4: An independent sample t-test analysis of the difference between Male and Female biology students and teachers on the strategies for promoting sustainable science education in the 21st century

Respondents	Gender	N	Mean	SD	Df	T	Sig	Decision
Teachers	Male	9	41.00	4.20	8	-0.34	0.74	Not Sig
	Female	11	42.01	4.70				
Students	Male	89	39.05	3.89	198	-0.15	0.88	Not Sig
	Female	111	39.13	3.80				

Table 4 shows that the mean ratings of male teachers on teaching strategies adopted by teachers for promoting sustainable science education in the 21st century ($M = 41.00, SD = 4.20$) are not significantly higher ($t = -0.34, df = 8, p = 0.74$) than female teachers' ratings ($M = 42.01, SD = 4.70$). Hence, the null hypothesis which states that there is no significant difference in the mean ratings of male and female teachers on teaching strategies adopted by teachers for promoting sustainable science education in the 21st century was not rejected. Thus, there is no significant difference in the mean responses

of biology male and female teachers on the instructional strategies for promoting sustainable science education in the 21st century. Table 4 further shows that the mean ratings of male students on teaching strategies adopted by teachers for promoting sustainable science education in the 21st century ($M = 39.05, SD = 3.89$) are not significantly higher ($t = -0.15, df = 1988, p = 0.88$) than female students' ratings ($M = 39.13, SD = 3.80$). Hence, the null hypothesis which states that there is no significant difference in the mean ratings of male and female students on teaching strategies adopted by teachers for promoting sustainable science education in the 21st century was not rejected. Thus, there is no significant difference in the mean responses of biology male and female students on the instructional strategies for promoting sustainable science education in the 21st century.

Discussion of Findings

The data presented show that instructional strategies namely guided inquiry, problem-solving, constructivist, cooperative, collaborative, project, and discussion strategies as well as creativity, critical thinking and communication promote genetics literacy for sustainable science education. The finding is in agreement with Nurul and Ixora (2021) who showed that the acquisition of communication skills enables students to develop their potential in biology. The finding is in line with Azubuike and Mumuni (2018) who stated that the guided inquiry instructional strategy was effective in promoting genetics literacy. The finding of this study is in agreement with Bakac (2018) who indicated that creativity was significant in promoting genetics literacy. The finding of the study is in agreement with Ormond, McClaren, Zandvliet, Robertson, Leddy, Mayer, and Metcalfe (2015) who revealed that new sets of competencies for sustainability such as problem-solving skills, critical thinking skills, and collaboration promote genetics literacy. The finding of the study supported Nwagbo and Aham (2015) who revealed that the constructivist instructional strategy was effective in promoting genetics literacy. The finding of the study supports the assertion of Mareike and Eilks (2013) who agreed that for promoting genetics literacy, teachers should use discussion, project, and collaborative learning strategies, and this ensures equipping students towards sustainable science education in the 21st century.

These sets of competencies namely problem-solving, critical thinking, and collaboration are all enshrined in the learning skills of the 21st-century skills. It is expected that STEM education could promote the acquisition of 21st-century skills by teaching using interactive instructional strategies in their various subject areas. This will not only promote literacy in the specific subject but also enhance the acquisition of 21st-century learning skills that will equip them for future life endeavors. Therefore, students need appropriate instructional strategies to promote their understanding of genetics literacy to transform the knowledge into sustainable science education.

Conclusion

Based on the results of this study it was concluded that effective use of instructional strategies such as guided inquiry, problem-solving, constructivist, cooperative and collaborative, and other innovative instructional strategies would promote the acquisition of genetics literacy skills as well as 21st-century skills needed for sustainable science education and adaptability of individuals and modern work environment. There was no significant difference in the instructional strategies for sustainable science education based on gender.

Recommendations

1. Teachers should employ appropriate interactive instructional strategies to ensure that acquisition of 21st-century skills would promote genetics literacy.
2. Curriculum planners should design a curriculum that would involve teachers and students in the teaching and learning process that would promote collaboration and skills acquisition.
3. Periodic seminars, conferences, and workshops should be organized by the government and professional bodies like STAN for the teachers to update their knowledge on the use of interactive and innovative strategies.

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