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Analytical Strategy as Critical and Brainstorming Thinking for Fostering Students' Drawing Ability in Sciences

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Abstract: The best learning outcomes for pupils in the classroom are determined by the teacher's pedagogical and content competence. In order to improve students' drawing abilities in the sciences, this study explores the effectiveness of analytical tactics such as critical and brainstorming thinking. In their intact groups, 87 senior secondary 2 science students took part in the study. The study used a semi-experimental approach. Science Drawing Kills Achievement Test (SDKAT), a practical essay test that measured drawing abilities, was used to gather data. It was verified using construct and face validity methods. The instrument's strong points were demonstrated by the split-half dependability of 0.86. Research questions are answered by the mean (X) and standard deviation (SD); analysis of covariance (ANOVA) was used to assess the hypotheses. The findings demonstrated that the analytic approach promoted students' drawing abilities; there was no discernible difference in drawing abilities between male and female students, and gender had no bearing on how the analytic method promoted students' drawing abilities. However, teachers are urged to guide and direct students in the use of the analytical method so that it is implemented successfully, and students are encouraged to respond by expressing their own perspectives and ideas in order to jointly identify and solve problems.

Keywords: Analytical Strategy, Critical and Brainstorming Thinking, Problem-Solving, Sciences, Drawing Skills, Gender.

Research Paper

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1. INTRODUCTION

In contrast to other sciences, biology is a live science that offers a thorough understanding of how organisms interact with one another and their surroundings (BioExplorer, 2021). For many STEM fields and disciplines in post-secondary institutions of learning, adequate scientific knowledge is required. The teaching and learning of the sciences, particularly biology, fosters an understanding of the diversity of species, links students to their immediate environment, and raises awareness of the distinctive flora and fauna in communities and ecosystems. The advancement of science and technology across the globe, particularly in the fields of medicine, surgery, forestry, agriculture, biotechnology, nursing, and food science and technology, as well as the prevention and treatment of disease, greatly benefits from knowledge of the sciences, especially biology.

In Nigeria, teaching science (biology, physics, computer science, and chemistry) in secondary schools is meant to prepare the students/learners to acquire the following: adequate laboratory and field skills; meaningful and relevant knowledge in the sciences; the ability to apply scientific knowledge to daily life in matters of personal and community health and agriculture; and a reasonable and practical scientific attitude. Field studies, guided exploration, laboratory procedures, and skills, coupled with conceptual thinking, are recommended for instruction in the curriculum in order to reach these goals (F M E, 2013). This suggests that studying the sciences is intended to give students practical concepts, principles, theories, and abilities that will help them to meet rising societal difficulties and, as a result, be responsible citizens.

Unfortunately, neither teachers nor students have been able to convert these objectives into desired curriculum learning results. According to Danmole & Lameed (2014), Okebukola 2020, Adam & Lameed 2022, and Bahar, Johnstone & Hansell (2010), there are a number of factors that prevent students from achieving the desired learning outcomes in the sciences, including poor teaching methods, a lack of practical knowledge, the absence of labs and teaching aids, student attitudes, class size, and challenging concepts.

According to the WAEC Chief Examiners' Report (2019), students are not particularly inclined toward scientific practicals due to their bad labelling, failure to give diagrams the proper titles, poor drawing skills, and inability to connect structure and function. The papers go on to blame pupils' poor performance in science practicals on their inability to adhere to the standards for generating scientific drawings, including those about the title, labelling, woolly lines, broking, and line thickness.

As a result, secondary school pupils' declining acquisition of practical skills is a factor in their subpar performance in the sciences. Additionally, practical activities that integrate the students with the laboratory skills stressed by the secondary school curriculum have not been incorporated into the teaching and learning of biology, physics, chemistry, computer science, etc. (Akintola, Ayanola & Sulaimon, 2021; Landin, 2015). In order to fully engage students in the teaching and learning processes, it is essential that sciences be taught using student-centred methodologies or approaches. According to constructivist learning theory, when students actively participate in science lessons, they observe, sketch, label, and relate structures to functions and are able to describe and debate the concepts with drawings (Oxford Cambridge & RC, 2015).

The national secondary scientific curricula (F M E, 2013) place a strong emphasis on practical exercises as essential components of biology, chemistry, physics, and computer science teaching and learning, as well as their summative assessment. In order to pursue a STEM-related career or subject in higher education, students must receive acceptable grades in science. This suggests that pupils need to cultivate proficient drawing abilities, which include abilities like observation and manipulation. Therefore, it is required of the students to provide precise, well-labelled scientific representations and recordings that will encourage or improve meaningful learning and concept retention. Drawing proficiency tests students' abilities in higher cognitive (such as analysis, synthesis, and assessment) and psychomotor domains of educational objectives. According to Wammes, Meade, and Fernandes (2016), student-drawn visual representations of concepts can aid in the development of hypotheses, the development of predictions and experiments, and the communication of results. These findings are in line with those of Schwartz, Reiser, Kenyon, Achier, Fortus, and Krajcik (2009), Ainsworth, Prain, and Tytler (2011), and Quillin and Thomas (2015).

Students' subpar performance in scientific practicals in particular and in general is due to errors and shortcomings in areas of bad labelling and drawing, as well as unfavourable student attitudes (Okereke, 2016). For instance, it was shown that some biology teachers do not involve their students in biological drawing activities during theory or practical lessons, despite the fact that most biology teachers assign biological drawings to their students as homework (Akintola & Ayanlola, 2019). As a result, the majority of students have a negative attitude toward learning sciences because they are unable to address issues or difficulties relating to the drawing and labelling of diagrams.

Studies have shown, according to reports, that using clearly labelled drawings to observe, describe, and explain the physiological and chemical processes that organisms go through in relation to their environment helps students understand the concepts being taught, which in turn boosts their achievement and encourages retention of newly learned concepts (Kamar & Bello, 2018; Uzuagba, 2000). Students are better able to recall the observable characteristics of creatures or specimens in the sciences when drawings are properly labelled, especially in biology. It serves as a vehicle for the transmission and storage of visual information in pupils' memories (Uzuoagba, 2000). For summarizing the relationships between physiological processes in machines, symbols, and plants and animals, a correctly labelled diagram can be a very effective tool. Because of the variety, complexity, intricacy, and connection of the diagram to students' performance, there is an urgent need for developing distinctive drawing and labelling skills in scientific students. However, the science teachers' chosen teaching approach (lecture, expository, and demonstration) undervalues the significance of students' drawing abilities in the teaching and learning of sciences. This requires teachers to use an effective teaching method that will encourage learners to adjust their behaviour in the desired directions (Tebabal & Kahssay, 2011).

According to Uzoma and Amadi (2018), effective scientific instruction necessitates a creative, student-centred approach to instruction that fosters students' willingness to engage meaningfully with the subject matter. In order for concepts to be fully comprehended and applied to daily life, sciences must be taught and learned in a practical, realistic, and analytical manner. One of the student-centred techniques that might encourage students to participate in more realistic and practical training to promote conceptual understanding and knowledge transfer to real-world applications is the use of analytical approach/problem-solving methodologies.

According to Hoi, Bao, Nghe, and Nga (2018), analytical thinking/problem-solving is a cognitive process that allows for the successful use of knowledge, skills, and personal experiences to recognize issues, develop solutions, and settle disputes in a classroom. Analytical strategy is an investigation task used in teaching and learning in which the instructor looks into different ways to solve problems using the knowledge provided in the classroom. According to Udo (2015), analytical strategy/problem-solving is a cognitive learning technique that fills the gap between conceptual comprehension and the representation of a phenomenon.

According to Ndukwe and Mumuni (2019), Analytical technique is a hands-on classroom activity that assists students in tackling challenging assignments about which they are clueless. It enables the student to advance beyond rote learning and fosters a thorough comprehension of science in the process. According to Qarareh (2016), analytical-based/problem-based learning focuses on fostering and solidifying students' confidence in their ability to solve problems, which promotes retention. The analytical strategy entails coming up with original solutions rather than just applying previously understood rules to a problem. Dhillon (1998) describes issue solving as an investigative task in which the solver looks into possible routes to a goal using the information at hand. Akinwunmi (2021) uses the Kolawole problem-solving(analytical) technique as an example of a teaching strategy that combines material, teacher activities, student activities, and evaluation in a way that all of these things can be done concurrently.

As a result, while using an analytical approach to teach science, the teacher's main responsibility is to support students' learning and overall understanding of the material, while the students generate fresh ideas and concepts based on their past knowledge. It's a method of instruction that gives pupils the chance to plan an investigative activity that uses questions to reach a conclusion. The process of analytical-based/problem-based learning typically starts with reading real-world issues that are chosen to engage students through presentation and discussion of the results. Students must be given the time they need to ponder, gather knowledge, and set their analytical/problem-solving tactics, and their creative thinking must be fostered throughout this process.

In an analytical/problem-solving approach, the teacher first defines the issue, after which the pupils and teacher come up with hypotheses. Additional data are gathered, examined, and the conclusion is confirmed. Learners are anticipated to achieve a higher degree of knowledge and recall of what they have learned in the classroom through this method. For instance, a biology instructor can begin by describing the issue before beginning to educate the class about rabbit dissection. After outlining the issues, theories should be put out to determine whether the rabbit still has life after being dissected. This inquiry enables the students to reflect. The pupils dissect the rabbit and create a diagram showing the process. The instructor explains while displaying to the students the dissected rabbit's liver, heart, and intestines to illustrate how this relates to real life. This provides the pupils' inquiries with answers, encouraging them to learn more about Mammalia. In an analytical/problem-solving teaching technique, the teacher leads and directs the students toward comprehension and retention of the topic, and the students respond by sharing their views and opinions in order to jointly discover and solve difficulties. The teacher asks pupils questions to see if they truly understood the prior lecture (Rahman *et al*., 2016).

Numerous studies on analytical thinking/problem-solving as a strategy that could support meaningful learning and improve student's learning outcomes are available in the literature. The impact of the analytical technique on behaviour and academic achievement in biology among senior secondary students in Nigeria with varying levels of ability was examined by Obochi (2021). The study's conclusions showed that analytical skills had a significant impact on low-ability pupils' academic achievement. The possible impacts of analytical-based learning (ABL)/problem-based learning (PBL), predict observe explain (POE), and problem-based learning-predict, observe, explain (PBLPOE) on students' analytical skills and self-efficacy in biology were also examined by Fitriani, Zubaidah, and Muhdhar (2020). Compared to Problem-Based Learning (PBE), Predict Observe Explain (POE), and traditional learning, Problem-Based Learning-Predict, Observe, and Explain (PBLPOE) has a more notable impact on students' analytical skills and self-efficacy. In a similar line, Kolawole's Problem-Solving/Analytical (KPS/KAS) and senior secondary school pupils' academic achievements in Biology were examined by Akinwunmi in 2021. The results of the study showed that using the Kolawole's Problem-Solving/Analytical (KPS/KAS) method improved students' academic performance in biology more than using the traditional technique.

In the literature, the moderating variable of gender has not been conclusively shown to have an impact on student's performance in the sciences. For instance, Jegede and Olu-Ajayi's (2017) study on the influence of mentoring and gender on low-performing students' achievement found that female students outperformed their male counterparts. Isaak, Kleinert, and Wilder (2022) also showed a significant gender influence on biology students' usage of learning techniques (practice, organization, effort, and time management). Other research (Lameed *et al*., 2023; Mashebe & Zulu, 2022; Obochi, 2021; Ekineh & Adolphus, 2019) revealed no significant difference between male and female learning results when taught utilizing creative, hands-on, and student-centred teaching techniques. This may imply that the effectiveness of using proper measures may have contributed to closing the gender gap. For instance, Obochi (2021) found that neither the male nor the female students in the treatment group significantly outperformed the other in biology in a study to determine the effects of analytical/problem-solving strategy on attitude and academic performance in biology among Senior Secondary Students of varying ability. In line with this, Lameed *et al.*,'s study from 2023, "Beyond the Boundaries of Achievement in Secondary School: Higher Order Thinking in Focus," revealed no evidence of gender differences among students who were taught analytical strategy's higher order thinking tasks in biology.

In order to build the abilities necessary for technological advancement in the twenty-first century, it is crucial to develop practical process skills. Studies on improving students' drawing skills are still comparatively scarce, despite the rising corpus of research on the effects of analytical/problem-solving techniques on students' learning outcomes in the sciences. Therefore, this study focuses on determining if problem-solving techniques may help secondary school science students improve their drawing skills. It then investigates the interacting effect of gender on these students' drawing abilities. The following goals are what the study aims to accomplish. To ascertain the effects of analytical/problem-solving strategy on students' drawing skills in the science of biology; gender on students exposed to problem-solving strategy on their drawing skill achievement; and (3) the interaction between gender and treatment on students' drawing skill achievement in the science of biology, physics, chemistry, and computer.

1.1 Research Questions

The following research questions guided the study:

1. Can the use of analytical/problem-solving strategy improve the students' drawing skills of science students than the conventional method?
2. Can the use of analytical/problem-solving strategy narrow the gender gap in drawing skills of students in sciences?
3. Can gender interact with an analytical/problem-solving strategy to impact on students' drawing skills in sciences?

1.2 Research Hypotheses

The following hypotheses guided the study:

- Ho1: There is no statistically significant difference in the mean scores of students' drawing skills in the experimental and control groups.
- Ho2: There is no statistically significant difference in the mean scores of male and female students' drawing skills in the experimental group.
- Ho3: There is no statistically significant interaction effect of gender and treatment on students' drawing skills in sciences.

2. METHODOLOGY

The study included 87 senior secondary II science students from two senior secondary schools in Lagos State. Southwest Nigeria's Lagos state is a cosmopolitan state or city. The sample used for the study consisted of two complete classes. One intact class served as the sample for the experimental group that received instruction in scientific drawing techniques using an analytical approach, while the other intact class served as the control group that received instruction in scientific drawing techniques using the traditional mode of instruction. The topic and stream of instruction were chosen based on two criteria. First, the choice of senior secondary class II was made because it covers a large portion of the curriculum's contents and topics for science, while the decision to focus on scientific drawing skills was motivated by observations of students' poor performance as a result of weaknesses in the WAEC chief examiners' report and the fact that the practical component carries a weighted mark of 40% in the summative evaluation. Data for the study were collected using a researcher-designed instrument. The participants in the experimental and control groups were given the Biology Drawing Skill Achievement Test (BDSAT), which consisted of 8 theory practical items to rate observational and drawing skills, appropriate title of diagrams, determining accurate magnification of diagrams, quality diagrams (neatness of label, clarity of lines), details on the diagram, and adequate labels.

2.1 Procedure

The first step in the treatment process was to secure the approval of two senior secondary schools and the agreement of the study's participants. The familiarization visit that followed was used to talk with the participants about the study's goals. Preliminary testing was given, and the topic and the rules for scientific drawing were introduced. While the participant saw and studied the dissection procedure, the researchers continued to dissect a rabbit and presented the internal organs such as the kidneys, heart, alimentary canal, and lungs. Participants were led to different schematic views by way of probing inquiries. The participants were instructed to sketch a 6–8 cm long, well-labeled drawing of a longitudinal segment of the kidney. Specimens of cervical and thoracic vertebrae were on display to start the second- class session. The participants were instructed to create detailed (4 cm – 6 cm) drawings of the provided specimens. Researchers fixed a slice of a cross-section of a monocot and a dicot stem on the microscope for the students to view, observe, and make well-labelled drawings to 6 cm to 8 cm during the third contact time of instruction. In the fourth practical activity, students observed and labelled drawings of juvenile toads and tilapia fish specimens before moving on to a cockroach and a maize weevil in the fifth practical activity. Students were also asked to describe how each species differed from the others in order to gauge their capacity for observation. The final steps included scoring, creating, and administering the posttest.

3. RESULTS

To analyze the data gathered in the study, descriptive statistics of mean, standard deviation, and analysis of covariance were used.

Table 1: Mean and SD of students' achievement in experimental and control groups

Group	Mean	Std. Deviation	N
Experimental	36.02	12.60	50
Control	27.76	13.87	37
Total	32.51	13.70	87

Table 1 shows that students who were taught analytical/problem-solving techniques achieved a mean score of (M = 36.02; SD = 12.60), compared to the control group's mean score of (27.76; SD = 13.87).

3.1 Hypotheses Testing

Ho1: There is no statistically significant difference in the mean scores of students' drawing skills in the experimental and control groups.

Table 2: ANCOVA – students' posttest achievement in analytical/problem-solving approach and control groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4117.472[a]	2	2058.74	14.37	.000	.255
Intercept	281.141	1	281.14	1.96	.165	.023
Pretest	2665.515	1	2665.52	18.61	.000	.181
Group	1297.949	1	1297.95	9.06	.003	.097
Error	12034.275	84	143.27			
Total	108078.000	87				
Corrected Total	16151.747	86				
a. R Squared = .255 (Adjusted R Squared = .237)						

The finding in Table 2 demonstrates the significance of the effect of analytical/problem-solving strategy [F (1, 84) = 9.06; p, .05]. This shows that the null hypothesis, according to which there is no discernible difference between the achievement mean scores of students who solve problems and those who don't, is untrue.

Table 3: Mean and standard deviation of performance of male and female students in the analytical group

Gender	N	Mean	Std. Deviation
Male	21	38.14	12.34
Female	29	34.48	12.77
Total	50	36.02	12.60

The results in Table 3 show that males had a higher performance mean score (M = 38.14; SD = 12.34) while females had a lower performance mean score (M = 34.48; SD = 12.77).

Ho2: There is no statistically significant difference in the mean scores of male and female students' drawing skills in the experimental group.

Table 4: ANCOVA- male and female students' performance in analytical strategy

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	847.337a	2	423.67	2.87	.066	.109
Intercept	1172.345	1	1172.35	7.95	.007	.145
Pretest	684.170	1	684.17	4.64	.036	.090
Gender	153.540	1	153.54	1.04	.313	.022
Error	6929.643	47	147.44			
Total	72649.000	50				
Corrected Total	7776.980	49				

a R Squared = .109 (Adjusted R Squared = .071)

There was no statistically significant difference in the performance of male and female students who were taught drawing techniques together with an analytical approach, according to the results in Table 4 [F(1, 47) = 1.04; p >.05]. This supports the claim that there is no statistically significant difference between male and female pupils who are taught analytical approach/problem-solving and drawing skills. Consequently, the hypothesis is upheld.

Ho3: There is no statistically significant interaction effect of gender and treatment on students' drawing skills in sciences.

Table 5: ANCOVA- Interaction effect between group and gender on performance of students in drawing skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4284.495a	4	1071.124	7.40	.0.00	.265
Intercept	300.778	1	300.778	2.08	.153	.025
Pretest	2637.419	1	2637.419	18.2	.000	.182
Group	1353.047	1	1353.047	9.35	.003	.102
Gender	126.526	1	126.526	.87	.353	.011
Group * Gender	22.312	1	22.312	.15	.70	.002
Error	11867.252	82	144.723			
Total	108078.000	87				
Corrected Total	16151.747	86				

a R Squared = .265 (Adjusted R Squared = .229)

The finding in table 5 [F (1, 82) =.15; p >.05] showed that there was no statistically significant interaction between therapy and gender on students' performance in drawing skills. This shows that the premise that there is no statistically significant interaction between treatment and gender is accepted.

4. DISCUSSION

The goal of this study was to investigate analytical approaches to developing students' scientific drawing abilities. As a result, the study focused on three distinct issues. These questions were "Can the use of analytical/problem-solving strategy narrow the gender gap in drawing skills of students in sciences?" and "Can the use of analytical/problem-solving strategy improve the drawing skills of science students than conventional method?" And does gender have a role in the analytical approach in how well pupils draw in the sciences? The investigation and calculations revealed five tables in this regard. The first question was to determine whether applying analytical techniques can enhance or promote pupils' ability to draw in the sciences. According to the results, students in the analytical/problem-solving strategy group scored on average 36.02 as opposed to 27.76 for the students in the control group. It was determined that the difference was statistically significant. This suggests that the analytical approach has outperformed the conventional teaching approach. The strategy's ability to first highlight the rules governing scientific drawings and the student's capacity to apply these rules to making drawings in consonance with the instructions and series of drawing exercises initiated by the teacher were the major contributing factors to the significant difference, giving the students an advantage over the students in the control group. As a result, the experimental group (analytical/problem-solving strategy) did better than the control group. This result supports Lameed *et al*.,'s (2023) study, which discovered that the analytical/problem-solving strategy improved biology students' capacity for higher-order cognitive tasks. The results are consistent with those of Obochi (2021), who discovered that students with poor learning abilities in biology performed considerably better academically when they solved problems. This suggests that when a teacher applies a constructivist-based instructional technique, they force students to make sense of the material and instruction they receive while connecting prior knowledge to the lesson plan and a sequence of analytical/problem-solving activities they complete. As a result, in an analytical/problem-solving technique, the instructor leads and directs the students toward meaningful knowledge of concepts, and the students respond by expressing their own opinions and ideas with the goal of jointly identifying and solving difficulties to improve effective learning. Once more, employing analytical/problem-solving strategies encourages students to apply their observational, interpretive, and analytical skills. As a result, students' creativity, critical thinking, and problem-solving abilities have increased. Additionally, there is substantial evidence that information is more effectively retained when students create diagrams that accurately label topics rather than memorizing pages of notes and engaging in rote learning.

Analysis of covariance on the gender drawing skill scores was done in an effort to ascertain how gender affected students' drawing abilities in biology. The results (Table 4) showed that there was no gender difference in the students' scientific drawing abilities. This result was attained because an analytical/problem-solving approach was capable of engrossing both male and female students with the majority of activities and so proved gender friendly. This research challenges the conventional wisdom that male students are more drawn to drawing-related disciplines than female students.

This finding confirms other research (Lameed *et al*., 2023; Obechi, 2021; Olasheinde & Olatoye, 2014) that gender has little bearing on students' academic success. The finding, however, contradicts the submission of previous studies (Jegede & Olu-Ajayi, 2017; Isaak *et al*., 2022; Ngwu *et al*., 2020) that found a strong gender influence on student achievement in biology. The study population, the learning setting (environment), and the idea used may have caused variations or divergences between the findings and those of the prior study. This suggests that teachers should constantly include their pupils in hands-on activities that are central to constructivist learning theories. The gender gap will shrink and boys and girls will equally pursue STEM occupations when both are offered equal learning chances.

Establishing if gender has an interaction effect with the instructor instruction approach was the third goal of the study. The results [F (1, 82) =.15; p >.05] indicated that there was no statistically significant interaction between gender and the instructional technique used by the teacher on the student's achievement in drawing skills. The results corroborate those of Lameed *et al.*, (2023), who found no statistically significant interaction between the analytical/problem-solving method and gender on students' performance on higher-order thinking tasks in biology. This suggests that gender was not related to the approach used to increase or enhance students' biology sketching abilities. This can be attributed to the strategy's effectiveness because it encouraged both genders to actively participate, giving them the chance to share ideas, compare drawings for potential corrections, and practice drawing in a variety of settings both inside and outside of the classroom. Gender did not, therefore, correlate with the instructional technique used in the classroom to promote student progress in drawing skills.

5. CONCLUSION

Unwanted student learning results in external exams have been a hot topic of significant concern to stakeholders in education (of all stripes). This has been linked to the negative attitudes and apprehension that children have shown toward learning science. The weighted score for the practical biology exam given to students is 40%, while the weights for the essay and objective are 35% and 25%, respectively. This shows that when students adopt a positive learning attitude and acquire the requisite drawing abilities for science, their performance advances and rises.

6. The Implication of the Study

One of the science courses having a top spot in the senior secondary curriculum is sciences, particularly biology. Because it is necessary information for many STEM-related industries or careers following secondary education, many students offer it. The research's findings have the following consequences:

i. Students have a negative attitude toward drawing; thus, they avoid inquiries about it in the essay and practicals in particular.
ii. Teachers should engage students in regular drawing activities while supporting them in learning and applying the standards for high-quality drawings in the sciences (biology).
iii. Science instructors should use a student-centred approach to instruction to inspire students to learn about biology, physics, chemistry, computer science, etc.
iv. To promote meaningful learning, teachers are urged to use analytical techniques when delivering teaching in the classroom.

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