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A Case Study on the Use of Inquiry-Based Instruction to Improve Science Learning in Junior High Schools in Ghana

Ibrahim, Mohammed Gunu[1#], **Ayisha Gomda** [2], **Lateef Adebayo Oseni** [3]

[1]Senior Lecturer, Department of Educational Management and Policy Studies, Faculty of Education, University for Development Studies, P. O. Box 1350, Tamale, Ghana.

[2]Lecturer, Faculty of Agriculture and Natural Resources, Tamale Technical University, Tamale, Ghana.

[3]Senior Lecturer, Faculty of Physical Sciences, University for Development Studies, Ghana.

#corresponding author

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Ibrahim, Mohammed Gunu /0000-0002-1608-0856

Ayisha Gomda /0000-0002-8445-3722

Lateef Adebayo Oseni /0000-0002-3521-4098

ABSTRACT

The study examined how Inquiry-Based Learning affects students' academic progress in science lessons and whether this approach can help low-proficiency users of English to comprehend scientific concepts. The study used a Quasi-Experimental design and looked at it through the lens of Self-Determination theory. The study included a total of 40 second-year Junior High School students from two distinct classes. The research was aimed at students aged between 13 and 15 years, and therefore, only students within that age range were selected to participate. Students in the experimental group received Inquiry-Based instruction, while the control group used traditional instruction. The study lasted for four weeks and was an experimental one. To see if Inquiry-Based learning is more effective than traditional teaching, a test with 20 questions was used as a pre-test and a post-test for both the experimental group and the control group. The results of the study showed that students who were taught using an inquiry-based method scored higher than those who were taught through a traditional technique. The main finding of this study is that students in the experimental group, who had a low level of English proficiency, were able to understand the lesson without switching to their native language to explain concepts.

Keywords: Inquiry-Based, learning, Instruction, Junior High School, students

Introduction

Inquiry-Based learning is a learner-centred pedagogy in which pupils participate actively in the exploration or development of scientific reasoning skills (Cetin, 2021; Vorholzer & von Aufschnaiter, 2019; Lazonder & Harmsen, 2016). Inquiry-Based learning has been shown to have beneficial effects on science education in a variety of studies in recent years (Cetin, 2021; Vorholzer & von Aufschnaiter, 2019; Barone & Barone, 2019; Eltanahy & Forawi, 2019; Aditomo & Klieme, 2020). These include critical and higher-level thinking skills (Gillies, 2008), problem-solving skills (Tawfik et al., 2020; Gillies, 2008), positive perceptions toward science (Chang & Wu, 2018; Chang & Mao, 1999), science process abilities (Simsek & Kabapinar, 2010), developing linguistic abilities to describe scientific phenomena, connecting science learning to the real world and gaining a full and coherent understanding of complex phenomena (Bouillion & Gomez, 2001; Hiltunen, Kärkkäinen & Keinonen, 2020). Most notably, the method of inquiry learning often necessitates a conceptual shift in the current understanding of everyday phenomena to active construction of scientific knowledge, discovery, critical thinking, and innovation (Ku et al., 2014; Carey, 2000).

In today's information technology era, scientific knowledge and technological advancements progress at a breakneck pace. The impact of science and technology can be established in every aspect of human existence (Foxley, 2020; de Menezes, 2020) making science and technology education critical for the present and future survival of societies. In this regard, the development of students' "scientific" knowledge and critical thinking should be the main goal of science education. The connection between the method of teaching and learning achievement is established in scientific research (Aslan, 2019; Boxall, Boxall & Lucas, 2010). The inquiry method occupies a significant position among the various methodologies (Martell, 2020; Cetin, 2021; Vorholzer & von Aufschnaiter, 2019; Dostál, 2015). In recent times, Inquiry-Based learning has been incorporated into science teaching systems in schools to improve the teaching and learning of scientific concepts (Derseh & Nurie, 2021; Riegle-Crumb et al., 2019; Frisch, Jackson & Murray, 2018; McLaughlin & MacFadden, 2014).

However, there are few empirical studies in the context of Africa to support such claims. Rote-learning and teacher-directed teaching dominate classroom practices in which science teachers deliver facts and knowledge. The situation pertaining to African classrooms is similar in Ghanaian Junior High Schools (JHSs). There is little evidence of the degree to which inquiry science instruction is being implemented in Ghana. Hence, the need to investigate the use of Inquiry-Based instruction in the Tamale Metropolis in Ghana.

In Inquiry-Based science, instruction pupils participate in the teaching and learning activities as the scientists utilize scientific processes to generate new knowledge. Traditional teacher-centred teaching methods, like teacher focus on textbooks, lectures, and so on, are being replaced by inquiry-

oriented approaches. In authentic Inquiry-Based practices, students experience appropriate understanding and can justify the information in the same way as scientists do.

Advocates of Inquiry-Based instruction maintain that teaching through inquiry enhances student engagement in learning and promotes a deeper understanding of scientific concepts (Eltanahy & Forawi, 2019; Capps & Crawford, 2013; Minner, Levy& Century, 2010; Hodson, 1992).In general, Inquiry-Based science instruction is appropriate for advancing learning outcomes for a wide range of students in a variety of disciplines, grades, contexts, and gender (Aditomo & Klieme, 2020).

The typical traditional classroom, on the other hand, often resembles a one-person display with a mostly uninvolved learner, with unilateral teaching as the normal standard in traditional schools. Followers of the traditional approach believe that the student must learn a set body of knowledge. Students are supposed to take the instructor's knowledge at face value without challenging it (see Stofflett, 1998). The teacher attempts to transmit his or her thoughts to the passive student, without providing an opportunity for student-initiated interactions and critical thinking. Also, activities-based topics do not promote debate or exploration of the concepts involved, despite the fact that the activities are performed in a group. This traditional approach neglects the critical thinking and ideas that are vital for true science literacy development (see Ku et al., 2014; Ampiah, 2008).

This teacher-centred teaching approach often accepts the notion that all students have the same degree of prior experience in the subject matter and can learn information at the same rate (see Yamagata, 2018; Ozel & Luft, 2013; Yuen &Hau, 2006; Lord, 1999). Traditional education which promotes a teacher-centred approach has contributed significantly to Africa's poor science literacy and innovation (Anamuah-Mensah, 2012; Shumba, 1999).

It must be mentioned that the president of the Republic of Ghana, Nana Addo Dankwa Akufo-Addo, in his address on the state of the Nation, on Tuesday, 9th March, 2021 indicated that the Government of Ghana is working to increase enrolment into tertiary institutions from the current 18.8% to 40% by the year 2030, focusing on Science, Technology, Engineering and Mathematics (STEM). This projection has the potential to become a reality when we promote effective engagement in the study of science at the basic school. The present inquiry-based study aims at promoting the effective study of STEM in Ghanaian schools. The use of inquiry-based instructions will provide the foundation and motivation for students to study science and understand the related concepts at the Junior/Senior High School (J/SHS) level and subsequently the tertiary institutions.

The study provides useful information to guide policy-makers or policy engineers and the relevant stakeholders in education on the best approach to improve the teaching and learning of science in Ghana. Also, this research would guide policy-makers on how to promote Inquiry-Based learning in Schools across Ghana.

Research Question

To what extent does the Inquiry-Based approach support the instruction of science in Junior High Schools in Ghana?

Self-Determination Theory

This study is grounded in the Self-Determination Theory (SDT) (Ryan & Deci, 2000; Deci & Ryan, 2008), which promotes students' classroom positive behaviour towards teaching and learning (see Núñez & León, 2015**).** SDT provides an opportunity to motivate students to attain positive learning outcomes (Kinnafick, Thøgersen-Ntoumani & Duda, 2014**)** and to explore and provide innovative solutions (Eyal& Roth, 2011). This theory is connected with Inquiry-Based pedagogies which creates the opportunity for successful interaction among learners and enhances students' ability to actively engage in scientific investigations (Wilmes & Siry, 2018; Riegle-Crumb et al., 2019).

Inquiry-Based instruction affords students the opportunity to gain increasing control over their learning as they progress through the academic system (Aulls, Magon & Shore, 2015). SDT is a theory of human-related motivation that seeks to provide an explanation regarding students'

classroom behaviour (Núñez et al., 2015). It promotes the concept of autonomy which is grounded in an individual is responsible for his conduct in the learning process as well as provides an opportunity for individuals to openly explore the learning content (Gagné & Deci, 2005; Reeve, 2009; Gillet, Vallerand & Lafrenière, 2011; Jang, Kim& Reeve, 2012).

SDT also enhances the development of self-concept and self-confidence. In this regard, autonomous motivation or self-autonomy makes students engage voluntarily in the learning process, and enhances constructive self-initiative, creativity, and an ability to respond to self-imposed pressure or pressure emanating from other people. Also, it promotes students as the initiators of their own activities and actions (Gillet, Vallerand & Lafrenière, 2011; Núñez et al., 2015). Engagement in classroom activity by students for pleasure and satisfaction is considered a sign of self-determination (Ryan & Deci, 2000; Deci & Ryan, 2008).

Students' behaviour in the context of SDT, is determined among others by the attitude of the teacher (see Deci & Ryan, 2000; Deci & Ryan, 2008; Núñez et al., 2015). Reeve (2009) explains that students' behaviour and feeling toward the learning content are largely on teacher behaviour. A good classroom environment is facilitated by the teacher. This is an important element that determines students' motivation and emotional status. The teaching style is of great importance in the management of teaching and learning in the school. In this respect, the ability of the individuals to voluntarily explore the learning and teaching process in order to feel satisfied with producing desired learning outcomes is in keeping with the dictates of STD (Kinnafick, Thøgersen-Ntoumani & Duda, 2014).

Materials and Method

The research design, the sample of the study, instruments for data collection, and the appropriate method of data analysis are discussed in this section.

Research Design

This is a quasi-experimental design (see Bryman, 2015) with a pre and post-test evaluation approach. This is an evaluation study seeking to assess the appropriateness of two instructional methods; inquiry-based and traditional instructional methods. The understanding of critical issues that pertain to the two instructional methods is grounded in the Self-Determination Theory (SDT) (Ryan & Deci, 2000; Deci & Ryan, 2008). This theoretical model was identified through a literature review.

Sample

The study was conducted with an experimental group of 20 Junior High School (JHS) pupils (aged 13-15 years) and a control group of 20 JHS pupils (aged 13-15 years) drawn from Zogbeli JHS Block C in Tamale, Ghana**.** This school has a medium-level exam achievement in the national Basic Education Certificate Examination (BECE). Purposive sampling was employed in the selection of the school. To ensure equivalence in the experimental and control groups, students' previous year's academic performances, intellectual ranges, class size, and pre-test results were all taken into account. The experimental and control groups were made to be statistically equal.

Instrument

Both groups received an Achievement Test as a pre-test and post-test evaluation. The exam included 20 multiple-choice questions designed to assess students' academic performance. For each question, there was one correct answer and three 'distracters.' The researchers designed this test. The content validity of the study was examined by two science teachers and two researchers.

Procedures and Implementation

Eight 45 minutes lessons were implemented. Inquiry-based lessons were conducted in the experimental group, while teacher-centred lessons were implemented in the control class (see Table 2). The same science teacher taught both classes.

The teacher was trained on the intent of the study and the Inquiry-Based Learning method before treatment began. Classroom observations were conducted to ensure that both treatments were

implemented in the control and experimental classes. The implementation of traditional methods of teaching by the researchers in the control group and inquiry-based instruction by the researchers in the experimental group were both carefully examined. During the observation process, the interaction between teacher-students and students-students, as well as student engagement and contribution to the learning activity, student behaviour and attitude, material availability in the classroom, and their physical conditions, were all taken into account.

Experimental Group

In the experimental group, pupils were taught through Inquiry-Based learning. To maximize pupils' active participation in the learning process, teaching and learning activities, including lesson plans on Inquiry-Based learning, were developed. The lesson plan focused on "Photosynthesis". This topic was selected from the current JHS 2 science syllabus. The teacher engaged the students in order to increase pupils' attention and interest to learn. Hence, pupils might create connections between their previous knowledge and their current learning experiences.

With the aid of a projector facilitated by the teacher, students were able to design experiments, produce graphs, and creatively interpreted results and their findings in these learning environments as is done in scientific processes. The teacher's role was limited to asking questions, suggesting approaches, providing feedback, and assessing understandings. Students demonstrated their grasp of connected ideas through activities employed in the explanation phase.

The teacher assisted students in developing logical and consistent generalizations, developing scientific vocabulary, and using this vocabulary to explain the findings of their investigations. The elaboration phase activities allowed students to apply their knowledge to new domains, such as posing new questions to investigate. The exercises presented in the evaluation phase allowed students to assess their comprehension and abilities. The activities in the assessment phases were used by the teacher for both formative and summative evaluations of student learning.

Control Group

In the control group, a teacher-directed strategy representing the traditional approach was used. The teacher used direct teaching and question-and-answer approaches to teach relevant topics and basic concepts. Basic explanations and question-and-answer procedures were utilized to teach "Photosynthesis", which suited the traditional teaching strategy of students being fully passive. The teacher's explanations and textbooks served as teaching tools.

The teacher instructed this group using lecture and discussion approaches to impart the ideas. These required written responses which reinforced concepts taught in class. Each lesson usually began with the teacher demonstrating how to solve issues correctly. The majority of class time was spent on instruction and participation in discussions prompted by the teacher's explanations and questions. The same textbook and handouts were used in both traditional and inquiry classes. The study took 4 weeks.

Data Analysis

A variety of research techniques were employed in conducting the research, presentation, and discussion of data in this study. The analysis in this research focuses on comparisons between groups and not individuals as the research design of this article stipulated (see de Vaus, 2001). In this regard, tables and histograms have been used to illustrate the information.

Results and Discussion

This section presents the results of the study. The details of the results are found below:

Table 1: Students' performance by treatment (control and experimental) before/after the intervention in the school

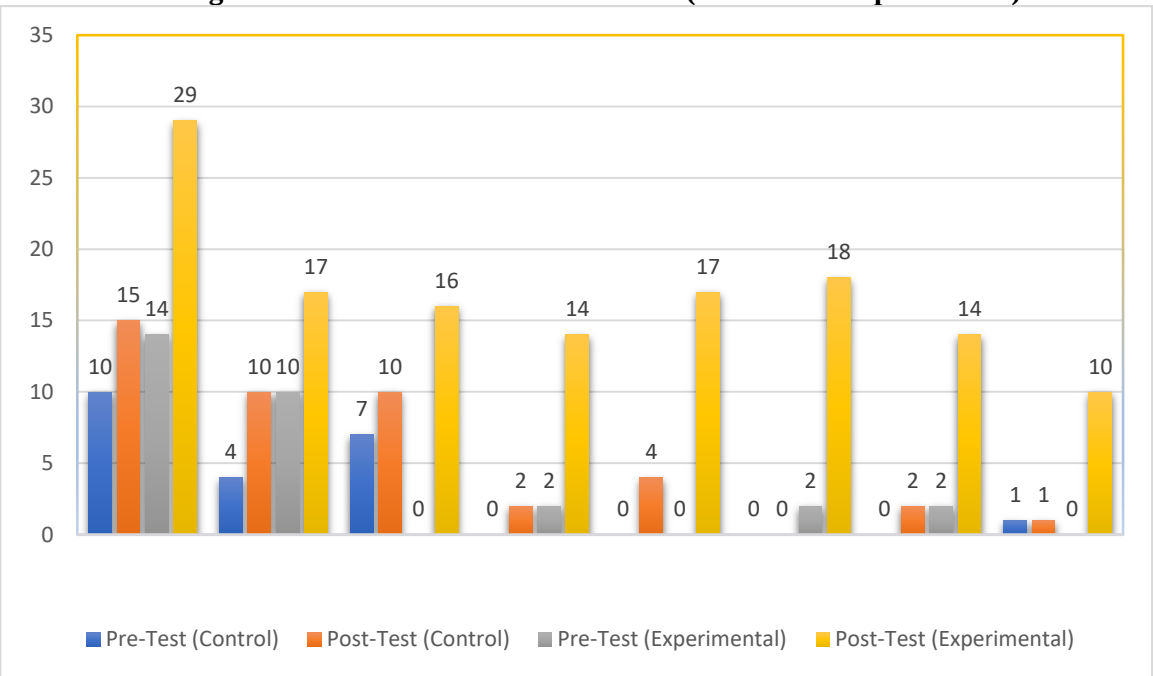
Topic	Photosynthesis				
Sub-Topic/Areas of questioning	**Code**	**Control**		**Experimental**	
		Pre-Test	**Post-Test**	**Pre-Test**	**Post-test**
The Concept of Photosynthesis	1.	10	15	14	29
	2.	4	10	10	17
	3.	7	10	0	16
	4.	0	2	2	14
	5.	0	4	0	17
Factors that Promote the occurrence of Photosynthesis	6.	0	0	2	18
	7.	0	2	2	14
	8.	1	1	0	10
	9.	3	10	4	12
	10.	4	8	4	18
	11.	4	4	0	10
	12.	2	10	1	8
Significance of Photosynthesis	13.	0	0	0	10
	14.	4	12	2	12
	15.	4	6	1	12
	16.	0	2	1	14
	17.	2	6	2	17
Photosynthesis and Plants	18.	0	2	0	12
	19.	2	2	4	15
	20.	0	0	8	20

Source: Field Survey, 2021

Table 1 indicates that respondents answered five questions on the concept of Photosynthesis, seven questions on the factors that promote the occurrence of Photosynthesis, five questions on the significance of Photosynthesis, and three questions on how generally Photosynthesis and Plants are related. Each question earned one mark.

The results in Table 1 show that Inquiry-Based instruction strategies implemented in the experimental group have been successful in achieving comprehension among all the students including those with low proficiency in the English Language. English is the medium of instruction in Ghana from Primary through to the tertiary institution but in some instances, teachers do code-switching in order to explain concepts in the native language, but in the case of the Experimental Group, students comprehended the lesson without code-switching between English and the native language to explain concepts.

Figure 1. Pre-Test and Post-Test Scores (control and experimental)



Source: Field Survey, 2021

The differences in post-test scores in the academic achievement test between the experimental and control groups as shown in table 1 and figure 1 are very clear. The analysis suggests that the scores of pupils taught science education utilizing Inquiry-Based instruction and those taught using a traditional approach differ significantly. This is in agreement with works done by researchers like Capps and Crawford (2013) and Murphy et al. (2006). They state that real Inquiry-Based instruction improves students' understanding and comprehension of science topics such as physics.

Table 2: Details of lesson implementation in both the Experimental and Control Groups

No.	Objective	Experimental Group Teaching Activities	Control Group Teaching Activities
Pre-Test Evaluation			
1. (L1)	Identify previous Knowledge of students regarding Photosynthesis	Pre-test Evaluation on Basic Understanding of Photosynthesis.	Pre-test Evaluation on Basic Understanding of Photosynthesis.
Lesson Implementation			
1. (L2)	Identify previous Knowledge of students regarding Photosynthesis	The classroom lesson started with the question: What is the importance of Sunlight to plants? Students were put into five groups and asked to organize two potted plants (plants in flower plots). Students were asked to expose one plant to sunlight and the other was kept in a dark room for one week.	Students started the lesson with the reading of the school recommended textbook. Teacher asked the students about their understanding of the topic. Some of the students responded based on what was read.
2. (L3)	Describe the Concept Photosynthesis	The lesson continued with the question which was arrived at based on consensus among the students: How do we know	Students read the textbook with the teacher. The definition was written on the board by the teacher. The teacher provided an

		that photosynthesis has occurred? Based on different pieces of scientific evidence gathered in stage1, each group proposed a hypothesis of how photosynthesis occurs.	explanation of the concept. In the end, the definition on the board was read again and students answered questions from the teacher, such as what is Photosynthesis?
3. (L4)	Describe two of the factors that promote the occurrence of photosynthesis	The lesson started the next day students were asked to pluck a leaf from the plants exposed to sunlight and the one kept in dark condition. Iodine solution was added to each of the leaves plucked, the one from the potted plant exposed to sunlight showed a blue-black colour, whilst the leaf from the potted plant kept in the dark did not show a blue-black colour. This shows that photosynthesis occurred in the potted plant that was exposed to sunlight. Students were made to present their work to the class. The students on their own reached a consensus that this is how photosynthesis occurs. The lesson started with a general decision from the students to deepen their understanding and be able to describe the factors that promote the occurrence of photosynthesis. Group work was presented on the factors. Students analyzed and presented their work based on the observations made in stage I& II.	Teacher started the lesson by using an analogy to explain the factors that promote the occurrence of photosynthesis.
4. (L5)	Identify significance of photosynthesis	**The lesson started with the question: what is the significance of** photosynthesis? Teacher facilitated the discussion to arrive at key points and reasons.	The teacher wrote the points regarding the significance on the board. It was used as a guide for studies as same is contained in the textbook. Students without the textbook copied what was written by the teacher on the board.
5. (L6)	Relate photosynthesis to plants	**The students responded to a question from a colleague which read as follows: how is** photosynthesis related to plants as a whole? Teacher facilitated the discussion and the students identified the relationships.	**How is** photosynthesis related to plants? Teacher further explained these relationships and examples were given,
6. (L7)	Revise learning regarding Photosynthesis	Revision of learning regarding Photosynthesis	Revision of learning regarding Photosynthesis

Post-Test Evaluation				
1. (L8)	Evaluate learning regarding Photosynthesis	Administration of post-test evaluation regarding Photosynthesis		Administration of post-test evaluation regarding Photosynthesis

Source: Field Survey, 2021
***L= Lesson**

Contextual Advantages of Inquiry-Based Instruction in the Teaching of Science

The Inquiry-Based instruction in this research developed the skills of the students to analyze data, formulate hypotheses, and critically constructed testable knowledge: Contextually, inquiry-based instruction made students in this study active learners capable of analyzing data, formulating hypotheses, and constructing testable information. This type of learning is preferred to the teacher-centred approach where students are positioned as passive recipients of a static body of information. There is a need to bring credibility into science teaching, in the sense that students must be involved in work that is similar to that of the scientific community as a whole. In structured inquiry, the instructor gives the student an issue to investigate as well as the methods and resources to investigate. This method of inquiry learning is used to teach a particular idea or ability, and it leads to open inquiry, in which the student creates his own problem to investigate (Bevevino et al., 1999).

Discussion

This study is a structured Inquiry-Based instruction (Blanchard et al., 2010), which is grounded in Self-Determination Theory (SDT). This theoretical underpinning is used to examine the epistemological and ontological constructions which govern the inquiry-based pedagogical approach.

This research is novel in Ghana as there is a dearth of literature on Inquiry-Based studies in the context of Ghana. The research shows that Inquiry-Based instruction strategies as implemented in the experimental group facilitate comprehension among all the students including those with low proficiency in the English Language. English is the medium of instruction from primary through to tertiary institutions but in some instances, teachers do code-switch in order to explain concepts in the native language. In the Experimental Group, in this case, students comprehended the lesson without code-switching between English and the native language to explain concepts.

This research also shows that Inquiry-Based instruction strategies are good in basic schools in promoting the teaching of science (Jeno, Grytnes & Vandvik, 2017; Vergara-Díaz et al., 2020; Blanchard et al., 2010; Gilal, Zhang, Paul & Gilal, 2019). This pedagogical model engages students in inquiry activities in an effort to promote the active construction of knowledge (see Ryan & Deci, 2000). Inquiry-Based instruction presents an opportunity for a collaborative learning environment (Vergara-Díaz, et al., 2020; Cetin, 2021; Vorholzer & von Aufschnaiter, 2019), reasoning skills (Cetin, 2021; Vorholzer & von Aufschnaiter, 2019; Lazonder & Harmsen, 2016; Kuhn, 2016), active thinking (Minner, Levy & Century, 2010) and enhances understanding of scientific concepts and theories (Kuhn, 2016). This resonates with the concept of the STD theoretical framework.

The Inquiry-Based instruction in this context developed the skills of the students to analyze data, formulate hypotheses, and critically construct testable knowledge. This type of learning is preferred to the teacher-centred approach where students are positioned as passive recipients of a static body of information (Dostál, 2015). This is rooted in STD which promotes autonomous motivation and allows students to voluntarily and actively explore the learning content (see Ryan & Deci, 2000).

This research established SDT as a theory capable of encouraging classroom work motivation that sustains the interest of the student in the learning activity. In structured inquiry, the instructor gives the student an issue to investigate as well as facilitates the methods and resources to do the investigation (Vergara-Díaz, et al., 2020; Blanchard et al., 2010). This inquiry learning method is used to teach a specific idea or ability, and it leads to open inquiry, in which the student creates his or her

own problem to investigate (Bevevino et al., 1999). It transforms students into active learners capable of initiating innovative and creative ideas.

Finally, the use of Inquired-Based instruction in this research shows that there was Knowledge improvement regarding scientific concepts greater than expected. The research participants in the experimental group gained greater improvement in their knowledge concerning the topic. This was not the situation in the control group where students gained minimal improvement in their knowledge or content area. On this basis, it is sound to reason that the use of Inquiry-Based instruction in the teaching of science at the basic level of education in Ghana will potentially result in great improvement as well as motivate students to study science.

Limitations and Future Studies

The study is associated with some limitations, these are as follows: First, the research was organized in one school involving one Control and one Experimental Group. In this respect, care must be taken in generalizing the results. It must, however, be mentioned that the participating school is located in the centre of the cosmopolitan Metropolis of Tamale as such the participation is representative of the different socio-economic and cultural backgrounds in Ghana.

In addition, the post-test evaluation was done immediately after the intervention. This means that the long-term effect and retention of the content learned were not examined. Despite all these limitations, the research suggests that students taught using the Inquiry-Based instruction technique were more successful than students who were taught using traditional teaching methods. The research recommends further studies into the implementation of inquiry science instruction in classrooms across Ghana. This is needed to uncover achievements, obstacles, opportunities, and other important aspects of this novel pedagogical tool. Further studies could also be conducted on the long-term effect and retention of the content taught using Inquiry-Based instruction.

Conclusion

The study shows that there is a substantial difference in achievement levels between pupils who were taught through the Inquiry-Based instruction technique and students who were taught using traditional methods. Pupils who were taught using Inquiry-Based education were more successful in comprehension and achievement tests than pupils who were taught using traditional teaching methods.

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