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EFFECTS OF TWO PROBLEM SOLVING STRATEGIES ON SECONDARY SCHOOL STUDENTS' SCIENCE PROCESS SKILL ACQUISITION IN BIOLOGY PRACTICALS IN NNEWI EDUCATION ZONE, ANAMBRA STATE

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ABSTRACT

The study investigated the effects of two problem solving strategies on secondary school students' science process skills in Biology practicals in Nnewi Education Zone of Anambra State. The study was guided by two research questions and three null hypotheses tested at 0.05 alpha levels. The study adopted a quasi-experimental research design. The sample of study consisted of 100 senior secondary two (SS 2) students offering Biology selected from 13,598 SS2 students using simple random sampling and purposive sampling techniques. The instrument used for data collection was Science Process Skills Test (SPST), which was adapted from Senior Secondary School Certificate (SSCE) past questions. The instrument was revalidated by three experts from Faculty of Education, Nnamdi Azikiwe University, Awka. The reliability of the SPST was established using inter-rater reliability with reliability coefficient of 0.89. The experimental groups were taught practical Biology using Bio Problem-Solving Strategy (BPSS) and Gayford Problem-Solving Heuristics (GPSH). SPST were administered as pretest and posttest to generate data for the study. The data collected were analysed using mean, standard deviation and analysis of covariance. The findings of the study showed among other things that GPSH is more effective in enhancing science process skill scores of students in Biology practicals than BPSS. Male students demonstrated higher mean gains in science process skills with GPSH than females but the difference was not significant. Based on the findings, it was concluded that both the Gayford Problem-Solving Heuristic Strategy (GPSHS) and the Biology Practical Skills Strategy (BPSS) effectively enhanced students' science process skills in Biology practicals. The study thus recommends that secondary school teachers should integrate both the GPSH and the BPSS in teaching Biology practicals.

Keywords: Science Process Skills, Biology Practicals, Problem-Solving Strategies.

Introduction

The importance of Biology to the society cannot be overemphasized as it helps us understand living organisms, their interactions with the environment and provides knowledge that supports advances in medicine, agriculture and environmental conservation. Biology is a life science which is described as an action subject which goes beyond talking and listening. It is a subject that has to

do with various unifying principles, concepts and processes that enables students to face the challenges that confront them in life. It is an inquiry oriented subject to which practical work plays an invaluable role. As a subject that engages students in varied science process skills such as observing carefully, classifying, interpreting, predicting events, designing experiments, organizing information, reporting completely and accurately. Biology not only deepens our understanding of life but also requires observation, experimentation, and critical thinking, it serves as a powerful avenue for developing essential science process skills in learners.

Science Process Skills (SPS) are essential competencies that enable students to engage in scientific inquiry, fostering critical thinking and problem-solving abilities. Martin (2019) defines science process skills as intellectual skills and learned capabilities which scientists use as self-management procedure in carrying out scientific activities. This implies that science process skills are the processes scientists use in carrying out practical activities. These skills make it possible for students to carry out objective investigation and draw conclusions based on results. The need for students to develop science process skills through the process of problem solving in suitable environment has been emphasized by science educators (Okeke, 2019). This is because Science process skills according to Okoro (2018) promote logical and sequential problem solving which can be used in many aspects of school life. The development of these skills is basic to scientific inquiry and the development of intellectual skills needed to learn concepts (Ibe and Nwosu, 2019). They also believed that the process skills can increase students' capabilities to answer questions and solve problems. The basic science process skills provide a foundation on which the integrated science process skills are learnt.

This study focused on key science process skills; manipulative, observational, communication, and cognitive skills that students can develop while engaging in problem-solving activities of an experimental nature. Manipulative skills refer to the correct handling of laboratory apparatus, setting up experiments, and preparing instructional materials. These skills are typically assessed through direct observation of students during laboratory work. Observational skills involve the ability to notice and interpret phenomena that occur during practical investigations, often relying on the effective use of the senses. Communication skills are demonstrated through students' ability to logically present experimental findings using accurate illustrations, respond clearly to oral questions and record results systematically. Cognitive skills, in contrast, assess students' conceptual understanding of scientific principles as demonstrated during practical tests. Mastery of these science process skills is strongly associated with academic achievement, as they underpin critical thinking, problem-solving abilities, and a deeper comprehension of scientific concepts. Since science process skills are best nurtured through active engagement and hands-on experiences, the choice of appropriate instructional strategies becomes crucial in enabling students to practice, refine, and apply these skills effectively.

Efforts to develop instructional

strategies to enhance student's problem-solving abilities in Biology have led to the development of many problem-solving models and has seen the establishment of these models in teaching and learning basic science (Nbina and Joseph, 2015). This has resulted in the enhancement of the academic achievement of students and acquisition of science process skills in Basic science. Various problem-solving models according to various authors include; i) Ashmore, Casey and Frazer problem-solving Strategy, ii) Selvaratnam and Frazer problem-solving Strategy, iii) The Ideal Problem-Solving Strategy by Bransford and Stein, iv) Systematic problem-solving Strategy by Mettes, Pilot and Rooserick, v) Inquiry-Based Framework for Practical Problem-Solving Strategy by West, Vi) Gayford Problem-Solving Heuristics and vii) Bio problem solving strategy. The problem-solving model considered in this study are Gayford Problem-Solving Heuristics (GPSH) and Bio problem solving strategy.

Gayford developed a 9-step strategy for solving experimental biological problems in a logical and step-wise approach. At each step, question which the problem solver is expected to go through are indicated, they are: a)What question, if any, do you want to ask, b)Write down exactly what you think the problem is or what you are trying to do, c)Think about how someone else is likely to judge how successful you have been in solving the problem, d) Is there anything that you have learned in school or anywhere else which mayhelp you with this problem? e) Think of many different ways of tackling this problem as you can. It is important that you discuss your idea with your group, f) Select the best method that you think will work with theavailable materials you have, g) Once you begin, decide if the method that you have chosen will work, do you need to make any minor or major changes? If so, what are they? h) Can you identify any further problem that you need to investigate before you canreally solve this one? i) How successful do you think that you have been? Why? Can you measure your success. This approach has many steps; it is wordy and cumbersome to be used in the classrooms. Assessing individual student 's participation in learning using the numerous steps can be difficult. However, this approach can serve for group or co-operative activities.

Moreover, the modified model of problem-solving strategy used in this study is termed Bio Problem Solving Model (BPSS). It consists of the following: recognition of problem; gathering and processing of information; experimentation (instructional material production, engaging in practical work, and observation); analysis of results (report, draw and discuss result) and evaluation. It is designed to assess individual student 's work. The main distinctive feature in this model is the inclusion of production of instructional materials.

Despite the emphasis on practical-based science instruction in the Nigerian secondary school curriculum, many students continue to struggle with critical thinking and problem-solving in scientific contexts, indicating a gap in the acquisition of essential science process skills. Conventional teaching approaches often emphasize rote memorization over experiential learning, thereby limiting students' ability to apply knowledge in real-life scientific contexts. Research suggests that problem-solving strategies, when effectively employed, can

enhance students' engagement, critical thinking, and mastery of practical skills. However, there is a dearth of empirical studies comparing the specific effects of different problem-solving strategies on students' acquisition of science process skills in biology practical tasks, especially within the Nnewi Education Zone. This gap necessitates an investigation into evidence-based instructional methods that can improve students' practical competence. Therefore, the study examined the effect of two problem-solving strategies on students' science process skill acquisition in Biology practical in Nnewi Education Zone. Specifically, the study sought to determine:

1. Effects of Bio problem-solving strategy and Gayford problem-solving Heuristics on senior secondary school students' acquisition of science process skill in Biology practical in Nnewi Education Zone.
2. Effects of Bio problem-solving strategy and Gayford problem-solving Heuristics on senior secondary school male and female students' acquisition of science process skill in Biology practical.
3. Interaction effects of teaching strategies (Bio problem-solving strategy and Gayford problem-solving Heuristic) and gender on senior secondary school students' acquisition of science process skills in Biology practical.

Research Questions

1. What is the difference between the mean science process skills acquisition scores of SS2 students taught Biology practicals using Bio Problem-Solving Skills (BPSS) and Gayford Problem Solving Heuristics (GPSH)?
2. What are the differences in the mean science process skill acquisition scores of male and female SS2 students' taught Biology practicals using BPSS and those taught using GPSH?

Null hypotheses

1. There is no significant difference between the mean science process skills acquisition scores of SS2 students taught Biology practical using BPSS and those taught using GPSH.
2. The is no significant difference in the mean science process skill acquisition scores of male and female SS2 students taught Biology practical using BPSS and those taught using GPSH.
3. There is no interaction effect of gender and teaching strategies (BPSS and GPSH) on SS2 students Science process skills acquisition in Biology practicals.

Methods

The study adopted quasi-experimental specifically, the pretest, posttest non randomised control group design was used. The study was carried out in Nnewi Education Zone of Anambra State. The population of the study comprised of 2927 (1198 males and 1729 females) senior secondary school students offering Biology from the 37 government-owned co-educational secondary schools in the Zone in 2023/2024 academic session. The sample of study consisted of 100 (40 males and 60 females) SS 2 students offering Biology drawn from four out of 37 co-educational secondary schools in Nnewi Education Zone

of Anambra State. The sampling was drawn using two-stage sampling techniques involving purposive and simple random sampling techniques. The instrument for data collection is Science Process Skills Test (SPST), which was adapted from SSCE past question made up of two sections A and B. Section A consisted of students' demographic data while section B is made up of science process skill test. In Science Process Skills Test, Students were exposed to a practical test where they were required to carry out practical activities using a number of specimens (mammalian skeleton and plant tissues). Students demonstrated the science process skills as they carry out the practical activities. The instrument was validated by three experts: two from the Department of Science Education and one from Department of Educational Foundations, all from Faculty of Education Nnamdi Azikiwe University, Awka. To determine the reliability coefficient of SPST, the instrument was administered to an intact class of 30 SS2 students in one of the schools in Awka Education Zone (outside the zone under study). The reliability for science process skills test in supporting tissues in animals and plants was established using inter-raters' reliability, with coefficient of 0.89. This was to ascertain the level of agreement between the independent scores obtained from two Biology teachers.

The treatment was done in two phases, in the first phase, the teachers in the experimental groups were briefed by the researcher before the treatment process on how to effectively implement Bio-Problem-Solving Instructional Strategies and Gayford problem solving Heuristic strategy. Thereafter, both experimental groups took a pretest as part of the pre-testing and familiarization phase. Thirty minutes was allowed for the pretest. The teachers invigilate their students in both experimental groups. At the end of the test the question papers and answers were collected from the students by their teachers. The pretest science process skill test papers were marked; scores were collected and handed over to the researcher. In the second phase teaching commenced on the next Biology class by their regular teachers for 4 weeks.

Teacher presented a problem situation: Students were to go over the problem statement if they failed to recognize the problem, Students referred to their theoretical knowledge in forms of facts, principles and theories relevant to the problem. The teacher can support students in activating their prior knowledge by posing relevant questions or making guiding statements that stimulate their thinking and direct their investigation. Additionally, students are encouraged to prepare instructional materials either before or during laboratory activities to enhance engagement and understanding, students engaged in practical activities using the instructional materials they produced as they solve the problem, students demonstrated the skills during laboratory session. After the teaching, posttest was administered on the participants by the Biology teachers. Thirty minutes was allowed for the test. The test was marked by the teachers. Scores was collated, collected by the teachers and handed over to the researcher. The aim of the posttest was to find out if there was any gain in knowledge that might have arisen from the treatment.

The data obtained from each group using the SPST was analyzed using mean,

standard deviation and Analysis of Covariance (ANCOVA) statistics. Mean and standard deviation was used to answer the research questions and ANCOVA was used to test the hypotheses. The choice of ANCOVA for testing the research hypotheses was based on its ability to control the effect of pretest. The hypotheses were tested at 0.05 level of significance. The decision rule for the hypotheses was that whenever the probability value (p-value) is less than or equal to the significant value of 0.05, the null hypothesis is rejected, otherwise the null hypothesis is not rejected.

Results

Table 1: Mean and standard deviation on science process skill scores of students taught Biology practicals using BPSS and those taught using GPSH

		Pre-test		Post-test		
Method	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean Gain**
BPSS	50	25.18	5.201	52.96	10.252	27.78
GPSH	50	26.40	6.433	59.16	10.662	32.76
Mean Diff		**-1.22**		**-6.2**		**-4.98**

The result in Table shows a difference in the mean science process skill scores of SS2 students taught Biology practicals using the Bio-Problem Solving Strategy (BPSS) and the Gayford Problem Solving Heuristic (GPSH) method in Nnewi Education Zone. The result revealed that students exposed to BPSS had a pre-test mean score of 25.18, which increased to 52.96 in the post-test, yielding a mean gain of 27.78. Similarly, those taught with GPSH recorded a pre-test mean of 26.40 and a post-test mean of 59.16, resulting in a higher mean gain of 32.76. This indicates that although both strategies improved students' science process skill performance, the GPSH group achieved a greater mean gain (32.76) compared to the BPSS group (27.78), suggesting that GPSH was relatively more effective in enhancing students' acquisition of science process skills in Biology practicals with a mean gain difference of -4.98.

***Table 2*: Mean and standard deviation on science process skill scores of male and female students taught practical Biology using BPSS and those taught using GPSH.**

			Pre-test		Post-test		
Method	**Gender**	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean Gain**
BPSS	Male	18	25.78	4.870	51.28	12.371	25.5
	Female	32	24.84	5.425	53.91	8.924	29.07
	Mean Diff		0.94		-2.63		-3.57
GPSH	Male	22	27.32	6.792	61.36	10.804	33.68
	Female	28	25.68	6.165	57.43	10.415	31.75
	Mean Diff		1.64		3.93		1.93

Table 2 shows the differences in the mean science process skill (SPS) scores of male and female SS2 students taught Biology practicals using the Bio Problem-Solving Strategy (BPSS) and the Gayford Problem-Solving Heuristic (GPSH) in Nnewi Education Zone. It was observed that male students taught with the BPSS had a mean gain of 25.5, while the female students had a mean gain of 29.07, resulting in mean gain difference of -3.57, which shows that BPSS was more effective for female students than male students. For the GPSH, male students had a mean gain of 33.68, while female students recorded a mean gain of 31.75, resulting in a mean gain difference of 1.93, which implies that GPSH was more effective for male students than for females. In comparing the two strategies, female students performed better in the BPSS group, while male students outperformed their female counterparts in the GPSH group. Overall, GPSH is more effective in enhancing the science process skills scores of both male and female students.

***Table 3*: Summary of Analysis of Covariance of Mean Process Skill Posttest Scores of Students taught Practical Biology using BPSS and GPSH**

Source of Variation	Sum of Squares	df	Mean Square	*F*	*P*-value
Corrected Model	286.312[a]	4	71.578	.908	.463
Intercept	12169.214	1	12169.214	154.381	.000
Pretest	77.596	1	77.596	.984	.324
Instructional Strategies	191.401	1	191.401	2.428	.122
Gender	1.770	1	1.770	.022	.881
Instructional Strategy * Gender	16.559	1	16.559	.210	.648
Error	7488.448	95	78.826		
Total	259578.000	100			
Corrected Total	7774.760	97			

Note: $P > .05$

The analysis of covariance (ANCOVA) results presented in Table 3 revealed that the overall corrected model was not significant, F (4, 95) = 0.908, P = .463. After controlling for pre-test scores, there was not a significant main effect of the methods on students' science process skills in Biology practical, F (1,95) =2.428, P=.122. Since P >0.05, the null hypothesis was not rejected. Thus, there is no significant difference between the mean science process skills posttest scores of students taught Biology practical using BPSS method and those taught using GPSH in Nnewi Education Zone. This shows that both instructional strategies had a similar impact on students' science process skills.

The analysis of covariance (ANCOVA) results presented in Table 3 revealed the effect of gender on science process skills scores while controlling for pre-test scores. The overall corrected model was not significant, F(4, 95) = 0.908, P = .463. After controlling for pre-test scores, there was not a significant main effect of gender on students' science process skills in Biology practical, F(1,95)=.022, P =.881. Since P >0.05, the null hypothesis was not rejected. Thus, there is no significant difference in the mean science process skill

scores of male and female SS2 students taught Biology practical using BPSS and those taught using GPSH in Nnewi Education Zone. This implies that gender did not play a significant role in students' science process skill acquisition, meaning both male and female students performed similarly regardless of whether they were taught using BPSS or GPSH.

Table 5 revealed the analysis of covariance (ANCOVA) results conducted to examine the interaction effect of gender and teaching strategies (BPSS and GPSHM) on SS2 students' science process skills acquisition in Biology practical while controlling for pretest scores. The overall corrected model was not significant, F(4, 95) = .908, $P > .001$. Also, after controlling for pre-test scores, there was no significant interaction effect between instructional strategies and gender, F(1, 95) = .210, $P = .648$. Since, $P > 0.05$, the null hypothesis was not rejected. Thus, there is no interaction effect of gender and teaching strategies (BPSS and GPSH) on SS2 students Science process skills acquisition in Biology practical in Nnewi Education Zone. This suggests that the effectiveness of BPSS and GPSH in developing science process skills was not influenced by gender, meaning both male and female students responded similarly to the instructional strategies.

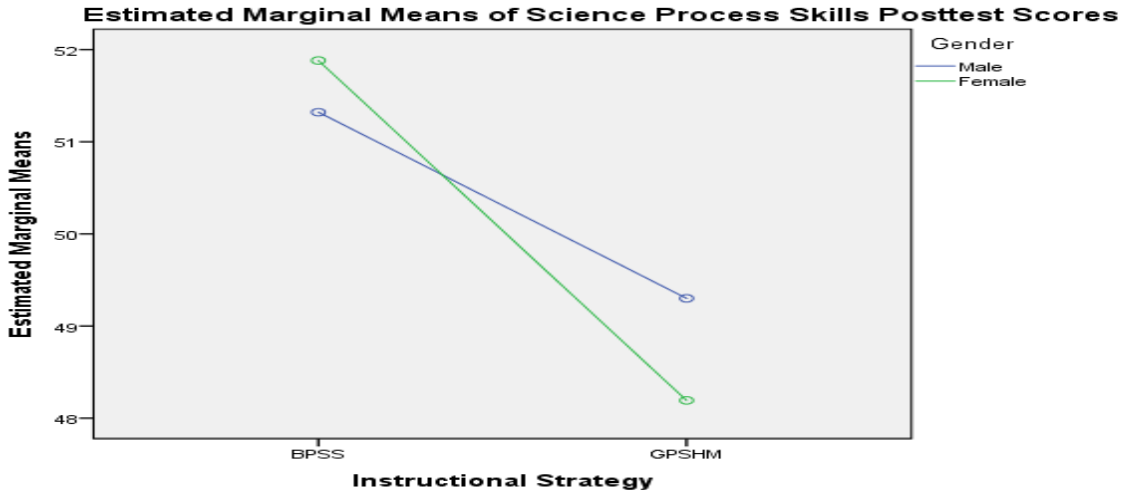


Fig. 1: Profile plots of interaction effect of gender and instructional strategies (BPSS and GPSH) on science process skills of students in Biology practicals.

The profile plots on the two strategies revealed that there is an interaction between instructional strategies and gender, though our earlier ANCOVA results showed this interaction was not statistically significant ($P = .648$). The graph above show that students exposed to the BPSS outperformed those taught using the GPSH across both genders. Female students recorded higher posttest means scores than their male counterparts under the BPSS strategy, suggesting its particular effectiveness for females. In contrast, under the GPSH strategy, male students slightly outperformed females, although both genders had lower scores compared to those in the BPSS group. The

intersection of the lines representing male and female students indicates an interaction effect, implying that the impact of instructional strategy on science process skill acquisition differs by gender.

Discussion

The finding of this study showed that students taught Biology practical with GPSH had a higher mean gain compared to those taught with BPSS. This indicates that compared to the BPSS, GPSH was more effective in enhancing students' science process skills. The finding of this study agrees with that of Ehikhamenor (2015) whose findings showed that Students exposed to Bio Problem-solving Instructional Strategy and Gayford Problem-Solving Heuristics performed better in their posttest than their pretest. Similarly, the finding of this study is in agreement with that of Ikitde (2014) which showed that the two experimental conditions (REPSOM and TEPSOM) proved to be a more stimulating and motivational approach to learning than the control condition in the development of cognitive skills, manipulative skills, observational skills and communicative skills.

The corresponding hypothesis showed that there is no significant difference between the mean science process skills scores of students taught Biology practical using BPSS method and those taught using GPSHM. This shows that both instructional strategies had a similar impact on students' science process skills. The finding of this study contradicts that of Ehikhamenor (2015) which revealed that there was a significant main effect of treatment on science process skills in Biology practical.

The finding of this study also revealed that female students had a higher mean gain science process skill score in the BPSS group than the males, while male students had a higher mean gain score than their female counterparts in the GPSH group. While the finding of this study revealed that both gender performed better in different strategies, it contradict that of Ibe and Nwosu (2019), whose study revealed that, male students had a slightly higher posttest mean science process skill score than the female expose to Pizzini, shephardson and Abel problem-solving strategy.

The corresponding hypothesis showed that there is no significant difference in the mean science process skill scores of male and female SS2 students taught Biology practical using BPSS and those taught using GPSH in Nnewi Education Zone. This implies that gender did not play a significant role in students' science process skill acquisition, meaning both male and female students performed similarly regardless of whether they were taught using BPSS or GPSH. This finding does not support that of Raimi and Fabiyi (2018), whose study showed that there is a significant interaction effect between gender and instructional strategy on students 'acquisition of science process skills. The inconsistency in the finding with the reviewed study may be due to variations in instructional methods, sample characteristics or learning environments across studies.

Furthermore, the study found that there is no significant interaction effect of gender and teaching strategies (BPSS and GPSH) on SS2 students Science process skills acquisition in biology practical. This suggests that the effectiveness of BPSS and

GPSH in developing science process skills was not influenced by gender, meaning both male and female students responded similarly to the instructional strategies. The finding of this study agrees with that of Ekairia (2017), whose study showed that gender was not a significant factor in determining students' acquisition of science process skills in Qualitative chemical analysis. The finding of this study contradicts that of Orimlogunje (2018), whose finding revealed a significant interaction effect between gender and instructional strategy on students' science process skill acquisition. Also, the finding of this study does not support that of Ibe and Nwosu, (2019), who's finding also revealed a significant interaction effect between gender and instructional strategy on students' acquisition of science process skills. In addition, the finding does not support that of Raimi and Fabiyi (2018), who's study showed that there is a significant interaction effect between gender and instructional strategy on students 'acquisition of science process skills.

The absence of a significant interaction effect between gender and instructional strategies in this study suggests that both male and female students benefited similarly from BPSS and GPSHM in acquiring science process skills. These differences in the reviewed study may stem from variations in instructional methods, classroom dynamics, sample size, or subject content across studies.

Conclusion

Based on the findings of this study, the study concluded that both the Gayford Problem-Solving Heuristic (GPSH) and the Biology Practical Skills Strategy (BPSS) effectively enhanced students' science process skills in Biology practicals, although with varying degrees of impact. GPSH demonstrated higher mean gain scores in science process skills than BPSS. Gender differences were observed, with male students showing greater gains in science process skills with GPSH, while females performed better with BPSS. However, statistical analyses revealed no significant differences in science process skill scores between male and female students, nor any interaction effect between gender and instructional strategies. This suggests that both teaching strategies are viable for fostering science process skills in Biology practicals, and their effectiveness is not significantly influenced by gender.

Recommendations

The following recommendations were made based on the findings of the study

1. Teachers should integrate both the Gayford Problem-Solving Heuristic (GPSH) and the Bio Problem-Solving Strategy (BPSS) in teaching Biology practicals, as both strategies have been shown to enhance students' science process skills.
2. Educators should consider incorporating elements of both GPSH and BPSS to cater for the learning preferences of male and female students, ensuring that both genders maximize their learning potential.
3. Training programs and workshops should be organized by government and school administrators to equip Biology teachers with the necessary skills and knowledge to effectively implement GPSH and BPSS, thereby improving students' engagement and learning outcomes.

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