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Application of Multimodal Instructional Technique in Enhancing Biology Students' Understanding of Concepts and Retention of Knowledge of Photosynthesis in Nifa SHS, Ghana

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Abstract. This mixed-method quasi-experiment research was aimed at enhancing Biology students' understanding of concepts and retention of knowledge of photosynthesis in plants through the application of the multimodal instructional technique (MIT) in Nifa Senior High School. It also investigated students' views and opinions about MIT. A stratified random sampling strategy was used in the selection of forty second-year Biology students as respondents. The sample size comprised 23 boys and 17 girls. Respondents were grouped into experimental and control groups of 20 students each. The study lasted for five weeks. The control group's participants were asked to review the lessons by using a question-and-answer approach and writing up activities in their textbooks as assignments. For the experimental group, MIT, instructional games, educational videos and practical activities were used to facilitate and review their lessons. A multimodal instrument for data collection (MIDCO) which consisted of the Photosynthesis Achievement Test (PAT), a Retention of Knowledge Test (RKT), an open-ended interview and observation checklist were used to collect both quantitative and qualitative data. Quantitative data was analysed using independent samples t-test while qualitative data was analysed thematically using descriptive statistics. Results of the analyses indicated a significant difference in both the PAT and RKT with the experimental group achieving

(PAT; $\bar{x}$ = 64.52, SD = 9.30, RKT; $\bar{x}$ = 39.92, SD = 5.77) and the control group (PAT; $\bar{x}$ = 52.36, SD = 13.95, RKT; $\bar{x}$ = 34.80, SD = 7.35). The research found no significant difference in PAT ascribed to gender, namely (PAT; $\bar{x}$ = 65.2, SD = 9.95) for the boys and (PAT; $\bar{x}$ = 61.3, SD = 10.31) for the girls. Results suggested that MIT was effective in promoting students' understanding of concepts and was an effective device in enhancing the retention of knowledge. The learners found MIT to be an effective strategy for reinforcing learning and as a tool for motivation.

Keywords: multimodal instructional technique; conceptual understanding; retention

1. Introduction

In general, students in a learning environment differ from one another with each learner possessing a distinctive and complex intellectual system of understanding, absorbing, and assimilating biological terms and concepts (Tetteh, 2021). Therefore, it is untenable to claim that learners should all be instructed using the same methodology. It is important that one develops better means of presenting lessons to learners. Perhaps, better techniques to achieve this might be realized by the integration of a variety of instructional methodologies that are more relevant as opposed to a one-way method of lesson presentation. The use of MITs such as instructional videos, educational games, science practical lessons, computer simulation activities, and online-classroom engagements are such instructional modes that, if effectively applied, will provide the right learning opportunities to Biology students (Tetteh, 2021). It will also provide the potential for not only holistic assessment but also effective interpretation of science students' learning progress.

Several works have been conducted on multimodal teaching and learning strategies in the classroom (Akudo et al, 2024; Al-Jarf, 2024; Firmansyah, 2021; Muraina et al, 2019). Muraina et al. (2019), for instance, described MITs as tools that are used in the teaching and learning process to help the learners' brains function effectively and efficiently in relation to content information to which the learners are supposed to work. The emergence of multimodality and its dominance in the era of 21st century has necessitated institutions of higher learning to consider modifying the style of their traditional and outdated approach to classroom instruction (Tetteh, 2021). The instructional technique of multimodal learning is a learner-centred strategy that depends on electronic technology to promote learning which enforces learner active participation in the instructional process (Akudo & Ochuba, 2024). They emphasized that this methodology is "evident in the modern teaching and learning environments" (p. 2). With advancements in electronic as well as Internet and digital literacy, technological ways of communication and instruction are recommended in the classrooms to complement prints, visual narratives, and digital books (Akudo & Ochuba, 2024). In terms of replacing traditional literacy values, MIT also referred to as multimodality, augments educational communities' literacy and increases the introduction of technological platforms for classroom lesson presentation.

According to Miller and McVee (2013), these new literacies cannot eliminate the traditional literacies. Biology students still must understand not only how to read and write, but also how to perform experiments, manipulate equipment, and apply content knowledge in solving problems of daily life. The outcomes of classroom learning may be the same, including reading and calculating, just to mention a few. However, these outcomes of learning are now focused in a new direction with the use of MIT in the learning environment. This represents a total shift from traditional means of teaching, including printed text, to abetter contemporary media such as electronic-based content. The decision to integrate multimodality into the teaching of Biology remains controversial in educational circles. The methodology of classroom teaching and learning has undergone a series of metamorphosis with the passing of time, with some arguments that the method of instruction must be in conformity with the affective and personal demands of the students.

It is critical to state that all forms of classroom activities, such as instruction, provide the learners with some perceived ideas of stimuli, while the intrinsic and retention of learners cause total internal distractions at the same time. It will serve a good purpose to integrate a variety of modes when guiding students to respond favourably to new content information at a specific time in the span of instruction and/or assessment. According to Muraina et al. (2019), every mode enables the learner to link any specific concept to a distinct dimension of sensory memory. According to them, educational videos, audio-visual materials, and science practical activities are all considered forms of MIT.

The idea of a MIT, or simply multimodality, involves the use of various modes such as the use of educational videos, science practical lessons and scientific games to present the same information to the learner (J. Eminah, personal communication, March 10, 2020). The multimodality term or concept was developed and advanced in the 1990s. The concept was eventually approved by educationists such as Kress (2003, 2000), Kress and Van Leeuwen (2001), and Cope and Kalantzis (2000). Educational scholars maintained that currently, classroom communication and instruction do not merely pertain to a one-way mode such as printed text which is conveyed through a medium such as a book. However, because of advancement in digitalization and technological literacy, all modes can be propagated via a single binary key. To this end, the media of the digital screens are now the major sites where a good deal of modes can be organised to make learning more meaningful in self-motivated ways.

Multimodality fits perfectly into the learning theory of constructivism. A quotation by Johan Huizinga (1971) "Let my playing be my learning and my learning be my playing" confirms that hands-on tasks and learning should not be in isolation but should be dependent on one another. Roblyer and Doering (2013) discussed that for effective learning to take place, it must be designed in the same way that students embrace having games or funs. According to constructivists, teaching is by far not just the process of transferring the knowledge from the teacher's brain to the learner's brain. It is predominantly an effective activity and meaningful interaction aimed at helping learners build concrete knowledge. The science educators' role is to act as facilitators and to provide guidance to help students construct their own knowledge efficiently and quickly, and not to be mere transferers of knowledge to their students. Proponents of the constructivists learning approach view the classroom as a form of social learning group, a society of learners participating in an activity, discussion, interpretation, exploitation, explanation and reflection (Fosnot, 2005). TheMIT connects different teaching tools and resources as a medium of lesson presentation in order to present clear meaning to the learners. Karmila et al. (2020) maintained that accomplishing success in learning can be achieved by the kind of learning media adopted and used. The authors further opined that by using adequate and appropriate educational media, complex topics to be presented to the learner can be effectively simplified in a way that the learner can absorb more easily.

As an instructional strategy, MIT keeps learners engaged as a result of the integration of multiple strategies in the same lesson, leading to higher retention of the material (Akudo & Ochuba, 2024). Ganapathy (2016) stated in his research work that the utilisation of multimodal teaching and learning approach enhances learner engagement in the instructional process. He further stated that with multimodal approach to learning, the learners seemed positively inclined. In addition, MIT increases learners' motivation, according to Akudo and Ochuba (2024). Karmila et al. (2020) explained that one of the relevant factors to successful learning is students' motivation to learn. If learners are highly motivated, they will have a better chance of achieving learning goals. Ganapathy's view on this was that students seemed adequately motivated to learn any content presented to them with the usage of MIT (2016). Furthermore, MIT improves the understanding of concepts as it carries information through several modalities such as visuals, and auditory and practical activities. It gives room for the application of the instruction to real-life situations by the learners (Al-Jarf, 2024).

Furthermore, MIT does not only improve retention of knowledge (Akudo & Ochuba, 2024), but also promotes creativity, innovativeness, and critical thinking in learners (Al-Jarf, 2024). It is well accepted that hearing and seeing something twice or more times facilitates better retention than once. Multimodality allows the same content to be taught to students' multiple times and through multiple senses. The more senses are actively involved in the learning process, the more knowledge one gains, and the more effectively the knowledge is retained (Tetteh, 2021). The extra benefit that can be derived from explicit MIT in science education includes assisting the learner to gain and sustain interests in the learning methodologies (Suflita, 2012). Maximum levels of learning and knowledge acquisition can be enhanced if the Biology teacher is fully committed to the development of engaging instructions; designing and re-designing of multimodal experiences. This will provide feedback to learners to make interconnections and evaluate several discrepancies resulting from varied forms of lesson illustration.

Bezemer and Kress (2008) explained that science teachers can use the MIT to align students' social learning sphere closely with both in and beyond the classroom environment. In addition, science educators can also make use of this style to communicate learners' comprehension into the less used literacies such as writing and interpretation. The multimodal technique can potentially impact learner's engagement and ways of learning as the technique provides several opportunities to re-teach the same content to the learners (Tetteh, 2021). Jewitt (2008) opined that meanings are constructed, disseminated, interpreted and reconstructed (as cited in Suflita, 2012) when multimodality is the tool for instruction. The strategy of multimodality goes beyond the ordinary transmission of information through varied channels, requiring students to discover and gain learning experiences through such multiple means via the application of their skills in order to exploit their interest while at the same time interacting with the subject content and the learning prospects that are accessible to them (Tetteh, 2021).

1.1 Research Objectives

The research seeks to achieve the following three objectives, namely to:

- Investigate any significant difference between the experimental group performance and that of the control group in the PAT and RKT;
- Investigate any significant difference between the performance of boys and girls in the PAT; and
- Assess learners' perceptions of the usage of MIT as a strategy for teaching and learning.

1.2 Research Questions

The following three research questions were outlined to guide the study:

- To what extent is the experimental group performance significantly different from that of the control group in the PAT and RKT?
- To what extent is the boys' performance significantly different from that of girls in the PAT?
- What are the perceptions of learners about the use of MIT for teaching and learning Biology?

1.3 Research Hypotheses

At 0.05 alpha level of significance, each of the following formulated null hypothesis was tested:

- H_{O1}: No significant difference exists between the performance of the experimental and control groups in the PAT and RKT.
- H_{O2}: No significant difference exists between the performance of boys and girls in the PAT.

2. Methodology

2.1 Research Design

The quasi-experimental research design was adopted. Thus, the design included two pre-test/post-tests. Normally, quasi-experiments are used when a researcher aims at establishing a possible "cause and effect" relationship that exists between dependent and independent variables (Creswell, 2012).

2.2 Sampling Technique

The technique used in sampling the research respondents was the stratified random sampling technique. This technique, according to Cohen et al. (2007), allows the population to be divided into manipulable strata in order to complete the process of sampling. The strategy is normally used by many educational researchers to permit all sub-groups of the population to be included in the selected sample (Tetteh, 2021).

2.3 Study Participants

Forty (40) Form Two Biology students of NISEC were selected as the participants for the study. This number comprised 23 boys and 17 girls. They were divided into the experimental and control groups based on the result of the pre-test to ensure parity of the group (Creswell, 2012). The former group comprised 11 boys and nine girls whilst the latter group had 12 boys and eight girls. The distribution of research participants according to their group and gender is shown in Table 1.

Table 1: Distribution of research subjects

Group/Gender	Boys	Girls	Total
Experimental	11	9	20
Control	12	8	20
Total	23	17	40

2.4 Instruments for Data Collection

Various instruments, collectively known as the Multimodal Instrument for Data Collection (MIDCO), were used for this study. The MIDCO comprised the PAT, RKT, an open-ended interview for the focus group, and observation protocols. The instruments were drafted, developed, and administered by all the researchers. The MIDCO was used to ensure that the data collected was effectively triangulated.

2.4.1 Photosynthesis Achievement Test (PAT)

A table of specification was constructed according to the guidelines provided by the Ministry of Education (2023) and used to develop the test items making up the PAT. The table of specification outlined the specific learning outcomes of the section of the syllabus containing the topic under consideration. The questions were distributed fairly to cover the complete unit. The PAT contained 33 test items assessing the four levels of Depth of Knowledge, namely recall and reproduction, skills of conceptual understanding, strategic reasoning, and extended critical thinking and reasoning. These areas were captured in the four (4) types of questions constituting the PAT – 12 fill-in the blanks items, three true or false test items, and 14 multiple choice items with the subjective type of question having 4 items. The maximum score for the PAT was 80 marks.

2.4.2 Retention of Knowledge Test (RKT)

In the construction of RKT to be conducted as a delayed test, questions were carefully selected from the pre-test questions, the PAT, in addition to new questions. TheRKT assessed four different degrees of objectives in Bloom's taxonomy, namely knowledge, comprehension, analysis, and application. The RKT constituted 20 test items. The objective was to assess learners' ability to retain and recall information that was presented to them four weeks after the intervention. The set of questions making up the RKT included seven (7) multiple choices, seven (7) fill-in questions and six (6) subjective questions. This test was taken four weeks after the post-test. The maximum score for the RKT was 50 marks.

2.4.3 Focused-Group Interview

Creswell (2012) opined that, in general, unrestricted types of questions are asked when conducting interviews as it helps in obtaining impartial results. The interview items were therefore developed accordingly and administered to the focus group of research participants. The interview aimed at investigating the views and opinions of respondents about the use of MIT as the intervention strategy for the experimental group of the topic under study.

2.4.4 Observation Protocol

Observation, according to Gorman and Clayton (2005), is an activity that deals with the prescribed method of recording observable actions, attitudes, behaviours, or reactions of people in a natural setting. Critical observation of participants' behaviours and attitudes as they perform an activity is important in research because it provides an insight into how a programme or activity operates that participants might not routinely mention in an interview. The researchers adapted an observation checklist which was developed by Gablinske (2014) and used it extensively during the intervention period to observe the overall behaviours of the learners. The covert observation form - where the students did not know that they were being observed - was employed and used by the researchers.

2.5 Instruments Validity

The PAT and RKT

To ensure effective validity of PAT and RKT, the Ghana Education Service teaching syllabus for SHS Biology was strictly followed in developing the test items. The test items were then presented to some Biology experts for their review and advice. As a result of their suggestions, three of the items were reframed with regard to scientific wording. Two other items were completely deleted, resulting in 33 and 20 items for PAT and RKT, respectively. Furthermore, one English language expert analysed the questions in terms of grammar and punctuation. Relevant adjustments were made to the items as his feedback provided useful information.

2.5.1 Interview and Observation Guides

Interview questions as well as observation guide were validated, accepted and approved for administration by a PhD Biology teacher, a principal tutor at one of the colleges of education, in terms of face and content validity. The validator restructured and reorganized a few of the instruments to enhance their validity.

2.5.2 Instrument Reliability

To ensure the reliability of both the PAT and RKT, the instruments were exposed to a test-and-retest reliability technique in order to establish that the data collection process is well-suited and repeatable. The instruments were given to colleague Biology teachers who tested and retested the instruments with their SHS Form Two Biology learners within a timeframe of four weeks between the conducting of the two tests. The reliability coefficients were calculated by means of the formula of simple linear correlation coefficient. The values obtained were 0.81 and 0.79 for PAT and RKT, respectively. These values indicated strong correlation, an indication that the research instruments were reliable.

2.5.3 Data Collection Procedures

Administration and Grading of PAT and RKT

The PAT set of questions was administered straight after the intervention as a post-test while the RKT was administered four (4) weeks later. Time allocated for PAT and RKT were 60 minutes and 45 minutes, respectively. Respondents' answer sheets were collected, marked and graded according to the final marking schemes prepared by the researchers. The marking schemes aligned with that of the West African Examinations Council. They were checked for adherence to instructions, clarity and coherence, content knowledge, accuracy and completeness of the task.

2.5.4 Focused-Group Interview

An interview was conducted for the experimental group after the intervention. During the interview, notes were taken by the researchers to ensure that the correct answers as presented by the interviewees were captured. To avoid participants' bias, the interviewees were contacted for specific clarifications on key points made before drawing conclusions.

2.5.5 Observation

To ensure the accuracy of the observation result, an observation checklist had been developed which was used to record specific behaviour during the period of intervention.

2.6 Intervention

The intervention was implemented for five weeks. Three lessons per week were held with each lesson lasting two hours. The photosynthesis pre-test was administered to the research participants prior to the intervention. The result of the pre-test was used to categorize the participants into control and experimental groups to ensure parity between the two groups as proposed by Creswell (2012). Teaching was then carried out using the traditional method of instruction for the control group. The teacher led the class in group discussions, quizzes, research projects and providing short answers to questions. Throughout the teaching process, the main resources used were the whiteboard, textbooks as well as notes compiled by the teacher. Research subjects of the control group re-examined the lessons as they made use of the question-and-answer approach. They were allocated activities in their textbooks as assignments and group work. However, MITs -- scientific games, practical lessons, and educational videos -- were used to facilitate and review the lessons of the experimental group.

Instructional videos on photosynthesis prepared and supplied by Centre for National Distance Learning and Open Schooling, also known as Presidential Special Initiative on Distance Learning, were extensively used. To ensure a serene and conducive environment for effective learning, the instructional videos were watched during evening prep. The videos' content matched the content of the Senior High School Biology syllabus. To enhance effective lessons, the videos were viewed severally, before and after the intervention of every sub-topic.

Five scientific games on various sub-topics, including Word Search, Categories, and Annotated Diagrams, were developed using the Xerte Toolkits App, with assistance and suggestions from colleague Biology teachers and other experts. In the process of developing the scientific games, specific objectives as well as the content of the photosynthesis topic were considered. A great deal of attention was paid as far as participants' age group and the suitability of each of the games to their intellectual levels were concerned (Selvi & Çoşan, 2018). To ensure the feasibility of the games, needs assessments were carried out by identifying learning objectives, assessing student engagement, and identifying areas where games can be integrated. A scientific game applicable to each sub-topic was played before and after the intended lesson for an overall picture of the nature of the sub-topic and to emphasize the content that had already been presented to the learners, respectively.

One practical lesson per week was held during the intervention period as stated by Ali et al. (2006) in the Senior High School Biology GAST. The practical lessons were aimed at the following:

i. To test for the presence of starch in green leaves;
ii. To demonstrate that oxygen is a by-product of photosynthesis;
iii. To investigate that carbon (IV) oxide is needed for starch formation in plants;
iv. To investigate that sunlight is needed for starch formation in plants; and
v. To investigate that chlorophyll is needed for starch formation in plants.

The practical science lessons progressed in the following three stages:

i. The teacher explained the steps involved in undertaking each of the activities to the learners, as they followed the PowerPoint slides.
ii. Demonstration lessons were given by the teacher.
iii. Participants in their groups carried out the activities. Each group had one of the researchers to guide them.

2.7 Data Analysis Procedure

Two categories of data, namely quantitative and qualitative, were collected. Quantitative data from PAT and RKT were analysed as the independent samples t-test was employed by making use of Microsoft Excel version 2018. The mean and the standard deviation were determined to explain how one outcome compares favourably with another. The independent samples t-test was run to examine the possible significant difference that may occur in the performance between the experimental and control groups for PAT and RKT at a 5% alpha (α) level. Qualitative data gathered from the interview were analysed broadly in thematic terms and by using frequency count while observation data were subjected to descriptive statistics analysis. Some results generated were presented in tables with their frequencies and corresponding percentages were applicable for easier interpretation and understanding.

2.8 Results and Discussion

Under this section, results from the research are presented and discussed according to the research questions.

2.8.1 Quantitative Results

Research Question One

The first research question compared the control group's performance to that of the experimental group in the PAT and RKT after the experimental group had been exposed to a multimodal learning technique as the intervention strategy. An independent samples t-test was used to analyze the outcomes of both tests. The result for the PAT is illustrated in Table 2:

Table 2: Independent samples t-test of PAT results

Groups	N	$\bar{X}$	SD	df	t stat	p_{val}
Control	20	52.36	13.95	38	3.63	0.0007
Experimental	20	64.52	9.30			

***Significant at p<0.05**

The experimental group's arithmetic mean mark, $\bar{x}$ = 64.52, at a standard deviation of 9.30, was significantly higher compared to that of the control group's mean mark, $\bar{x}$ = 52.36, at a standard deviation of 13.95. A significant difference was realized between the two groups with reference to their PAT scores at a t-statistic of 3.63. A p-value of 0.0007 was obtained which was less than the stated significant level, namely 0.05. Cohen's d was calculated to determine the size of the effect the intervention had on the research and a value of 1.03 was found. The value suggested a very large effect size (Cohen, 1988). Cohen d was the appropriate assessor for effect size when the two groups were of the same size.

The result agrees with many other studies that had supported the use of MIT in instruction as it provides an engaging atmosphere suitable for learning. For instance, Muraina et al. (2019) opined that using MIT enables science educators to help learners attain a nuanced understanding, efficiently demonstrate the knowledge they acquired and be better able to reveal their intellectual abilities (as cited in Tetteh, 2021). Ganapathy (2005) concluded that using MIT as instructional strategy promotes learners' engagement significantly in the learning process. In addition, learners' perception is viewed as very engaging, self-reliant and learner-centred, while effective meaning-making is enhanced with less direction from the science teacher.

Furthermore, Selvi and Çoşan (2018) suggested that educational games be used in teaching as they find these to be effective in teaching the topic of "Kingdoms of Living Things". The result also agrees with that of Akudo and Ochuba (2024), namely that learners perform better as a result of the utilisation of a multimodal instructional technique. They stated that "the mean scores increased significantly from the pretest to the posttest, indicating a positive impact of the Multimodal Instructional Strategy" (p. 9). Moreover, the finding was in agreement with the study of Firmansyah (2021) which indicated that learners in the experimental group who were exposed to the multimodal approach outperformed those in the control group who were instructed using the conventional method of teaching. The results of RKT are presented in Table 3 and then discussed.

Table 3: Independent samples t-test for RKT

Group	N	$\bar{X}$	SD	df	t stat	P_{val}
Control	20	34.80	7.35	38	2.74	0.009
Experimental	20	39.92	5.77			

***Significant at p<0.05**

As illustrated in Table 3, the average mark ($\bar{X}$ = 39.92), of the experimental group at SD of 5.77 for RKT was higher than that of the control group's mean mark ($\bar{X}$ = 34.80) at SD of 7.35. Therefore, a significant difference in favour of the experimental group was achieved [$t_{(38)}$=2.74, $p<0.05$]. Thus, the experimental group performed better than the control group in the RKT.

It was demonstrated that the utilization of a MIT to teach learners photosynthesis in Biology had played a significant role, culminating in the participants of the experimental group having a better understanding of the concepts. This produced a positive result in the conservation and retention of knowledge of the new information on the topic. Moreover, it can be argued that the activities as well as the questions in the MIT promoted effective learning of the material as the participants' intellectual abilities were triggered. This, in addition to other factors, escalated the total understanding and knowledge retention. This agrees with the Corporation for Public Broadcasting's 2004 research finding that learners who viewed educational television as a form of learning had made significant gains and had lasting learning outcomes.

The research also established a positive relationship between the viewing of educational videos by children and mental performance at both early and advanced levels. Also, a summary of research studies conducted in the early 1970s by Fisch (2003) provided robust evidence of how effective watching *Sesame Street* was in terms of education. Early-grade students who habitually viewed *Sesame Street* exhibited substantial growth in their academic journey. These outcomes have positive lasting benefits to the learners, as exemplified by the research of "recollect" which established that high school students who viewed *Sesame Street*, educational television, and additional instructional videos frequently as early graders had achieved improved grades and also exhibited more exceptional pedagogy and self-worth than their classmates who did not (Cruse, 2007). The results aligned with other suggestions by some educational researchers that the adoption and utilisation of multifaceted instructional strategies should be considered by all teachers in order to meet the growing number of learning mechanisms in the classroom environment (Achor, 2008; Akubuilo, 2004; Maduadum, 1994).

Research Question 2

Research question two (2) analysed the performance of boys compared to girls of the experimental group who were taught using the multimodal learning technique. The objective was to determine any likely significant difference that may arise in the performance of learners in the PAT as far as the gender variable is concerned. The results of the analysis are presented in Table 4, followed by a discussion.

Table 4: Independent samples t-test for gender variable

Groups	N	$\bar{X}$	SD	df	t stat	Pval.
Boys	11	65.2	9.95	18	0.83	0.42
		61.3	10.31			
Girls	9					

***Significant at p<0.05**

The results as presented in Table 4 indicated that no significant difference existed in respondents' performance in the Photosynthesis Achievement Test that was credited to gender [$t_{(18)}$=0.42, p>0.05]. This group of learners was taught using the same strategy (MIT). In terms of this result, it was stated by the researchers that the application of MIT in the study was aimed to achieve specific subject knowledge for every learner at a definite educational level regardless of the gender of that learner.

The result was again attributed to the fact that MIT motivated both boys and girls extrinsically and inspired them to study. The technique thus magnetized their attention equally and advanced their participation equitably as learners at the same level and in the same class. Furthermore, the outcome was fairly credited to the kind of conducive learning environment to which both boys and girls were exposed, which essentially contributed to the equivalence in learners' understanding of subject matter and hence equal performance in the PAT by both boys and girls. The result obtained agrees with other findings where both boys and girls gained equal understanding whenever they were exposed to the same intervention under the same conditions with reference to content learning of a specific subject (Al-Tarawneh, 2016; Klisch et al., 2012).

2.8.2 ***Qualitative Result***

Research Question Three

The third research question was formulated to seek learners' perceptions about the use of MIT as the intervention strategy for the teaching and learning of photosynthesis. After intervention, a focus-group interview was held for the learners in the experimental group. Their views and opinions were analysed based on codes and the final results were tabulated. Participants' views on the question "*What are some of the benefits you derive from the use of MIT in teaching and learning?*" are presented in Table 5.

Table 5: Respondents' views about the use of MIT in learning

Participants' view/opinion	Frequency	Percentage
My engagement was promoted in the lesson as MIT was used.	20	100%
MIT assisted us in learning more of the content.	19	95%
Our interest was boosted and sustained in the lessons.	18	90%
Our retention of concepts was much improved.	18	90%

MIT nurtured our self-confidence in the lessons.	17	85%
MIT enhanced our understanding of concepts.	17	85%
MIT enhanced new learning experiences.	16	80%
MIT was effective for team collaboration.	14	70%
Revision was easier with the use of MIT.	13	65%
Our motivation was improved.	13	65%
MIT developed our critical thinking skills.	11	55%
We worked effectively on our mistakes.	7	35%
MIT eliminated distraction in class.	6	30%
No laziness was experienced.	6	30%

As illustrated in Table 5, during the interview, the majority, namely19 of the participants, which represented 95% of the sample size (f=20), specified that using MIT as an instrument for teaching and learning enabled their engagement throughout the lessons, and hence assisted them in learning more of the content. In addition, a 90% of the research subjects (f=18) opined that "our interest was boosted and sustained in the lessons" as a result of the utilisation of MIT during the intervention period. This culminated in higher knowledge retention of the material presented to the learners. These revelations aligned with Cruse's contention (2007) that two-thirds of science teachers who use TV and videos for weekly lessons concluded that studies by learners are more effective when television or educational video is used. In addition, approximately 70% of the teachers found that the use of videos enhances students' motivation.

Furthermore, more than 50% of people who frequently use TV and educational videos expressed the view that as a consequence of video usage, learners are able to use new terminologies for academic work. Moreover, 17 of the participants, which represented 85%, opined that MIT nurtured their self-confidence in the lessons which then enhanced their understanding of the topic. In addition, 80% stated that the strategy of MIT helped them in the development of new learning experiences. Moreover, MIT was more effective for team collaboration, as mentioned by 70% of the learners while, 13 of the respondents, representing 65%, indicated that the methodology made revision easier. Moreover, another 65% stated that "our motivation was improved" as a result of the use of MIT. This buttressed the position of CPB (2004) that television and instructional videos for teaching and learning enhance not only learner motivation but also enthusiasm. Some respondents, representing 55% and 35% expressed the view that MIT "developed our critical thinking skills" and that "we worked effectively on our mistakes", respectively.

In addition, in the course of the interview, participants were asked, *"Overall, state how you would rate your opinion/views for the use of MIT in learning on a rating scale of 'excellent', 'very good', 'good', 'satisfactory', 'poor' and 'very poor'?"* The answers provided by the students to the question were outlined in Table 6 after they had been analysed.

Table 6: Participants' perceptions about the use of MIT for instruction

Participants' views	Frequency	Rate
With MIT, our participation was promoted.	20	Excellent
Our interest was sustained in learning photosynthesis with MIT.	19	Excellent
MIT enhanced our understanding of the topic.	19	Excellent
Learning was much easier with MIT.	18	Excellent
MIT improved my knowledge retention.	16	Very good
Our self-confidence was developed with the use of MIT.	16	Very good
Motivation was promoted and enhanced.	15	Very good
MIT encouraged team work and collaboration.	14	Good
We were exposed to new learning experiences.	12	Good
MIT provided more opportunities for lessons revision.	10	Good/satisfactory
I enjoyed all the lessons with enthusiasm.	9	Good/satisfactory
All my mistakes were identified and corrected.	7	Satisfactory

As Table 6 indicated, 20 students (100%) maintained that "with MIT our participation was promoted" in the lessons during the intervention period and therefore rated the utilization of MIT as an "excellent" tool for learning Biology. Furthermore, another set of research subjects (f=19), representing 95% of the selected sample, opined that the usage of MIT was excellent as it sustained their interest in the learning of the topic of photosynthesis as well as facilitating their understanding. In line with this revelation, Mayer (2001) maintained that whilst viewing educational videos may be considered as secondary, it can simultaneously be an efficient instrument for exceptional intellectual activity essential for dynamic learning. He contended that ''well-structured multimodal instructional information can elevate active intellectual processing in learners, even when they (learners) appear inactive." Furthermore, 72% and 64% of the respondents rated the use of MIT as excellent and very good for making learning easier and promoting retention of knowledge, respectively.

Further views expressed by some of the respondents on the second question were outlined as follows: "MIT motivated us to develop self-confidence. We can now learn on our own by sharing ideas," said EF_2S3. "Going back to the old methods of teaching and learning Biology will be very boring and will make us inactive in class again". This was said upon realization that the intervention period was over. Other specific views expressed by some of the learners were as follows:

> *EF_2S13: Learning with MIT provides a lot of assistance and makes the lessons easier to understand. It affords me the opportunity to evaluate my learning progress as I participated fully in the lessons. I worked hard on my shortcomings by engaging with my colleagues in sharing ideas. My*

> *interest in learning the topic – Photosynthesis – has advanced. I did my best to score better marks in the games with my group members.*
>
> *EF_2H17: I want to state that MIT helped us learn a lot within this short period. We were able to follow the procedure provided to perform all the experiments during the practical lessons. I developed interest in watching the videos. It was very clear to our understanding. In fact, I can explain all that we were taught because I can remember all.*

2.8.3 *Discussion of Observation Results*

During the intervention period, the respondents' behaviour, attitudes and reactions were critically observed. The results of the observation were noted in the observation log and presented below. Educational videos on photosynthesis were watched during their evening private study time because normal teaching hours would not have been convenient. Students exhibited much interest in the videos, arriving at the venue earlier than the scheduled time (Tetteh, 2021). They usually rushed for the front seats.

In the course of watching the educational videos, respondents were all quiet and focused. They were almost all seen to be taking notes. There were no distractions, and no form of communication was observed. No noise was heard in the classroom and the activity proceeded as planned. The participants watched the videos with rapt attention. At the end of each viewing, students discussed their notes and findings among themselves in order to share ideas. They also asked questions and sought teachers' explanation on areas that seemed difficult to them. Some respondents expressed concern that the video should have lasted longer. Students were able to answer a few evaluation questions from the teacher immediately after watching the video. For example, *"Outline any three structural adaptations of the leaf of a plant for photosynthesis."* Answers that learners provided to this particular question included, but were not limited to "The leaf has a flat shape, providing a large surface area to allow maximum absorption of sunlight and carbon (IV) oxide" and "The numerous networks of veins supply the photosynthetic cells with water and minerals and removes the products of photosynthesis". Learners asked for permission so that they could watch the educational videos again during their free time, which was granted.

During the games, most respondents understood and obeyed the rules of the games (Tetteh, 2021). Initially, some were unable to finish within the stipulated time but as the games progressed, they were able to. There were interesting competitions among the various groups. Some students were quiet at the commencement of the games, but their interest was aroused as the games proceeded and winners were being identified. The respondents created their own strategies and techniques to finish early and be awarded higher marks. The Wordsearch Game, in particular, contains all the technical terms in the topic being studied and was therefore the last game to be played. The game created very exciting moments as most learners expressed the view that the scientific games were interesting and entertaining and caught their attention. It was observed that most of the students were much more focused as the time stipulated to end the game approached. A few students were alerted by their teammates whenever they committed an error for prompt remedy. Another observation made was that there was heightened competition among the various groups upon the announcement that the winning team would be given special recognition in class the following day. The participants experienced a well-structured and dynamic learning environment, which culminated in effective teamwork and collaboration as well as good working relationships among the various groups and individuals.

Practical Biology activities were held once per week in accordance with the tasks outlined in the Biology syllabus. The tasks were spread over the intervention period of five weeks. For each practical lesson, learners were attentive to the instructions and explanations of procedures and processes involved in the practical work. Participants frequently asked for further explanations on certain procedures that were unclear to them. During the teacher's demonstration lesson, which preceded the group activities, the students were not only highly attentive as the procedures were explained but also showed great interest in the process. In addition to the PowerPoint presentation, the research participants were observed taking notes on points they found important. During the group's initial trial activity, the researchers observed that the respondents carefully handled the reagents and the equipment, perhaps to ensure that the apparatus was not destroyed or that they did not miss out on any of the steps of the activity. They followed the procedures systematically and submitted to laboratory rules during their practical work. The learners were happy and positive after undertaking the activity and achieving the results.

In the course of the intervention period, the learners participated actively at all times. In addition, the students demonstrated "the spirit of collaboration and communicated brilliantly with their mates" (Tetteh, 2021). One of their hallmarks was their punctuality and regularity regarding class attendance. They demonstrated a positive attitude towards the lessons and were committed to every session throughout the period of intervention. Nevertheless, some cases of absenteeism were observed at a negligible level.

3. Conclusion

The main goal of this research study was to investigate how MITs can best be used to enhance second-year Biology students' understanding of concepts and their retention of knowledge of photosynthesis in NISEC. The research outcomes demonstrated a significant difference in both PAT and RKT in the experimental group's favour. It was also indicated that MIT usage assisted in promoting learners' understanding of biological concepts and practical activities associated with the topic under consideration. The MIT acted as a catalyst for enhancing learners' ability to retain new cognitive knowledge. Members of the experimental group were generally positive about the use of MIT as a teaching and learning strategy. It assisted the learners to play active roles in the lessons, promoting effective teamwork and collaboration. It also promoted their intellectual accomplishment and served as a tool for excellent motivation and retention of knowledge. In general, it can be concluded that the utilization of MIT in teaching Biology has positively impacted learners' conceptual understanding and retention of knowledge based on the results of the study.

4. Recommendations

As a consequence of the results obtained, it is recommended that:

i. MIT be adopted and used as an instructional strategy for teaching Biology in NISEC as well as other second cycle institutions offering Biology as one of their subjects;
ii. Workshops and educational seminars be organized by the Ghana Education Service (GES) and the National Teaching Council (NTC) for science tutors to assist them in designing and using MIT for instructional purposes;
iii. The universities that offer educational programmes and the colleges of education include the models of designing and using MIT for teaching and learning as part of initial teacher preparation programmes; and
iv. Further research studies be conducted on the effect of using MIT on learners' academic performance in the sciences with larger number of participants, possibly in both basic and second cycle institutions.

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Appendix 1

Sample Lesson Plan
Subject: Biology
Topic: Photosynthesis in Plants Nuclei Acids 2
Sub-topic: The Process of Photosynthesis and Testing for Starch in a Leaf
Class: SHS 2 (2 Science 1)
Week: One (1)
Duration: Two Hours

RPK: Learners are aware that plants manufacture their own food.

Objectives: By the close of this lesson, the learners will be able to:

i. explain the process of photosynthesis.
ii. write a balanced chemical equation for photosynthesis
iii. outline the process and be able to test for starch in a leaf.

Teaching and Learning Resources (TLRs):
Projector and Laptop, water, ethanol, iodine solution, beakers, test tubes, water troughs, white tiles, green leaves, Bunsen burner and video.

Teacher and Learner Activities:

i. The teacher played a short video for 3 minutes on the process of photosynthesis after which he discussed the process with the learners.
ii. The teacher discussed the balanced chemical equation with the learners using a projected PowerPoint slide on the marker board through brainstorming.
iii. Using the appropriate TLRs, and following the steps on the PowerPoint slides, teachers demonstrated an activity for testing for starch in a green leaf.
iv. The teacher then gave out the apparatus for the various groups to carry out the activity on testing for starch in a leaf. The teacher went round to monitor the group work.

Closure: Teacher played another video on the experiment to test for starch in a leaf to recap the day’s activity.

Appendix 2

Observation Protocol (Adapted from Gablinske, 2014), p.121.
A case study of student and teacher relationships and the effect on student learning)

Date: ……………………………………………………………………………………

Time: …………………………………………………………………………………..

Observation site: ………………………………………………………………………..

Person(s) being observed: ………………………………………………………………

Description of observation activity:
………………………………………………………………………………………………

Observation notes (site)	Reflective notes (observer)
……………………………………………………	………………………………...
……………………………………………………	………………………………..
……………………………………………………	………………………………..
……………………………………………………	………………………………...

Appendix 3

Instruction: Answer all questions on the question paper

Time allowed: 1 Hour

Respondent's Identification No: …………………………

1. Write a balanced chemical equation for photosynthesis.

   ……………………………………………………………………………………

2. Name the products of photosynthesis.

   ……………………………………………………………………………………

3. What conditions are necessary for photosynthesis to occur?

   ……………………………………………………………………………………

4. The light stage of photosynthesis takes place in the ……………………… of the chloroplast.

5. Write the first equation for photosynthesis.

   ……………………………………………………………………………………

6. Which of the following is a factor that affects the rate of photosynthesis?
   a. O_2 concentration
   b. CO_2 concentration
   c. H_2 concentration
   d. N_2 concentration

7. Write the full name for **RUBP**

   …………………………………………………………………………………….

8. Name the first product of photosynthesis.

   …………………………………………………………………………………….

9. The dark stage of photosynthesis is controlled by an enzyme and is therefore not affected by temperature. **True/False**

10. Which of the stages of photosynthesis is also called the Calvin Cycle?

    ……………………………………………………………………………………

11. Explain photolysis.

……………………………..……………………………………………………

…………………………………………………………………………………

……………...……………………………………………………………

……………………………...…………………………………………

…………………………………………………………………………………

What observation would you make when testing for starch in a leaf?

…………………………………………………………………………………

12. Which of the following is a hydrogen acceptor in photosynthesis?
    a. FAD
    b. NAD
    c. ADP
    d. NADP

13. What is the importance of RUBP in photosynthesis?
    a. it is a hydrogen acceptor
    b. it reacts with GP to form TP
    c. it is a source of phosphate ions
    d. it reacts with carbon (IV) oxide to form GP

14. The rate of photosynthesis increases when temperature …………………
    a. increases
    b. decreases
    c. remains constant
    d. remains at 0°C

15. Name the reagent used when testing for starch in a leaf: …………………

16. When a variegated leaf is used as both the control and the experimental set-ups the researcher is investigating the necessity of?
    a. light for photosynthesis
    b. chlorophyll for photosynthesis
    c. carbon dioxide for photosynthesis
    d. water for photosynthesis

17. The light stage of photosynthesis involves which of the following?
    a. fixation of carbon dioxide
    b. the reduction of ribulose bisphosphate
    c. photolysis of water
    d. oxidation of NADPH to NADP

18. Discuss the term photosynthesis.

………………………………………………………………………………………

………………………………………………………………………………………

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19. The rate of photosynthesis in plant is high when
    a. light intensity is low
    b. carbon dioxide concentration is low
    c. light intensity is high
    d. water content of soil is low

20. The tissues which manufacture carbohydrates in the leaves is the
    a. epidermis
    b. hypodermis
    c. endodermis
    d. palisade

21. Which of the following compounds in the light stage of photosynthesis is needed in the dark stage?
    a. Hydroxyl ions
    b. $NADPH_2$
    c. Oxygen
    d. ADP

22. One of the major components of air that serves as raw material for photosynthesis is
    a. nitrogen
    b. oxygen
    c. water vapour
    d. carbon dioxide

23. The by-product of photosynthesis is
    a. nitrogen
    b. oxygen
    c. water vapour
    d. carbon dioxide

24. The first step of light independent stage is that CO_2 combines with RuBP to form a
    a. 3C sugar
    b. 4C sugar
    c. 5C sugar
    d. 6C sugar

Use the following organs of a plant to answer questions 26 and 27

I. Leaf II. Stem III. Root IV. Fruit

26. Which of the organs traps the gas needed for photosynthesis?
    a. I
    b. II only
    c. III only
    d. IV only

27. Which of the organs contains phloem cells for transporting sugar?
    a. I only
    b. II and
    c. III only
    d. IV only

28. Explain why the leaves of a seedling may be yellowish in appearance

    ……………………………………………………………………………………

    ……………………………………………………………………………………

29. State the main function of the stem of a plant as far as photosynthesis is concerned.

    ……………………………………………………………………………………

30. Excessive supply of macro nutrients to plants leads to their becoming toxic and hence may cause plants to die**. True/False**

31. Describe a simple experiment performed by you or your teacher in the laboratory to demonstrate the need for chlorophyll in formation of starch in a plant.

    ……………………………………………………………………………………

    ……………………………………………………………………………………

    ……………………………………………………………………………………

32. RUBP is a 6-carbon compound. **True/False**

33. Explain why you would advise a young boy not to destroy the leaves of tomato plants in the backyard garden.

    ……………………………………………………………………………………

    ……………………………………………………………………………………

    ……………………………………………………………………………………