AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

COMPARATIVE STUDY OF THE MR-SR BASED PIMCA MODEL AND THE CONVENTIONAL APPROACH ON STUDENTS' PERFORMANCE AND ATTITUDE IN OPTICS

SIMON TANKO

NOVENBER, 2024

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BY

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NOVEMBER, 2024

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Simon Tanko

Signature:……………………………… Date: ………………………………

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah Menka University of Skills Training and Entrepreneurial Development.

Dr. Isaac Owusu-Mensah (Principal Supervisor)

Signature:…………………………………. Date:…..……………………………

Rev. Dr. George Oduro-Okyireh

Signature:…………………………………. Date:…..……………………………

ABSTRACT

The study compared the MR-SR Based PIMCA Model and the Conventional Teaching Approach on academic performance and Attitude of Senior High School Physics Students in optics in Mampong Municipality and Sekyere South District, both in the Ashanti Region of Ghana. This research study employed the non-equivalent groups pretest-posttest quasi-experimental design. Samples of 164 SHS two Physics students drawn from four intact classes were used for the study. Two research instruments, known as Optics Concepts Achievement Test (OCAT) and the Optics Learning Attitude Questionnaire (OLAQ) were used to gather data for the study. The study comprised of one research question and three hypotheses. Descriptive statistics such as mean, standard deviation and mean difference were used to answer the research question, while one-way between groups analysis of covariance (one-way ANCOVA) was used to test the hypotheses. The results revealed that students taught using MR-SR Based PIMCA model performed better in the Optics Concepts Achievement Test (OCAT) than those taught using conventional approach ($F_{(1,161)}$= 129.090, $p=0.000<0.05$). There was no gender ($F_{(1,72)}$= 0.319, $p=0.574>0.05$) and ability ($F_{(1,49)}$= 0.44, $p=0.835>0.05$) differences in academic performance on the use of MR-SR Based PIMCA model. It was also found from the pre-intervention (M= 1.0531, SD= 0.06033) and post-intervention (M=3.7686, SD=0.12531) questionnaire responses that the PIMCA model enhanced students' positive attitude towards Physics. Using the Model was concluded to be more effective than the conventional teaching approach in enhancing SHS students' academic performance and attitude in optics. It was therefore recommended among others that Physics teachers in the Mampong Municipality and Sekeyere South District should use the MR-SR Based PIMCA model to teach optics and other challenging Physics concepts in the Senior High School.

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DEDICATION

I dedicate this thesis to my lovely Parents, Mr. Peter A. Tanko and Mrs. Abena Sarah

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ABBREVIATIONS

ANCOVA	-	Analysis of Covariance
APA	-	American Psychological Association
BECE	-	Basic Education Certificate Examination
CTML	-	Cognitive Theory of Multimedia Learning
FAO	-	Food and Agricultural Organisation
GDP	-	Gross Domestic Product
GES	-	Ghana Education Service
ICT	-	Information and Communication Technology
IoT	-	Internet of Things
MOE	-	Ministry of Education
MOMBI	-	Model of Model Based Instruction
MOOC	-	Massive Open Online Course
MR	-	Multiple Representation
OCAT	-	Optics Concept Achievement Test
OLAQ	-	Optics Learning Achievement Questionnaire
PIMCA	-	Presentation, Idea-Mapping, Conceptualisation, Assessment
SD	-	Standard Deviation
SDG	-	Sustainable Development Goal
SHS	-	Senior High School
SR	-	Semiotic Resources
WAEC	-	West African Examination Council
WASSCE	-	West African Senior Secondary Certificate Examination
ZPD	-	Zone of Proximal Development

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter covers the background of the study and statement of the problem. It as well expounds the purpose of the study, the research objectives, research questions and hypothesis formulated for the study. The chapter also highlights the significance of the study, justification of the Study, delimitation as well as limitations and ends with the organisation of the study.

1.1 Background of the Study

Science and technology is a necessity to economic growth and development and is undeniably the panacea to all the current issues confronting humanity, in relation to health, business, communication, transportation, sanitation and the likes. There can possibly be no meaningful life and living without it. Science, according to Bentil et al. (2019), has a significant impact on how we think, investigate, generate, and use knowledge about our surroundings. As a result science education is now a major concern, and improving it is a top priority in practically every country (Abreh et al., 2018; Coffie, 2019). Science and technology is the building blocks upon which the quick evolving and shifting technological environment is built. Seemingly, in order to be abreast with the times and the way the world is changing, every individual must have scientific knowledge and effectively be engaged in science. Quansah et al. (2019) postulate that, every person needs general scientific literacy to be able to adapt and function successfully in the society and to make thoughtful choices at all times in a technologically and scientifically advanced environment.

A nation whose citizens do not have an in-depth knowledge in science education will be deficient in economic growth and development. This is because, science education is essential for the growth of economies in all nations on earth (Coffie, 2019; Abreh et al., 2018). Since education in science and technology appears to be the backbone of development in recent times, economic growth and sustainable development of a state lingers until attention is given to science education. For this reason, many nations have made science education an utmost priority; Ghana is no exception.

The introduction of science into the Ghanaian educational system was irrefutably an attempt to equip its citizens with scientific knowledge to be able to find solutions to the plethora and never-ending challenges of life. The Ministry of Education (2010) postulated that, every person need to have a fundamental understanding of science to be able to operate in Ghanaian society today. This criterion, according to the ministry, will significantly contribute to the success of the nation's strategic aim of obtaining technological and scientific literacy as soon as feasible, which will facilitate the growth of a scientific culture in the neighbourhood and the nation at large.

Meanwhile, without studying Physics, science and technology can never be understood any better. According to Coffie et al. (2020), Physics is a long-standing branch of science that examines everything from common phenomena to far-off galaxies, to the tiniest components of nature, to the functions of the human body and as well examines core philosophical issues. There must be total focus on the dynamic field of Physics in science because all the other natural sciences, according to Abreh et al. (2018) are derived from Physics, with chemistry being principally applied Physics and biology being basically applied chemistry. Kanim (2020) claims that this is because everything in the universe around us is made of matter, and as a result, everything we do in the course of our daily lives involves some aspect of Physics and that, most fundamental concerns about the nature of the physical cosmos are addressed by Physics.

According to Ghana's Ministry of Education (2010), Physics as a subject has had and still has a crucial impact on people as well as the society at large. Also Kanim (2020) and Abreh et al. (2018) are of the views that, Physics makes a significant economic contribution to any nation and is essential to many different industrial areas, including telecommunications, architecture, engineering, building and transportation, as well as the production and transmission of electricity as a science. Mabee et al. (2021) expound that, Physics makes it possible for people to respond to the queries that nature poses and contributes enormously to our understanding of how the universe works. As a result, the importance of Physics is so enormous that contemporary life will not be anyhow meaningful without it. This implies that the school system in Ghana will not be beneficial to individual and societal development without knowledge in Physics. This according to Appiah-Twumasi et al. (2020), is as a result of the crucial role Physics plays in contemporary scientific and technological advancement.

Amankona (2021) posit that, there is substantial evidence from around the globe that investing in a nation's human capital is a key indicator of economic growth. Investing in human development through education cannot be trivialized as far as national growth is concerned. Nations who have made investments in their human capital have advanced through science and innovation (Amankona, 2021). According to Abreh et al. (2018), a significant link exists between a country's development and prosperity and the standard of education it offers its population. Additionally, Kwadwo et al. (2019)

affirm that nations that have invested in education and have highly educated populations typically have consistent economic growth.

Nonetheless, this in Ghana seems otherwise. It appears that the income spent on Ghanaian education yields less than expected returns (Amankona, 2021). Ghana seems to be lagging behind, despite all the numerous efforts of investment in education. The Ministry of Education (2018) propounded that, although Ghana has been able to give access to school for the majority of children, but the quality of education in the nation is still lacking. Research from Kwadwo et al. (2019) affirm that, Ghana's distribution of educational resources is inefficient. They asserted that, although Ghana spends about 6.16% of her Gross Domestic Product (GDP) on education but still attains less, whilst the top-performing nations spend an average of 4.18% of their GDP and attain more.
The Chief Examiner’s reports of the West African Examinations Council (WAEC) have indicated that, one of the areas of science that has delivered less than expectation is Physics (WAEC, 2016; 2017; 2018; 2020). Despite having a significant impact on all aspects of life and facilitating efficient living, Coffie (2019) believe that Physics is the most challenging field among the sciences and generally has poor results from students and as well draws fewer students than chemistry and biology.

Results of students’ performance in Physics, particularly in the West African Senior Secondary Certificate Examination (WASSCE), have consistently shown to be abysmal. WAEC Chief Examiner's Reports on Senior High School (SHS) Physics stated that candidates' performance was woefully low or even poor, despite the fact that candidates were lauded for adhering to the paper's rubrics, giving concise answers, and organising their presentation of response (WAEC, 2017; 2018; 2020; 2021). It is evident that students struggle to find answers to questions about some particular Physics concepts. One of those areas is optics, which was identified as students' weakness in the WAEC Chief Examiner's report.

For example, optics was mentioned as one of the key concepts in Physics where students found it very difficult to answer questions from (WAEC, 2017;2018), definition of focal length of a converging lens was among the few areas that were considered as students' weaknesses in Physics (WAEC, 2021). Also, Dido et al. (2021), Hartati et al. (2021) and Yzuel and Peinado (2022) all found that, optics as a Physics concept is becoming more challenging to SHS Physics students. As a result, the appalling performance in optics has become a major problem in many higher education institutions both nationally and internationally (Darko, 2019). Buabeng, et al. (2014) assert that, educational researchers are working tirelessly to find mitigating factors that can explain the reported poor performance in light of students' optics performance and achievement.

Optics is the area of Physics that examines the characteristics and behaviour of light, including how it interacts with materials and how to build devices that can detect it (Serway & Vuille, 2018). The SHS two Physics course covers the Optics concept of reflection under the general heading "wave motion" (Ministry of Education, 2010). Due to its applicability in contemporary life, the concept of optics plays a significant part in daily life and so deserves to be given an extra attention. Despite optics' crucial role in contemporary life, it has been noted that candidates are unable to acquire and understand the concept, as shown by their performance in WASSCE (WAEC, 2017; 2021).

Numerous reasons contribute to students' generally poor performance in Physics particularly in optics in WASSCE. Buabeng et al. (2014) were of the view that, both factors inside and outside the classroom have an impact on students' academic performance, interest and attitude toward a subject. Researchers have attributed the meagre performance of learners in optics to the adoption of improper and inadequate teaching methods by Physics teachers, inadequate and inappropriate teaching resources, inadequate facilities, overcrowded classrooms and laboratories, misconceptions about the subject, low student self-efficacy, the abstract and theoretical nature of the course, inadequate hands-on experience, and a lack of learning resources are all factors that may be inhibiting the performance of students in Physics (Abreh et al., 2018; Appiah-Twumasi et al., 2020; Buabeng et al., 2014; Mabee et al., 2021).

Yang et al. (2020) assert that, many nations have created policies in order to encourage equal educational opportunities. Yzuel and Peinado (2022) propound that Physics has factually been depicted as a reserved field for only the brilliant. Meanwhile, Yang et al. (2020) assert that students, regardless of socioeconomic situation or academic background, require equal access to chances to build these competences. According to educational studies, Vanlaar et al. (2016) posit that effective instructional strategies and qualified teachers can enable low-achievers to catch up with their high achieving peers. Despite this fact, many attempts by researchers and policymakers to close the achievement gap between low and high achieving student groups have no or occasionally even a negative impact. For low achievers, Vanlaar et al. (2016) suggest that, effective learning experiences that emphasize higher-order competencies are crucial.

These have the potential to not only assist students become more academically successful and so close the achievement gap, but they also have the potential to start a cycle of ongoing progress (Yang et al., 2020). Low-achieving students can improve their academic performance and catch up with their high-achieving peers in the Physics classroom when teachers adopt effective instructional strategies. In order to increase learning for both low ability and high ability students, Hsieh and Knudson (2017) recommend that teachers take into account ways to encourage students' enthusiasm and confidence in tackling pertinent professional problems and this can best be done by adopting an effective learner centred teaching technique in the Physics classroom.

Additionally, numerous studies on educational research have looked into the fascinating topic of gender issues (Cheryan et al., 2017). Gender as a contributing factor to academic success in Physics has engendered a lot of apprehension for science educators. Numerous research have shown that there are gender variations in participation and accomplishment in Physics over the time and across many nations (Gunawan et al., 2019; Elizabeth et al., 2017). Yzuel and Peinado (2022) found that, females' participation and accomplishment in optics has been poorer as compared to their male counterparts. According to Yzuel and Peinado (2022), scientific instructors continue to be deeply concerned about the gender gap in Physics, which has been widely publicised. Elizabeth et al. (2017) opined that the idea of equality between the sexes emphasises equality and equity in order to improve both sexes' competences and endowed capabilities being effectively and efficiently recognised, developed, and utilised. Day et al. (2020) adds that, Gender equity does not support or imply that one sex should dominate the other in academia or other fields involving the development of human resources.

Consequently, education is a crucial tool for achieving human resource development without gender discrimination (Blue et al., 2019). Because men are genetically predisposed to having a larger aptitude for Physics and mathematics than women. Researchers, scientists, the government, and international bodies have long argued that Physics is dominated by males (Miller-Friedmann et al., 2017; Day et al., 2020). According to Vilia et al. (2020), the public's perception of Physics as a male-dominated field is to blame for this. Cheryan et al. (2017) found that, males are more drawn toward physical sciences as their female counterparts are toward biological sciences. Day et al. (2020) stated that a lot of girls may also think of Physics as a field dominated by males which affect their inclusion and participation (Day et al., 2020). Even in situations where the female looks to be more intelligent than their male counterpart, this view inherently excludes women from consideration for major professional discipline (Barros et al., 2019). According to Physics studies, gender differences have an influence on students' academic performance, particularly on the side of female students (Elizabeth et al., 2017; Francis et al., 2017).

Darmaji et al. (2019) postulate that, despite several initiatives to create gender parity in science education, females are frequently underrepresented in most of the Physics courses and perform worse in achievement tests than boys. And this is particularly noticeable in optics (Yzuel & Peinado, 2022). Meanwhile, Cheryan et al. (2017) propound that, even though the African context creates tremendous limits on the female gender and demands a higher input of daily domestic labour from her than from the male, yet the low performance in optics is not gender-specific; it affects both male and female students. Semela (2010) also found that, females outperform their male counterparts in optics tests when they are given equal treatment. Idika (2017) asserts that, students learn in different ways depending on their gender or cognitive style.

Teaching pedagogies have great impact and must be considered as far as equal performance is required from both genders. Day et al. (2020) assert that many studies typically attribute the causes for females' underachievement in optics to school pedagogies rather than gender deficiencies or maladaptiveness. Hence, it is the way the concept is taught in the classroom, not the girls that needs to be altered in order to resolve this problem. Therefore, it is advised that Physics instructors employ an effective and efficient teaching strategy like the MR-SR Based PIMCA Model, which fosters an atmosphere where all types of students can learn purposefully both individually and in groups, as well as provides males and females with an equal opportunity to learn (Poluakan & Katuuk, 2022).

It should come as no surprise that a lot of scientists are concentrating their studies on students' academic performance and achievement (Peng & Kievit, 2020; Steinmayr et al., 2015). Academic success is a performance indicator metric that demonstrates an individual's level of achievement in a particular objectives that were the emphasis of their efforts in educational settings, precisely in schools, colleges as well as universities (Abanikannda, 2016; Assem et al., 2023). The most significant result of formal school experiences is thought to be academic accomplishment (Moore, 2019). There are many different indicators of academic performance, including more curriculum-specific ones like test scores, cumulative ones like degrees and certificates, and extremely general ones like procedural and declarative knowledge acquired through educational systems (Moore, 2019). A student's ability to continue their study at the post-secondary level is dependent on their test results and grades (Ceylan & Elitok, 2017). Because of this, academic performance determines whether a person can enroll in higher education or not and, depending on the educational degrees they receive, affects their ability to find employment when they graduate (Assem et al., 2023).

Academic performance is extremely important for a country's wealth and prosperity, in addition to its relevance to an individual (Steinmayr et al., 2015; Ceylan & Elitok, 2017). It therefore stands to reason that, teaching strategies in the Physics classroom that stands the chance and has the potency to improve the academic performance of students is to be embraced. This according to Lasmawan and Budiarta (2020) is because, the method that teachers employ to provide material to students greatly affects the performance of a country's educational system.

More so, Attitude is one of the key factors influencing a person's interest with regards to an endeavour. Although there are numerous descriptions of attitude, all definitions concur that attitude refers to a person's tendency to think, feel, or act in a good or negative way toward the things in his or her environment (Vilia et al., 2020). Vilia et al. (2020) assume that the participation and performance of students in optics as a concept in Physics appears to be influenced by their attitudes towards it. Mamengko et al. (2021) and Sumardi et al. (2019) also affirm that the educational goal of cultivating favourable attitudes toward optics lessons is not fully attained not only in Ghana, but also globally.

Jufrida et al. (2019) postulate that, for learning to be successful and meaningful, learners need to approach it with the correct mindset. According to research on students' attitudes toward science, Jufrida et al. (2019) found that attitudes are important in deciding whether or not to pursue science as a future field of study, achieve academic excellence in it, or consider it as a potential career. Attitude governs behaviour in all spheres of human experience, including the classroom and it is possible to anticipate scientific attitudes by examining how people feel about scientific items and how their attitudes toward science are related to those sentiments (Appiah-Twumasi, 2016; Vilia et al., 2020).

It is evident that teacher's approach or technique, both inside and outside the classroom, can have positive or negative impact on students' learning (Idika, 2017; Kurniawan et al., 2019). Sugano and Mamolo (2021) postulate that, one of the main duties of every scientific teacher is to foster in their students a positive attitude toward the teaching and learning of optics as a concept in Physics. Research from Jufrida et al. (2019) has shown that attitudes influence behaviour and are related to academic achievement and performance. Therefore, Maulidah and Prima (2018) suggest that, it is very important to cultivate in the pupils a good attitude toward science optics in the Physics classroom. Factually, teaching strategies are central factors that influence students attitude and academic performance, and irrespective of how well established a curriculum is, its success depends on the eminence of the instructors executing it (Buabeng et al., 2014). Effective classroom instruction and learning according to Precious and Feyisetan (2020) depend heavily on the teaching strategies used, which also have a substantial influence on students' attitude and academic performance. This is because the learning process is one of the key components for fulfilling educational objectives, and has a significant impact on how students are evaluated (Tokolang et al., 2021). When it comes to contact, activity, and teaching style utilized by the teachers in the classroom, there are essentially two dimensions or perspectives that may be seen. Appiah-Twumasi et al. (2020) suggest that the interaction could be based on a classic (conventional) perspective of teaching and teaching as a bipolar process, in which educators and students are involved in all parts of the instruction and learning process.

In the conventional methods of teaching, also referred to as traditional method of teaching by some researchers (Aziz & Hossain, 2010; Scheurs & Dumbraveanu, 2018), more emphasis is placed on the teacher and makes students more passive recipients of knowledge. Ersel (2018) affirms that the organisation of learning is set by the teacher whiles students only listen to the content, take notes, engage in some restricted conversation, and then recall or retrieve the knowledge for assessment reasons. Muganga and Ssenkusu (2019) found that, in the teacher-centred learning, teachers take on the role of knowledge providers while students serve as passive information consumers. Rizvi et al. (2015) assert that, the instructor typically exercises control over the subject matter that pupils are studying in a teacher-centred classroom.

The employment of teacher-centred teaching methods like lecture, demonstration, and debate methods have been connected to the low academic performance of students in optics in external examinations (Bara & Xhomara, 2020; Ersel, 2018). These conventional approach to teaching science places a greater emphasis on memorising than on the transmission of knowledge, which has prompted some educators to label them as ineffective teaching strategies (Precious & Feyisetan, 2020).

Meanwhile, for an effective classroom instructional delivery and learning, that will produce expected learning outcomes, students in the classroom must be given ample time and chance to participate in the lesson. The adoption and implementation of an instructional strategy that emphasises integrating active learning and student-centred pedagogy into a course that was previously primarily lecture is consequently necessary since these adjustments will result in enduring enhancements in students' attitudes and performance (Rizvi et al., 2015). Lancaster (2017) propounds that the emphasis in classroom instruction has changed from being teacher-centred to being student-centred. This according to Serin (2018) is because, conventional teaching has come under fire for failing to foster a climate in the classroom that fosters the growth of critical thinking and problem-solving abilities.

According to Precious and Feyisetan (2020), student-centred teaching method, in contrast to the teacher-centred teaching, transfers the activity's centre of attention from the teacher to the students. The learner must be vigorously engaged in the learning process and be the focus for classroom instruction to be successful and produce positive results, even though instructors continue to be the most valuable resources in education and play an important role in improving learning outcomes (Ministry of Education, 2018). It is a teaching strategy that downplays the teacher's role as one who solely makes decisions and solves problems in the classroom and instead views the teacher as a facilitator, consultant or coach throughout the intervention process (Precious & Feyisetan, 2020). In an attempt to increase the performance and attitude of students in the optics lessons in SHS Physics classrooms, Poluakan and Katuuk (2022) suggest that, the student centred approach of teaching is what is required. A student-centred learning method has become more popular in education since it has been shown to be more productive than a teacher-centred approach, particularly for developing skills in this 21st-century (Radzali et al., 2018).

In this case, the teacher does not serve as the "sage on the stage" as in the case of the traditional teacher-centred approach but rather as the "guide on the side," who views the pupils not as empty canisters to be filled with information, but as intellectual seekers. The foundation of the student-centred approach is constructivism, which, according to Applefield et al. (2017), is the idea that in order for learning to be effective, students must construct and reconstruct knowledge. Constructivist believe that learning is more successful when the students are allowed to participate in the construction of a meaningful product as part of an activity. This epistemological view holds that learners are the engineers of their own exclusive idiosyncratic meanings of theories, notions and natural phenomena (Precious & Feyisetan, 2020; Serin, 2018; Lancaster, 2017).

The disruption phenomenon which alters the educational landscape is prominent in 21st-century education (Poluakan & Katuuk, 2022). Reskin et al. (2022) believe that optics requires appropriate learning, which can lead students to engage in active learning, develop their academic skills, and master other key Physics concepts through problem-solving. Due to the selection poor teaching models, there is always an issue with students' understanding of the optics concept (Herrero et al., 2021). According to Poluakan and Katuuk (2022), Massive open online courses (MOOCs) and their associated learning tools are gaining popularity. The Internet of Things (IoT) is being used in practically every facet of life, and the global community is being compelled to adapt and must be implemented especially by educational institutions (Poluakan & Katuuk, 2022).

As a result, Patol et al. (2021) assume there are numerous issues with teaching and learning activities, such as how to communicate and find the right strategies, approaches, methods, and learning models. Therefore, a holistic approach to learning is required, along with an instructional model that can adapt to the needs of the 21st century learning (Poluakan & Katuuk, 2022; Reskin et al., 2022; Pusch et al., 2021). The MR-SR Based PIMCA model (simply referred to as PIMCA) which offers multiple ways for presenting the same idea, is one of the learning models needed for the 4.0 era of education and will keep students actively engaged in the class (Hartati et al., 2021). In an attempt to have an effective and successful classroom interaction, Prof. Dr. Cosmas Poluakan created the PIMCA learning model, which places more emphasis on learning Physics on multiple representations and semiotic resources (Hartati et al., 2021; Herrero et al., 2021). This learning model presents concepts in four main steps. The steps are: Presentation (P), Idea Mapping (IM), Conceptualisation (C), and Assessment (A) which gives it the abbreviated name, PIMCA (Poluakan & Katuuk, 2022). With the display of several representational formats, learners receive preliminary information at the Presentation stage.

Additionally, during the second stage, referred to as the Idea Mapping stage, students generate concepts and create a conceptual fabric using data from the various modes of representation from the first stage. The third stage, Conceptualisation, is where students are given information and instructions by the teacher who serves as a facilitator, resource person, and/or instructor. In order to prevent misconceptions from developing, the idea mapping which is immature is now repaired and reconstructed into the right concept. Formative assessment, the fourth stage, is used to make sure that the learner's idea of knowledge is accurate. Performing diagnostics or scaffolding might be based on the formative assessment stage (Poluakan & Katuuk, 2022; Karim et al., 2021; Reskin et al., 2022). With the use of images, animations, videos, and other media, learners will learn how to comprehend and solve problems using Multiple Representation - Semiotic Resources (MR-SR) learning (Hartati et al., 2021).

The usage of MR-SR Based PIMCA models in numerous research demonstrates how this model can enhance students' learning results, particularly in terms of their understanding of Physics concepts (Herrero et al., 2021). Herrero et al. (2021) and Patol et al. (2021) propose that the MR-SR Based PIMCA model as an instructional model should be used as an alternative to address the learning challenges in the education 4.0 era, which is to stimulate students to be capable of critical thinking, creativity, high level thinking abilities, and adaptation to the usage of ICT, besides being able to communicate and collaborate effectively. The MR-SR Based PIMCA model has been shown through research to be efficient and capable of positively affecting students' knowledge and, as a result, their academic performance and attitude (Koming et al., 2021; Pusch et al., 2021). Herrero et al. (2021) conclude that it is necessary to continue research employing MR-SR Based PIMCA learning model to be applied to the study of Physics, Mathematics and the other Sciences.

In light of the foregoing, this study compares the MR-SR Based PIMCA model to the conventional teaching method for teaching Optics in the Senior High School, taking into account gender, student abilities, and the impact of the MR-SR Based PIMCA learning model on students' academic performance and attitude in Optics.

1.2 Statement of the Problem

The study of optics as a concept in Physics has had and continues to have a tremendous impact on individuals and the society at large (Yzuel & Peinado, 2022). It follows that a lack of knowledge in optics in Ghana's educational system would be detrimental to individual lives and the country at large. This is because of the key part it plays in contemporary scientific and industrial advancement. In everyday life, optics is present. The visual system's widespread use in biology suggests that optics, the science of the five senses, is crucial. Contact lenses and eyeglasses help a lot of people, and optics is essential to the operation of many consumer products, such as cameras (Mamengko et al., 2021).

Mamengko et al. (2021) suggest that the education sectors must pay special attention to optics due to its applicability in our daily lives and because it is regarded as a dynamic area of Physics. All efforts to make optics and other Physics concepts a loving one for SHS students appear to have had low or even no discernible impact (Dahliani et al., 2020; Dido et al., 2021). Over the years, Darko (2019), Ersel (2018) and Yzuel and Peinado (2022), found that, learners' performance in optics in the internal examination has been incredibly poor. Optics was mentioned as one of the key concepts in Physics where students found it very difficult to answer questions from (WAEC, 2017; 2018). In WAEC (2021), definition of focal length of a converging lens was among the few areas that were considered as students' weaknesses in Physics. Also, Dido et al. (2021) found that, students could only memorise the characteristics of images formed in a plane but could not demontrate nor explain them in practical terms. Hartati et al. (2021) also found that, Physics students could hardly explain the term reflection of light and some other basic concepts in Optics. As a result, the appalling performance of SHS Physics students in Optics has become a major problem in many higher education institutions both nationally and internationally (Darko, 2019).

Numerous factors have been identified as contributing to students' appalling academic performance in optics. According to several studies, circumstances within and outside the classroom may have an impact on students' academic performance, interest and attitude (Abbiw et al., 2019; Akhtar et al., 2018; Buabeng et al., 2014). Abbiw (2019) and Aboagye & Gyan (2019) claim that, much emphasis has been laid on the choice of teaching pedagogy teachers use during lesson deliveries as a strong mitigating factor that greatly affect students' academic performance and attitude. Undoubtedly, some Physics theories and concepts are seen as being abstract, and as a result, they appear to be challenging for pupils to comprehend if the right instructional techniques are not employed. This notion may have a significant role in the students' abysmal performance in optics and Physics at large.

Bara and Xhomara (2020) assert that though, Physics teachers are said to have been using student-centred teaching approaches as prescribed by the Ghana Education Service (GES), yet, there seem to be no or low improvement in students' academic performance and attitude. The reason may be that, the most appropriate and effective learner centred teaching approach that will improve students' academic performance and enhance their attitudes in the learning of optics has not been identified. In effect, teachers seem to be using different approaches, majority of which are not effective enough to enhance students' academic performance and attitude in the Physics classroom.

The use of the MR-SR Based PIMCA model as an alternative model in the teaching and learning process has the potential to improve students' performance irrespective of their gender and abilities and as well inculcate in them positive attitude towards science, particularly Physics and in the STEM fields (Hartati et al., 2021; Karim et al., 2021; Patol et al., 2021; Reskin et al., 2022).

Meanwhile, it seems this instructional model is not well known in Ghana and perhaps, teachers are not utilising it in their Physics classrooms since no work has been done on it. This has made it necessary to compare the MR-SR Based PIMCA model to the conventional teaching method in the Senior High School Physics classroom in order to test for its effectiveness, hence the need for this study.

1.3 Purpose of the Study

The purpose of this study was to compare the effects of MR-SR Based PIMCA Model and the conventional teaching approach on academic performance and attitude of Senior High School Students in Optics.

1.4 Specific Objectives

The specific objectives of this study are to;

1. determine the effect of the MR-SR Based PIMCA model on students' attitude towards the learning of Optics.
2. determine the differences in academic performance between students instructed through the conventional method and those instructed through the MR-SR Based PIMCA Model.
3. determine the differences in academic performance between males and females senior high school Physics students instructed through the MR-SR Based PIMCA Model.

4. determine the differences in academic performance between high and low achieving senior high school Physics students after instruction through the MR-SR Based PIMCA model.

1.5 Research Question

The study was guided by this research question:

1. What is the effect of the MR-SR Based PIMCA model on students' attitude towards the learning of Optics?

1.6 Research Hypotheses

The succeeding hypotheses were formulated for this research:

H_{01}. There is no significant difference in academic performance between students instructed using the MR-SR Based PIMCA learning model and those instructed using the Conventional method.

H_{a1}. There is a significant difference in academic performance between students instructed using the MR-SR Based PIMCA learning model and those instructed using the Conventional method.

H_{02}. There is no significant difference in academic performance between male and female senior high school Physics students after exposure to the MR-SR Based PIMCA model

H_{a2}. There is a significant difference in academic performance between male and female senior high school Physics students after exposure to the MR-SR Based PIMCA model

H_{03}. There is no significant difference in academic performance between high and low achieving Physics students in the senior high school after exposure to the MR-SR Based PIMCA model.

H_{a3}. There is a significant difference in academic performance between high and low achieving Physics students in the senior high school after exposure to the MR-SR Based PIMCA model.

1.7 Significance of the Study

This study will fill the gap in research relative to how the conventional teaching approach and the MR-SR based PIMCA model influence SHS students' attitude and academic performance in Optics. The Physics teachers will be enlightened about the need to utilise the learner centred approach of teaching, suggesting to them to adopt different and better teaching and learning strategies that are appropriate to their lessons, thereby arousing the interest of the students and increasing their academic performance and enhancing positive attitude in optics and the other Physics concepts. The teachers will again be informed about the MR-SR Based PIMCA model, an effective learning model of the 21st century, that is apt to the demands of the times.

1.8 Justification of the Study

The MR-SR Based PIMCA model and its effect on students' academic performance in Physics has been researched into and tested in some findings elsewhere. However, the justification of this study is that, little work of the MR-SR Based PIMCA model on students' academic performance and attitude in optics appears to have been done especially in Ghana.

1.9 Delimitation of the study

This study was delimited to form one SHS Physics students in the Mampong Municipality and Sekyere South district since the Optics concept under study is treated at their level. Also, Optics as just one of the many concepts in Physics at the SHS level was used. Again, only quantitative data was collected and used in analysing the attitude of students. Lastly, the MR-SR Based PIMCA model and the conventional teaching approach were used among the number of Physics teaching approaches that exist.

1.10 Limitation of the study

The research employed the pretest posttest nonequivalent groups comparison design where the participants were not randomly assigned.

1.11 Organisation of the study

This study was organised into five main chapters. The first chapter talks about the introduction of the study which consists of background of the study, problem statement, the purpose of the study, the research objectives, research questions and hypothesis formulated for the study as well as the significance of the study, justification of the Study, delimitation and limitations of the study and ends with organisation of the study. The chapter two outlines the literature review of the study. It highlights on key components such as the theoretical and conceptual frameworks of the study. Empirical evidences for the use of the PIMCA model on students' academic performance was also discussed.

Chapter three also discusses the methodology and has subsections such as the research design and paradigm, population and participants of the study, sampling and sampling techniques, together with research instruments, validity and reliability, data collection procedure, the intervention processes and ends with data analysis procedure.

Chapter four also highlights the findings of this research with respect to the specific objectives. The chapter ends with the discussion of results as presented previously in the chapter in the light of the scientific literature. Chapter five also outlines the summary and presents the conclusion, recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

In this chapter is found reviewed literature that are related to this study. The chapter has been organised under headings such as the MR-SR Based PIMCA model, multiple representation, semiotic resources, stages of the PIMCA model, theoretical basis for the study, educational psychology, constructivist learning theory, behaviourist learning theory, cognitivist learning theory and humanistic learning theory.

Additionally, the zone of proximal development concept**,** conceptual framework, empirical evidence of the study, implementation challenges of the MR-SR Based PIMCA model, students' attitude and academic performance, gender and academic performance, teaching methods and academic performance were also highlighted**.** This chapter then ends with the summary of issues emanating from this review.

2.1 The MR-SR Based PIMCA Learning Model

The disruption phenomenon is evident in the 21st-century educational landscape (Poluakan & Katuuk, 2022). They result in changes in the learning environment since learning activities are becoming more casual and demand that students be self-motivated. As a result, Massive Open Online Courses (MOOCs) are gaining popularity as a means of providing educational resources. Reskin et al. (2021) postulate that the adoption of the Internet of Things (IoT) in nearly every aspect of life has prompted the global community to adjust.

According to Poluakan and Katuuk (2022), during the teaching and learning process, a variety of difficulties come up, such as communication strategies, approaches, and need-based learning models. Consequently, the learning process requires a holistic approach through a learning model that is appropriate for the needs of the present and adaptable to 21st-century learning requirements (Poluakan & Katuuk, 2022). Karim et al. (2021) postulate that, the MR-SR Based PIMCA model is an alternate approach to learning that is flexible to the demands of the moment. This according to Hartati et al. (2021) is because it offers chances for the application of information technology and multimedia. Prof. Dr. Cosmas Poluakan, established and created the PIMCA model in the year 2020. PIMCA is an instructional model that evolved from model of Model-Based Instruction (MOMBI), but it stresses the teaching and learning process based on MR (Multiple Representation) and SR (Semiotic Resources) developed from Vygotsky's Zone of Proximal Development (ZPD) theory (Nasra et al., 2021; Lampeang et al., 2021; Reskin et al., 2021; Hartati et al., 2021; Mayampoh et al., 2021). According to Poluakan and Katuuk (2022), the MR-SR Based PIMCA model was developed to alternate the learning models and to address the challenges posed in the 4.0 era of learning, which include motivating students to be able to think critically, be creative, possess sophisticated thinking skills, and be adaptive to the usage of Information and Communication Technology (ICT) additionally to being able to team up and communicate effectively.

Prior to the MR-SR Based PIMCA model being used as an efficient scientific learning model in the discipline, a trial was conducted in the field of Physics at the department of Physics of Manado State University in Indonesia using a variety of chosen instructional resources using students as target sample learners and as teaching models

(Poluakan & Katuuk, 2022). Experts in the domains of psychology and pedagogy evaluated the model's syntax, and experts in the field of Physics validated the materials used as teaching aids. Dido et al. (2021) posit that, the PIMCA model is a learning model that is anticipated to make Physics concepts, particularly in optics, easier to understand.

2.2 Multiple Representations (MR)

Multiple Representation is defined by Sunyono and Meristin (2018) as a scientific procedure that elucidates the same concept in various ways. Toding et al. (2019) further explained representation as something that represents or stands for things or actions. Koming et al. (2021) cited words, animations, images, diagrams, graphs, computer simulations, and mathematical equations as few examples of what can be used in Physics. According to Patol et al. (2021), some representations are more concrete and operate as referents for notions that are more abstract, such as free-body diagrams, motion diagrams, and sketches. Toding et al. (2019) stated that, when it comes to learning, it can be said that providing students with more diverse representations by broadening the variety of external representations affects their cognitive abilities, can produce positive outcomes, offer special advantages when learning difficult new concepts, and makes concepts easier to comprehend.

Multiple representations might be utilised to describe an observable event or occurrence in Physics in order to make a complex and abstract notion easier to understand. The primary purpose of Multiple representations as asserted by Nasra et al. (2021) is to limit interpretation and build comprehension. According to the Cognitive Theory of Multimedia Learning (CTML) in addition to multimedia principles, the utilisation of various resources and multiple representations is beneficial since learners study more effectively from words and pictures than from words alone (Sunyono & Meristin, 2018). The use of Multiple representations as asserted by Sunyono and Meristin (2018) serves these purposes;

- First, it aids in the completion of cognitive processes or the providing information.
- Second, it can lessen the chance of misunderstanding based on prior statements and representations.
- Third, using multiple representations can help students develop a thorough knowledge of the situation.

Sunyono and Meristin (2018) propound that, Students' ability to solve problems can be aided by the use of multiple representations in classroom instruction. Additionally, they discovered that adopting multiple representations while learning can improve students' conceptual understanding, general scientific abilities, critical thinking, and mental models. Physics concepts and problem-solving go hand in hand. As a result, the required particular techniques in multiple representations-based learning are: understanding concepts by analogy, elaborating on concepts with some representation, applying concepts to problem-solving situations, and reflecting on the outcomes of learning activities (Wiyarsi et al., 2018).

2.3 Semiotic Resources (SR)

Semiotic resources are defined by Danielsson and Selander (2021) as those that we employ to categorise our understanding of the world, create meaning in our interactions with others, or create meaning for ourselves. In simple terms, they are classified as merely symbolic communications. To Danielsson and Selander (2021), the actions, objects, and tools we use to communicate, whether they are created physiologically (for instance, with our vocal chords, the muscles involved in making gestures and facial expressions), technologically (for instance, using a pen and ink or software and hardware for computers), or both, are referred to as semiotic resources.

These resources can also be organised in various ways. According to Hartati et al. (2021), Semiotic resources refer to the means employed by families in manufacturing facilities and are used in social semiotics and some other fields and might take the shape of words, photos, diagrams, graphs, or different types of symbols.

Mamengko et al. (2021) also make the assumption that a teacher must cultivate the usage of varieties of semiotic sources so as to enhance the learning objectives being effectively grasped. To help students with problem-solving and working with multiple representations, semiotic resources can communicate the meaning and pertinent disciplines. Five major meaning-making systems or semiotics have been identified, namely; written-linguistics, visual, auditory, gestures, and spatial patterns of meaning. According to research by Nasra et al. (2021), using semiotic representations improves student learning results. Semiotic resources are never picked at random to create meaning. Instead, more or less deliberate decisions are made based on the modes or specific resources that are available in the context of meaning-making. The decision is also influenced by the resources available and the messages we wish to convey and to whom it is conveyed (Danielsson & Selander, 2021).

Rettob et al. (2021) and Weliweriya et al. (2018) postulate that, Physics and semiotic resources are closely related, and encouraging students to use a variety of semiotic resources can help them focus on comprehending Physics processes and concepts. Student meaning-making can be modelled within the frame of solving problems in Physics as a process of realizing and communicating Physics knowledge through the use of various semiotic resources (Weliweriya et al., 2018). To better represent an idea or a concept in Physics, Weliweriya et al. (2018) suggest that students must be capable of intelligently blend several semiotic sources.

2.4 Stages of the MR-SR Based PIMCA Model.

Four intervention steps, namely Presentation, Idea Mapping, Conceptualization, and Assessment (formative), make up the MR-SR Based PIMCA Model (Mamengko et al., 2021; Poluakan & Katuuk, 2022; Reskin et al., 2022).

Stage 1. Presentation

The primary emphasis at the presentation stage is on the application of multiple-representation (MR), basically founded on the behaviouristic learning theory and prioritises the process of giving stimulation (Poluakan & Katuuk, 2022). Tokolang et al. (2021) affirm that this stage is where new knowledge is learned through the display of multiple representational formats. The instructor performs a number of presentations to clarify the theory or concept. Depending on the type of concept being studied, the instructor carefully chooses the right presentation to employ in the lesson. Poluakan and Katuuk (2022) assume that, the presentation will prepare instructors and students to make the best use of multimedia through YouTube videos, animated visuals, virtual laboratories, simulations, demonstrations, and film projects.

The use of multimedia during the delivery of instruction will greatly serve the learners' interest, call for their attention, and encourage maximum involvement in the lesson. Multimedia has become the norm and addresses the demands of the time in the 21st century. Engaging in multiple representations with the help of semiotic resources and multimedia, Lampeang et al. (2021) affirms that students can create knowledge by developing conceptual concepts in relation to continuous learning resources.

Stage 2. Idea – Mapping

Idea Mapping is the stage in which students create concepts and mental connections using information from the Multiple Representations received at the first stage (Tokolang et al., 2021). Poluakan and Katuuk (2022) assert that, this is the point at which learners' first demands for critical thinking start to take shape. Patol et al. (2021) assume that students can acquire conceptual understanding of ongoing learning materials with the aid of multimedia to construct knowledge.

The influence of the stimulus through the employment of Multiple Representations in the initial stage is the creation of a reaction in the students in the form of a conceptualization process, though Reskin et al. (2021) assume that, immature concepts may be built by the learners at this stage. According to cognitive psychology, this concept's formation is described as a type of perceptual alteration that does not always manifest as behaviour (Fetsco & McClure, 2018). However, the orientation, elicitation, and restructuring of ideas commonly referred to as constructivist learning theory begins with the built concept. This is in line with Vygotsky's theory, according to which aid is necessary during the Zone of Proximal Development stage for concepts to form through self-regulation (Reskin et al., 2021).

Stage 3. Conceptualisation

Conceptualisation is the stage wherein the instructor, acting as a facilitator, provides guidance to the students along with information so that scaffolding functions can take place (Poluakan & Katuuk, 2022; Tokolang et al., 2021). At this stage, Tokolang et al. (2021) and Patol et al. (2021) state that, ensuring that no incorrect concepts are built, the immature idea mapping is repaired and built into the right concept. Poluakan and Katuuk (2022) are also of the view that, the concepts of the ideas that were developed earlier should be clarified at this point in order to prevent the formation of an incorrect concept understanding. Following this, the concepts should be directed into a network of pertinent and significant concepts to produce a comprehensive concept map. Mamengko et al. (2021) supported that, in order to avoid misunderstandings in the future, it is important that the concepts created during the idea mapping stage are made clear and that the mapping of immature ideas is addressed.

Reskin et al. (2022) clarified that concepts are implanted through demonstrations, project assignments, conversations, and other activities such as experiments (laboratory practices or virtual laboratory experiments). At the conceptualisation stage, as asserted by Poluakan and Katuuk (2022), the enactive-iconic-symbolic (Bruner) model of intellectual development is used through three main stages: the information stage (during which students who are learning obtain a lot of knowledge about the subject being considered), the transformation stage (during which the attained information is analysed, altered, or converted into a conceptual or abstract form), and the evaluation stage (during which the learners evaluate the degree to which they can locate and arrive at the correct concept, which can then be shown on a concept map).

Stage 4 Assessment (Formative)

An assessment component for both the learning results and the process is crucial for the success of learning (Koming et al., 2021; Patol et al., 2021). In order to ascertain what has to be done in terms of learning, assessment is designed to gather a variety of data regarding the learning process and outcomes. To ensure that the concepts of knowledge developed by the students are accurate, it is necessary to verify the knowledge that has been established. This is done during the formative assessment stage of the PIMCA model. Formative assessment is a systematic process in which teachers use information gleaned from monitoring student progress to modify current teaching practices (Nasra et al., 2021; Tokolang et al., 2021). Reskin et al. (2022) attest that, students receive timely, targeted, non-evaluative feedback from formative assessments, which helps them perform better. Tokolang et al. (2021) believes that the effectiveness of learning, both in terms of the learning process and the learning results, is influenced by evaluation. The multiple-choice test is one of many tools available for measuring learning outcomes (Hartati et al., 2021; Herrero et al., 2021). Multiple-choice questions with thoughtful design can be used in conjunction with other assessment techniques to provide strategies of education for accelerating the process of learning, provide accurate and thorough evaluations of the performance of students, and further pinpoint students' comprehension of the concept of Physics (Tokolang et al., 2021). This phase can act as a foundation for conducting diagnostics and also as a scaffolding assessment (Patol et al., 2021; Nasra et al., 2021).

The MR-SR Based PIMCA model, as shown in Figure 2.1, was proposed by Poluakan and Katuuk (2022).

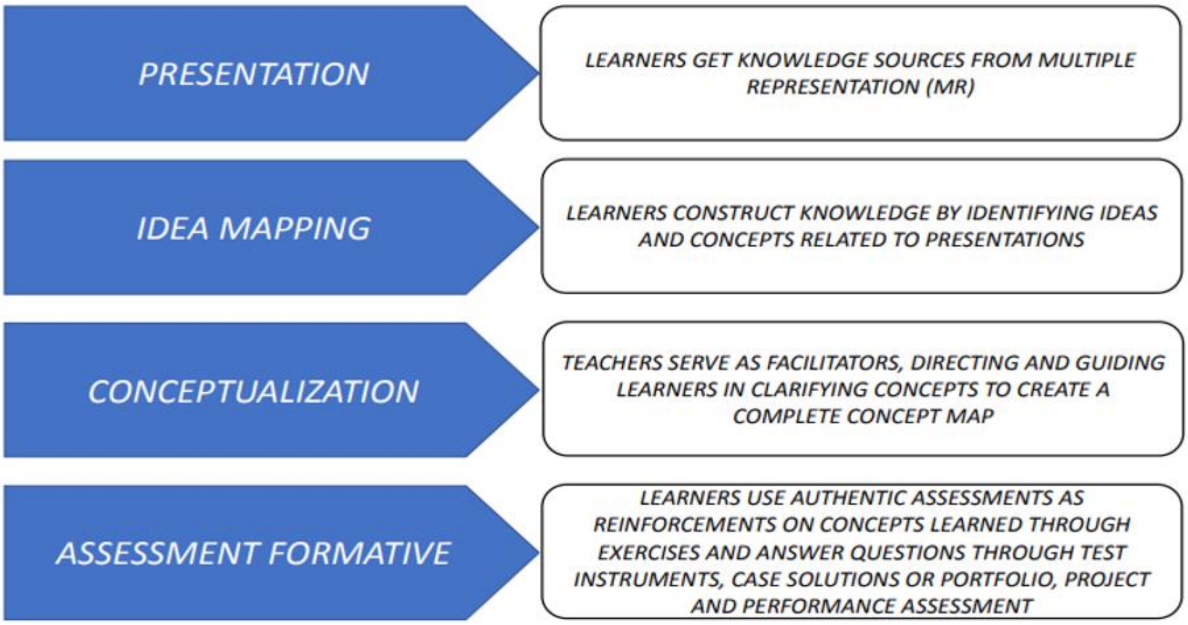

Figure 2.1: ***The MR-SR Based PIMCA Model***

2.5 Theoretical Basis of the PIMCA Model

The MR-SR Based PIMCA model is founded on the principles of integrated learning theory and educational psychology, namely, the constructivist learning theory, behaviouristic learning theory, cognitive learning theory and humanistic learning theory (Poluakan & Katuuk, 2022).

2.5.1 Educational Psychology

Fetsco and McClure (2018) defined Educational Psychology as the area of psychology that focuses on understanding the ideas and behaviours related to human education and learning. Educational psychologists ponder the characteristics of good instruction, the nature of students and learning, and the effects of classroom dynamics on learning. According to Plucker and Makel (2021), psychology of education identifies the core psychological precepts underlying lifelong learning to address the issues with psychological theory in the context of education. Narkuzieva (2020) opines that Within the context of the continuous idea of education, it is required to establish the categories, identify elements in the development of education taking into consideration human nature (genetics, psychophysiology, etc.), and also encourage professional and personal development. According to Schwartz et al. (2022), five basic domains of developmental theories, learning and motivation, classroom instruction, student heterogeneity, and assessment and evaluation are shared by the discipline of educational psychology.

Educational psychologists' main objective is to research how individuals learn (Fetsco & McClure, 2018). Schwartz et al. (2022) presume that by utilising their expertise, educational psychologists work to make all students successful learners by enhancing classroom instruction. Educational psychologists must therefore consider a wide range of aspects of learning in order to achieve this goal. These aspects of learning include social and emotional as well as cognitive processes.

Education psychologists believe that education and psychology are connected by and as a result, it is their duty to pinpoint the branches of psychology that are relevant to the study of education (Schwartz et al., 2022). The field of educational psychology's division of learning and instruction has long included a variety of conceptual and theoretical domains, including complex cognitive processes, human development, behavioural and social cognitive views of learning, acquiring knowledge through social constructivist views, self-regulation and managing a classroom, motivation, and classroom assessment techniques. These domains are also intersectional with culture, technology, language, and various levels of education.

2.5.2 Constructivist learning Theory

Constructivism, according to Applefield et al. (2017), is an epistemological perspective on knowledge acquisition that places more emphasis on knowledge building than knowledge transmission and the recording of other people's messages. Djan (2022) opines that, as a learning theory (proposed in psychology) and an epistemological or knowledge theory (proposed in philosophy, particularly in epistemology), constructivism spans both the philosophical and psychological fields. The premise of constructivist education is that knowledge is created and retained by students when they actively engage in the process of creating it, as opposed to simply receiving it. (Newman & Latifi, 2021). To them, meaning and knowledge are created by learners. Constructivist teaching, according to Villanueva and Ventura III (2022), promotes critical thinking and develops motivated, self-reliant learners. The works of Piaget and Vygotsky, who both emphasised that previous beliefs must be disequilibrated in light of new information before there can be a cognitive shift, is cited by Tekos and Solomonidou (2013) as having strong roots in the educational heritage and being heavily influenced by the constructivist movement.

The constructivist theory holds that, making a connection between the new information and the knowledge already held by an individual is the process of learning. Each individual forms the foundation of information by providing his or her own comment, rather than piling on information. In the constructivist method, where the student is at the core of the educational process system, teachers play a crucial role. Instead of imparting knowledge directly to students, teachers assist them find the information they need and then construct it themselves (Villanueva & Ventura III, 2022). Applefield et al. (2017) state that, teachers assist students in learning and self-development by acting as a liaison between them and educational programs.

The learning process must be structured by teachers in accordance with students' interests and needs, and they must encourage students to ask questions, come up with original ideas, make assumptions and observations, collaborate, and test their theories (Ayaz & Şekerci, 2015). One of the most crucial ideas in educational psychology is that information cannot simply be imparted to students by teachers; rather, it must be created by them. The teacher can assist this process by giving students opportunities to find or apply ideas on their own, by providing them with opportunities to do so, and by educating them to be conscious of and employ their own learning processes (Slavin, 2003). Villanueva and Ventura III (2022) add that although educators can provide students with ladders that lead to greater learning, it is up to the students to use these ladders. For them, the core of constructivist theory is the notion that for students to truly own complex information, they must independently find and transform it.

Constructivist approaches are sometimes referred to as student-centred instruction since they place a strong emphasis on students as active learners (Ayaz & Şekerci, 2015; Slavin, 2003). Applefield et al. (2017) postulate that, a teacher in a student-centred classroom function as a guide rather than a sage on stage, assisting students in finding their own meaning as opposed to lecturing and overseeing all classroom activities. According to Applefield et al. (2017), constructivism contends that learners' conceptions of knowledge come from a process of creating unique interpretations of their experiences during the meaning-making process.

2.5.3 Relationship Between Constructivism and the MR-SR Based PIMCA Model

Constructivist education according to Newman and Latifi (2021) is based on the assumption that rather than students just absorbing information, learning occurs when they actively engage in the process of producing meaning and knowledge. The MR-SR Based PIMCA Model has provided a framework for this assumption because the teacher in a constructivist environment can only support the process by instructing in approaches that allow students to discover or apply concepts independently, making knowledge interesting and relevant to them, and by instructing pupils to recognise and intentionally employ their own techniques of learning. Constructivists hold that while teachers can provide students with ladders leading to greater understanding, it is ultimately up to the students to ascend these ladders.

Due to this, during the Idea- Mapping stage of intervention, the MR-SR Based PIMCA Model enables students to create their own knowledge. Tokolang et al. (2021) assert that, using information from the Multiple Representations they obtained in the first stage, pupils are now able to conceptualise ideas and make connections in their minds. Poluakan and Katuuk (2022) affirm that, at this point, learners' critical thinking demands, which are wholly a constructivist creation, start to take shape. In the MR-SR Based PIMCA learning, where the student is at the centre of the instructional system which is a constructivist point of view, teachers are not exempted from the process but play a crucial role. Instead of teaching students directly, they help pupils find the information they need and then build it themselves. In the PIMCA model, the Idea-Mapping and the Presentation stages make the best contributions to the development of both critical and imaginative thinking abilities (Poluakan & Katuuk, 2022).

2.5.4 Behaviourist Learning Theory

The concept of behaviourism, which was primarily associated with the works of Thorndike, Watson, and Ivan Pavlov, centres on the notion that all behaviours are acquired through interactions with the environment (Djan, 2022; Lika et al., 2022). This learning theory according to Widiarini (2022) states that behaviour is acquired from the environment, intrinsic or hereditary variables have little to no bearing on behaviour. According to Watson, a pioneer and proponent of behaviourism, the environment influences learning more so than genetics do (Djan, 2022). Olugbenga (2021) proposes that the behaviourism paradigm emphasises behaviours that can be observed, and that learning is the acquiring of new behaviour depending on contextual circumstances.

Widiarini (2022) asserts that since external factors (stimuli and environment) have an impact on human behaviour, which is quite complicated, teaching methods should centre on the behaviourist perspective of external observations of people's behaviour in response to external stimuli and the legal and causal relationships between them. In behaviourism, Farrokhnia et al. (2022), advocate for teachers to employ mechanical and methodical teaching strategies. Behaviourist learning theory as cited in Lika et al. (2022) explains that the idea of learning is a modification in behaviour that can be seen, measured, and evaluated practically. They believe that behaviourism has a significant impact on the educational system and has replaced constructivism and cognitivism as the fundamental philosophy of learning.

Learning has taken place when a suitable reaction to the display of a specific environmental stimulus is demonstrated. The continued existence of these behaviours, as reported by Farrokhnia et al. (2022), depends on three key components: a stimulus (which elicits behaviour), a response (which is triggered by a stimulus), and reinforcement (which acts as a marker for the appropriateness or inappropriateness of the reaction and encourages its repetition or suppression in the future). Lika et al. (2022) observed that, in behaviourism, one of the most pertinent aspects of learning is that someone is deemed to have learned something when they exhibit a change in their own behaviour.

Farrokhnia et al. (2022) discovered that external factors, as opposed to internal factors, account for the majority of causes or motivations for behaviour in the behaviourist perspective. Hence, students are seen as more or less passive recipients of knowledge that teachers lecture on and present to them, such as the steps they should follow to accomplish a particular goal. Djan (2022) assert that, behaviourism focuses solely on explaining, characterising, and influencing behaviour, hence it has unique characteristics.

Behaviourism as asserted by Widiarini (2022), emphasises the significance of those performances' outcomes and contends that behaviours that are rewarded are more likely to happen again in the future. Widiarini continues by saying that instead of actively exploring their environment, the learner is said to be reactive to circumstances in their surroundings. Thus, it is believed that the organisation of inputs, reinforcement, and environment are the elements that affect learning. The environment is taken into account together with learner behaviour, but the behaviourist believes that the environment is more crucial and needs to be given more attention (Djan, 2022).

2.5.5 Relationship Between Behaviourism and the MR-SR Based PIMCA Model

Teaching techniques should focus on the behaviourist perspective of external observations of people's behaviour in reaction to external stimuli and the ethical and causal relationships between them, according to constructivists, who believe that external factors such as stimuli and environment have a great impact on human behaviour and learning, which is quite complicated (Widiarini, 2022). Students go through a stage in the PIMCA model termed the Presentation stage since the environment affects learning more than genetics do (Djan, 2022). Students are given many presentations using semiotic resources (SR) that have been carefully chosen by the teacher depending on the topic or theory to be learned during this intervention stage, which is the first stage of the learning process. The instructor now gives a number of presentations to help students understand the topic or subject.

Poluakan and Katuuk (2022) posits that, through YouTube videos, animated graphics, simulations, virtual laboratories, demonstrations, and film projects, the Presentation stage teaches teachers and students to use multimedia as effectively as possible, which has a positive impact on students' learning. Poluakan and Katuuk (2022) assert that the behaviouristic learning theory is the foundation for the use and implementation of multiple-representation at the Presentation stage of the PIMCA model, which prioritises the process of providing stimulation.

2.5.6 Cognitivist Learning Theory

According to cognitivists, learning is the creation of neural connections that help us understand how our bodies react to new experiences (Djan, 2022). According to Farrokhnia et al. (2022) cognitivism is defined by thought, knowledge of the framework of knowledge, and the internal environment rather than the behaviourist exterior environment. According to cognitivists, the internal environment of the student is where learning occurs. Cognitive structures use cognitive tools like insight, processing of information, perception, and memory to facilitate learning by giving events meaning, and it emphasises cognitive processes rather than externally observable behaviour (Idika, 2017).

In the Cognitive Learning Theory, Farrokhnia et al. (2022) assert that the mind is thought of as an information-processing system, and social interactions and environments are important for cognitive development. Interacting with others who possess the information and skills is how one gains them (Widiarini, 2022). To obtain knowledge, Farrokhnia et al. (2022) propound that for assistance and direction, the individual looks to those who are knowledgeable, such as instructors, peers, or parents. According to Widiarini (2022), factors that help learners' cognitive talents improve include active engagement in the learning process, interaction with adult teachers, access to knowledge with clear instructions, and instructional materials with easily discernible objectives. The main principles of applying cognitive theory in the classroom are active participation, learner cognition, and teacher-student interaction. Cognitivist according to Lika et al. (2022) suggest that, teachers should emphasise the significance of cognitive frameworks like knowledge structures (that is, mental schema) and help students organise and relate new material to current or already existing knowledge in their memory to make learning meaningful (Idika, 2017). Farrokhnia et al. (2022), add that, cognitivism stresses giving people real-world learning opportunities where they may encounter new information that does not align with their pre-existing beliefs or that is against them (i.e., a disequilibrium condition).

From the cognitivist perspective, Farrokhnia et al. (2022) again states that when students can overcome this condition of disequilibrium by taking in new information and incorporating it into their prior knowledge, learning is said to have occurred. Similar to behaviourism, cognitivist learning environments encourage individual learning possibilities; nonetheless, learners' active participation in the acquisition and integration of knowledge is essential (Djan, 2022).

2.5.7 Relationship Between Cognitivism and the MR-SR Based PIMCA model

According to Widiarini (2022), active participation in the learning process, interaction with adult teachers, access to information with clear instructions, and educational resources with plainly detectable objectives are all aspects that aid in the improvement of learners' cognitive knowledge. The use of multimedia into the classroom is thought to increase student engagement, foster interactive learning, and improve performance. It is crucial that students actively participate in the acquisition and integration of knowledge (Djan, 2022).

Therefore, the MR-SR Based PIMCA learning model makes room for students to participate actively in the lesson through their interaction with instructional materials (semiotic resources through multimedia) during the multiple representations at the Presentation stage. Students also interact with their teachers for guidance and direction at the Conceptualisation stage. This is done in order to avoid misunderstandings in the future. It is important that the concepts and theories built by students at the idea mapping stage are elucidated in order to avoid the formulation of misconceptions and immature ideas. This is made possible as students interact with their teachers.

2.5.8 Humanist Learning Theory

Humanism, also known as humanistic psychology, developed in response to Sigmund Freud's psychoanalytic theory's identification of flaws in Skinner's behaviourism theory (Djan, 2022). Lika et al. (2022) assert that, the behaviourist view of reinforcing stimulus-response behaviour, which is based on animal research, is rejected by the humanism hypothesis since it is seen as dehumanising. According to Idika (2017), experiential learning governs humanism since learning necessitates the instructor creating a space for the student to experiment and grow. However, for the learner to grow, Poluakan and Katuuk (2022) suggest that there is always a need for an atmosphere that allows them to feel accepted, heard, and understood. This means that the learner must be given the opportunity to speak and be heard in the classroom (Lika et al., 2022).

As a result, teachers should pay close attention to the students' perceptions, feelings, beliefs, and intents since the humanistic learning theory places a strong emphasis on the experience and internal sentiments of the learners in order to comprehend their psychological behaviour, dignity, ideals, and interests. To this, Ajoke (2017) posits that, since role modelling, experiences, exploring, and observing others all encourage individual learning, creating the ideal environment for learner centeredness and interacting with every learner is essential. This suggests that learning from a humanist perspective might be characterised as a natural and individual process to realise one's potential and achieve self-actualisation.

As the humanistic learning theory lays a heavy emphasis on the experience and internal sentiments of the learners, humanists think that for growth to occur, there is always a need for an environment that enables individuals to feel accepted, heard, and understood (Poluakan & Katuuk 2022). The MR-SR Based PIMCA learning gives opportunity to the students to speak and be heard during the instructional delivery**,** teachers pay great attention to students' perceptions, feelings, beliefs, and intentions during the conceptualisation stage and provide support as needed.

2.6 The Zone of Proximal Development (ZPD) Concept

Lev Vygotsky, a Russian and Soviet psychologist, created the zone of proximal development (ZPD), which is a component of his social constructivism theory (Eun, 2019; Lasmawan & Budiarta, 2020). According to Tololiu et al. (2019), the cognitive or cognition process of thinking is unquestionably necessary for the teaching and learning processes. The Zone of Proximal development, according to Vygotsky, is one of the various methods of cognitive growth (Tololiu et al., 2019). The Zone of Proximal Development, according to Vygotsky, is the difference between an individual's actual development as indicated by a particular problem and their potential development as indicated by working with more experienced peers or addressing problems under one's own supervision (Eun, 2019; Rettob et al., 2021).

The enhancement of one's mental capacity through the use of semiotic mediation techniques, surroundings, and peer or adult tutors is described by Vygotsky as taking place in a zone of proximal development (Reskin et al., 2022). According to Lasmawan and Budiarta (2020), Vygotsky's theory paints a picture of human development as being inextricably linked to social and cultural interactions. ZPD refers to the student's actual level of development and the next level, which can be attained with the use of peer facilitation, adult guidance, and environmental and semiotic mediation techniques (Rettob et al., 2021). Reskin et al. (2021) add that the idea of Vygotsky's theory is to employ the Zone of Proximal Development in a variety of activities too complicated for children to learn on their own but may be mastered under the supervision of an adult (teacher or parent). According to Tololiu et al. (2019), scaffolding is a concept from Vygotsky's theory that refers to giving students support while they are studying in order to increase student understanding.

According to Vygotsky's cognitive theory, social interactions and cultural factors have a role in the process of learning and the development of knowledge (Poluakan & Katuuk, 2022). Newman and Latifi (2021) observed that, ZPD is crucial since it contributes to the growth of children's cognitive skills through social interaction and serves as the foundation for modern group-based learning. According to Vygotsky Learning is essential and a part of human development, particularly in terms of psychological processes (Eun, 2019). In other words, education transforms us become actual people (Lasmawan and Budiarta, 2020). According to Vygotsky, social and linguistic interactions are where learning takes place in both of its primary senses (Lampeang et al., 2021; Nasra et al., 2021).

The level of actual development together with the level of potential development are the two categories into which an individual's abilities can be subdivided (Hartati et al., 2021). According to Newman and Latifi (2021), the ability to solve a problem on one's own, without the aid of adults or peers, without the use of mediation instruments, is regarded as the most fundamental mental function a person possesses. Help from others (scaffolding) is required to develop one's fundamental mental abilities (Nasra et al., 2021). On the other side, potential development is established when a person is able to resolve conflicts amicably with the assistance of peers or adults and mediation tools (Nasra et al., 2021). Vygotsky's ZPD is illustrated in figure 2.2 below.

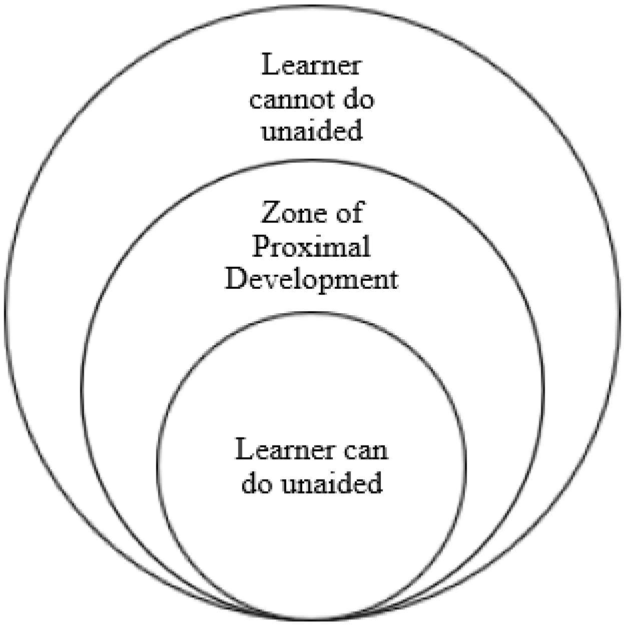

Figure 2.2: Illustration of the Zone of Proximal Development

Lasmawan and Budiarta (2020) contend that children's talents under the direction of parents, instructors, or peers who possess more advanced skills reveal their level of prospective development. This potential ability will advance to a new stage of actual development due to the fact that: in order to solve a new problem, you will need the guidance and assistance of adults. We refer to this as a new potential development, and it will continue to do so as long as the student is engaged in a real learning, continuous learning, and lifelong learning process (Poluakan & Katuuk, 2022). In the theory Vygotsky, sharing and collaboration are emphasised, and since each person's growth is a product of his or her culture, success is seen as a mirror of cultural triumph (Nasra et al., 2021). According to Tokolang et al. (2021), Vygotsky's theory of development primarily applies to mental growth, like the processes of reasoning, language, and thinking.

According to Vygotsky's understanding on ZPD, Tokolang et al. (2021) postulate that, instruction and learning provide a path for development to come about rather than being dependent on it. According to Lampeang et al. (2021), the significance of the ZPD has been acknowledged in the domains of psychology and education as a notion that provides insightful information about the nature of human growth. Research has indicated that, the Zone of Proximal Development was essential in providing guidelines for effective learning in both formal and informal settings, across a range of human functioning domains. ZPD's emphasis on the social genesis of all mental processes in humans led academics to concentrate on how distinct cognitive and affective processes emerge in genuine human interactions (Eun, 2019; Lampeang et al., 2021).

Eun (2019) assert that, the link between the people living in the zone and the social context should be taken into account while defining the ZPD. Depending on the individual's stage of development, the social setting has different relationships with the individual. Because of this, a child's age or developmental stage may affect how the same environment affects him/her. When kids are doing things that they couldn't accomplish on their own but can do with help from peers or adults, it's said that they are functioning inside their zone of proximal development (Tololiu et al., 2019). For instance, if a student could differentiate between refraction and reflection of light by himself but could do so with some guidance from the facilitator, then differentiating between refraction and reflection of light is probably in the student’s zone of proximal development. In the MR-SR Based PIMCA model classroom, students are given guidance by the teacher in the first stage of the interventional process to be able to formulate theories and concepts which they found difficult or could not do at all through the presentation of semiotics resources.

2.7 Conceptual Framework of the Study

In this study, social interdependence exists among the various variables. According to Appiah-Twumasi et al. (2020), when an individual's results are impacted by the actions of others, social interdependence is said to be present. Such interactions tend results across an extensive array of learning objectives, such as a source of inspiration, excitement, positive attitude, and enhanced academic performance. The interaction of research variables in this study was conceptualized as shown in figure 2.3

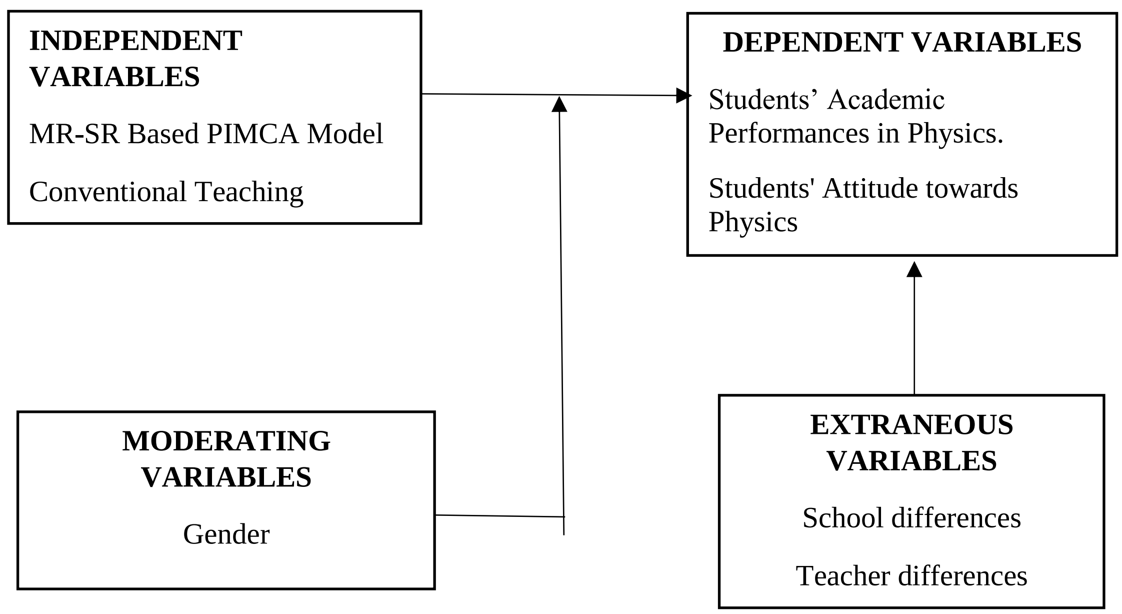

Figure 2.3 Conceptual Framework of the study

The conceptual framework displays how the independent variables interacts with both the moderating variables and the extraneous variables to influence the results of the learners in the instruction and learning of Physics. The independent variables for the study were the instructional methods (PIMCA model and the conventional teaching approach). Gender and students' ability levels were classified as moderating variables. Both teacher and schools' characteristics such as school differences, and teacher differences are also extraneous factors that could affect the process of teaching and learning and affect students' performance and attitude in Physics. These factors (the dependent variables, extraneous variables, and the moderating variables) were conceptualized as factors influencing the dependent variables, that is students' academic performance and their Attitude towards Physics.

2.8 Empirical Evidence of the MR-SR Based PIMCA model

The PIMCA model, which essentially seeks the welfare of students and an effective classroom interaction between the teacher and the students, has been sought after as a substitute learner-centred teaching approach since the focus of classroom instruction has shifted from teacher-centred to learner-centred. A person must cultivate the skills necessary for critical, logical, and creative thinking, which can be accomplished by using an interactive learning model like the MR-SR Based PIMCA model.

Poluakan and Katuuk (2022) asserted that, PIMCA model, which has been validated and accepted as an effective teaching approach and may be used as an alternative to teaching Physics, is one of the most reliable ways to increase the performance of learners academically and raise their interest and attitude toward Physics. The main conclusions of their study suggested that the MR-SR Based PIMCA Model can be used successfully as an alternate method of studying physics. It is necessary to continue research using the PIMCA Models to be used to the learning of science and mathematics, including Physics, biology, engineering, and chemistry. In addition, the PIMCA model can be used to create research guide covering educational psychology, learning theories, and assessments and evaluations of educational programs. Analysis of a number of studies confirm the statement of Poluakan and Katuuk (2022).

Nasra et al. (2021), conducted research on the subject of electric charge learning in Physics using MR-SR Based PIMCA model. The study was aimed at determining how the PIMCA model affected student learning. An average pretest score of 18.88 and an average posttest score of 75.16 were obtained with (Sig 0.00 <0.05) as a consequence of data processing and analysis. As a result, they concluded that there was a significant difference between the students' average pretest and posttest scores. The level of concept mastery rose. They asserted that the PIMCA model is particularly helpful in assisting students in locating and comprehending the proper Physics topics. They also came to the conclusion that the MR-SR Based PIMCA model is a very effective new model for the teaching and learning process, particularly in the STEM fields of learning Physics, Mathematics, and Science.

Reskin et al. (2021) carried out research on the "The use of the PIMCA Model to assess the learning outcomes of students in a programme of study for physics education using convex mirror material". The goal of this study was to compare the improvement in the learning outcomes of students before and after using the MR-SR Based PIMCA learning model. The analysis of the data revealed that the typical score prior to the test was 20.69, while the typical score following the test was 72.41. A gain of 0.9 with a maximum value of 75 was attained. This indicates that because g>0.7, the results of learning increased in the high category. The findings of this study suggest that the PIMCA model can enhance the learning outcomes of students in terms of Physics concept comprehension. They asserted that, the use of instructional model is crucial for enhancing students' academic performance. Students can solve problems procedurally and systematically by using photos to correctly establish the convex mirror image's characteristics. Students can learn while they are studying by using the PIMCA model to represent images. On average, the learning outcomes of students are better after the application of the MR-SR Based PIMCA model when compared to student learning results before implementing the MR-SR Based PIMCA model, according to their research on convex mirror learning that was conducted on respondents of 29 prospective Physics educators at Manado State University. This is especially true in ascertaining the characteristics of the image on the convex mirror. As a result, it is possible to draw the conclusion that MR-SR-based PIMCA treatment can enhance students' learning results in terms of their understanding of Physics concepts.

The impact of the PIMCA model on students' academic performance was investigated by Hartati et al. (2021). They used total respondents of 28 students for their study, which was conducted on the Physics education students at Manado State University's college of mathematics and science. The goal of their study was to ascertain whether employing the MR-SR Based PIMCA learning model on students' learning outcomes on the Autik lup material had improved. As a result of the test, the mean value increased from 27.86 to 75, as evidenced by the findings. Additionally, it demonstrated how the MR-SR-based PIMCA learning model could enhance students' learning outcomes and help them comprehend Physics concepts, particularly when it comes to the topic of magnifying glasses. They came to the conclusion that the experimental class research on the material for optical loop instruments using the PIMCA model in the study program of Physics education generally exhibited a positive effect, indicating that the application of this instructional model can best improve students' learning outcomes in optics and on optical loop instrument. The research from Hartati et al. (2021) indicated that, the best way to alternate teaching Physics in the classroom is by integrating multimedia and semiotics using the PIMCA model.

The MR-SR Based PIMCA Learning Model was used for research on magnetic field learning in Physics by Patol et al. (2021). The research was done twice, using both a large group trial and a small group trial. The pretest mean score in the small group trial findings was 0.2, and the posttest mean score was 2.2. The outcomes of the pretest and posttest trials were 0.7 and 2.5 for the big group, respectively. The findings of this study suggest that the MR-SR Based PIMCA Model is a useful tool for teaching Physics concepts, particularly those related to magnetic fields, to students. The students made development in their capacity to abstract by creating and employing symbols as part of a strategy to solve difficulties. Additionally, after engaging in the PIMCA model of instruction, students were asked for their opinions. It was evident that 46.6% of respondents offered very good responses, 40% replied competently, 13.4% reacted well, and no one provided a poor response. The research concluded that, the MR-SR Based PIMCA model can significantly improve students' attitudes toward and interest in Physics. The MR-SR Based PIMCA Learning Model, they continued, if widely employed in the learning process and can serve as a guide for teachers.

Also, a study was conducted by Koming et al. (2021). The PIMCA model was used in this research to teach convex lens material in Physics. The goal of this study was to determine whether the average learning performance of students in the Physics education increased in the odd semester. After processing and analysing the data, it was discovered that, the average pretest score of 23, and the average posttest score of 79, and a standard ideal value of 75 was attained. The gain-test value was 1.0769, and the data demonstrated a significant improvement in learning outcomes following the adoption of the MR-SR Based PIMCA model. They claimed that it is much simpler for learners to conceptualise concepts aesthetically without having to work hard to comprehend the concepts mathematically to apply the learning model or method using MR-SR or media. They concluded that the PIMCA model does an outstanding job of enhancing comprehension of the convex lens concept.

Research has been carried out by Tokolang et al. (2021) relative to the use of multiple choice assessment in the PIMCA model. They hold the opinion that the evaluation of students is significantly influenced by the learning process because the learning process is one of the key components in attaining educational aims, and the evaluation of both the learning process and the learning outcomes is a key component in determining the effectiveness of learning. The study was aimed at assessing how well the PIMCA model could influence students' performance in the learning of Doppler effect in Physics. The study included 24 trainee teacher candidates as participants. They found that studying Physics requires a grasp of the fundamental principles. Consequently, employing an efficient model, such as the PIMCA Model, can help students comprehend the material and spark their interest in the learning process. Their study revealed differences in students' performance following the application of the MR-SR Based PIMCA model in the learning Process, along with direct interviews to ensure that the conceptualisation contained in the PIMCA Model during the intervention process is expressed and well received by the learners so that the teacher can determine the level of understanding students have attained. This revealed the understanding level in the Doppler effect concept. The average pre-test score obtained was 1.25, and the average posttest score was 7.13, showing a difference between the results of the students before and after the PIMCA model treatment. Meaning that, the application of the PIMCA model has an impact on improving learning outcomes. The study's findings demonstrated that employing the MR-SR Based PIMCA Model with Multiple-Choice Assessment can enhance comprehension of the Doppler Effect conceptual material.

Similarly, research works from Patol et al. (2021), Lampeang et al. (2021), Tokolang et al. (2021), Mamengko et al. (2021), Koming et al. (2021), and Mayampoh et al. (2021) on the use of the MR-SR Based PIMCA model showed improved academic performance and attitude in the Physics classroom. They all found the MR-SR Based PIMCA model to be efficient and could be used as an alternative to teach Physics and other related subjects since it had a significant influence on the students' learning outcomes.

2.9 Implementation Challenges of the MR-SR Based PIMCA Model

The student-centred MR-SR Based PIMCA model has been proven to be effective in the process of teaching and learning, arousing the interest and enhancing positive attitude of students and as well improving their academic performance, yet not without challenges. Its mode of implementation is quite different from the conventional teaching method and hence requires different techniques.

Poluakan and Katuuk (2022) stated that the main challenges that may arise in the use of the PIMCA model includes the following:

- Inability to cover much during the instructional period. There is always a loss of content coverage since the PIMCA model demands a lot of time than other teaching methods like the conventional lecture method.
- The need to fish out for appropriate resources from YouTube or the web. This gives teachers extra burden to prepare for lessons since it requires a lot of work.

- Lack of trust for the students to construct and formulate theories by themselves. The Idea-Mapping stage of the PIMCA model requires students to construct knowledge and concepts through their exposure to the various forms of presentations, some teachers think the knowledge should rather be passed directly from them to the students since that may avoid misconceptions and wrong formulation of theories and as well save instructional time.
- The MR-SR Based PIMCA model is relatively a new teaching model and for that matter teachers are not very familiar with its usage. Many teachers are used to the conventional method in teaching Physics, hence, changing and adapting to the new method will take time and intense in-service training.

Reskin et al. (2022) recommend that teachers should develop and master the necessary skills as school authorities assist them in getting access to resources required for the effective implementation of the model.

2.10 Students' Attitude and Academic Performance

Attitude is one of the key factors that determines a person's behaviour (Sumardi et al., 2019). Jufrida et al. (2019) postulate that students' attitudes about school, classes, and academic accomplishment are some of the most imperative aspects that influence their academic progress and success. Takwe (2019) defines attitude as the propensity for people to organize their thoughts, feelings, and behaviours toward a psychological object. Kurniawan et al. (2019) also defines attitude as the totality of a person's feelings, prejudice, preconceptions, fears, threats, and convictions towards any given subject. Kurniawan et al. (2019) believe that humans acquire their attitudes over time; they are not born with them. Some attitudes are based on personal experiences, knowledge, and talents, while others are learned from outside sources. However, the attitude does not remain the same; rather, it evolves over time (Guido, 2013).

Darmaji et al. (2019) assert that, attitude can alter how information is seen and how much it is retained. It is acknowledged that students' interests and attitudes may have a significant effect on students studying science. Attitude is simply a person's thoughts, sentiments, emotions, or intentional behaviours that reflect their positive or negative evaluation reactions to things, events, or programmes (Jufrida et al., 2019). Kurniawan et al. (2019) propose that either a positive or negative attitude toward learning could exist. Positive and negative attitudes toward a subject have a big impact on how well students perform academically and how interested they are in it. According to Kurniawan et al. (2019), students' interest in and academic performance in the topic of Physics are often positively impacted by positive attitudes toward the subject, whilst the opposite is true for negative attitudes. Jufrida et al. (2019) reported a strong link exists between a positive attitude and academic success in the subject. Kurniawan et al. (2019) add that Students' positive attitudes toward science have a significant influence on their performance and achievements, in addition to their motivation to learn the subject.

It is imperative to put into practice the development of students' attitudes toward learning a subject since it not only has a beneficial impact on academic accomplishment but is also necessary for the development of future careers (Sumardi et al., 2019). Guido (2013) also affirms that, the effect of students' attitudes toward science is crucial since problem solving calls for tolerance for uncertainty, tenacity, and willingness to take risks. Negative attitudes undoubtedly have an adverse effect on pupils and are a significant contributor to their low academic achievement. When students have good views regarding a subject, they are inspired to act positively, fulfil their academic obligations as necessary and even go farther and above.

Kurniawan et al. (2019) posits that if a student approaches Physics with a positive attitude, he or she will not only love studying it but also find fulfilment in the understanding of the Physics concepts they acquire. Mzomwe (2019) attests to the fact that, if a student has a positive attitude toward the subject of Physics, he or she will certainly be engaged in the subject's teaching and learning and consequently improve their performance in it. Students that have a negative attitude toward Physics typically show little to no interest in and desire for it. As stated by Kurniawan et al. (2019), if students have a bad attitude about learning Physics, it will be harder for them to learn the subject now and in the future, which will result in subpar performance. Kurniawan et al. (2019) opined that, when learners can understand Physics topics more thoroughly and apply their learning in a practical way, they develop a positive attitude toward the subject.

Many researchers think that Physics students' attitudes toward the subject might improve if they are given the opportunity to demonstrate higher cognitive abilities through a student-centred teaching and learning approach (Jufrida et al., 2019; Guido, 2013). New teaching techniques and technology must be used in Physics education in order to improve student achievement and attitude (Mzomwe, 2019; Sugano & Mamolo, 2021).

2.11 Gender and Academic Performance

Gender is one of the several factors that could make it more difficult for some students to receive an equitable science education (Takwe, 2019). For science educators, gender has become a major source of concern in relation to student progress in science (Posselt et al., 2018). This is due to research in the field of Physics, which has shown that gender stereotypes have a negative impact on the academic performance of students, particularly that of female students (Elizabeth et al., 2017; Francis et al., 2017). Geordan (2020) asserts that attaining gender equality is crucial for achieving "peaceful societies, the realisation of the full potential of individuals, and sustainable development.

Regardless of race or gender, the fourth sustainable development goal is to guarantee inclusive, equitable, high-quality education and to encourage possibilities for lifelong learning for everyone. Additionally, it states that equal access to each of the educational and training programmes at all levels as well as the eradication of gender disparities in education, should be achieved by the year 2030 (Government of Ghana, 2019). Gender equity, equality, and women's empowerment are also emphasised in Sustainable Development Goal 5 (SDG 5). This suggests that all students should be taught science and technology as part of a proper education, and that men and women should have equal access to these disciplines as well as equal possibilities to succeed in them as well as equal motivation to learn new things. Takwe (2019) proposed that, the multiplier effect for every other development areas makes fostering gender equity in science education essential in the effort to speed up sustainable development, which could benefit society and humankind as a whole. Ruck and Faul (2019) observed that, keeping the gap between male and female students' academic achievement to a minimum can help to balance social development.

Ruck and Faul (2019) suggest that for the students' success, selecting the best teaching strategy and providing Physics instruction that is gender-balanced are both crucial. Another crucial aspect of teaching style is minimising gender bias and performance gaps while improving the conceptual knowledge of a subject among all students. Takwe (2019) found that two fundamental elements determine educational equity. One of them is fairness, which indicates that circumstances unique to a person's personal life shouldn't get in the way of their ability for academic success. This suggests that in order to accomplish equal performance and success in the field of study, all students, regardless of gender, should be treated in a very equal manner in the Physics classroom.

2.12 Teaching Methods and Academic Performance

According to Olifer (2020), effective classroom instruction necessitates multidimensionality, or the successful accomplishment of many various sorts of activities. In the academic process of teaching, there are two groups of participants: the instructor and the learners, as well as the information which includes imparted knowledge, skills, values, and attitudes (Precious & Feyisetan, 2020). Sawant and Rizvi (2015) postulate that, the teacher and student may engage in a variety of activities throughout a lesson, including inquiry, explanation, the use of analogies and illustrations, or demonstration. The activities might be referred to as techniques or skills. The application of these strategies varies depending on the type of learning objectives, the subject matter, the student's age, and the class size, among other variables.

According to Precious and Feyisetan (2020), effective teaching and learning strategies are crucial, because they significantly affect students' academic progress. Marbach-ad and Rietschel (2016) affirm the ways that lessons are taught in the classroom have a significant impact on the students' academic success. The teaching strategy used is essentially what determines whether or not a lesson is successful in the classroom. Sawant and Rizvi (2015) assume with justification that once teaching is enhanced, so will learning. Serin (2018) lists different methods of instruction, including lectures, discussions, demonstrations, games and simulations, project-based learning, problem-solving activities, inquiry-based learning, and field trips. Some educators have categorised these various teaching techniques into two approaches: teacher-centred and student-centred (Olifer, 2020; Precious & Feyisetan, 2020).

Teacher-centred teaching according to Bara and Xhomara (2020), typically refers to settings in which the instructor has authority over the subjects that students study and the techniques people employ to learn them (where, when, how, and at what speed). It encompasses all methods of instruction where the instructor directs the lesson's flow and organises the students' actions in terms of what has to be done (Precious & Feyisetan, 2020). In classes that would be considered teacher-centred, Sawant and Rizvi (2015) recount that the teacher usually speaks the most and is the most animated person in the space. Bara and Xhomara (2020) add that, it normally takes place in the form of lecturing, explaining ideas, reading aloud, or giving directions. They affirm that, since the teacher determines What the learners will study, how it will be taught to them, and how it will be assessed, students in such a classroom environment spend the majority of their time seated in desks, taking notes, listening, and giving succinct answers to questions the teacher poses.

Teachers also choose to instruct pupils in ways that are simple, comfortable, or generally preferred, but that may not be effective for many students (Ersel, 2018). The five areas identified by Sawant and Rizvi (2015) as areas where teacher-centeredness is clearly seen in the classroom include power dynamics, the purpose of the subject matter, the instructor's job, the obligation of the learner, the objective, and the methods of assessment. The teacher-centred teaching approach leaves students inert with no ability to create meaningful knowledge during the course of instruction and learning due to the unidirectional flow of information (Bara & Xhomara, 2020; Marbach-ad & Rietschel, 2016).

Although a teacher-centred teaching approach, such as the conventional lecture course, may be effective for quickly distributing a substantial body of content to a great deal of students while allowing for the effective utilisation of time and resources, these one-way exchanges frequently encourage passive and superficial learning that fail to arouse learners' motivation, attitude, confidence, and enthusiasm (Precious & Feyisetan, 2020; Sawant & Rizvi, 2015). In effect, science education in general and Physics in particular have shifted toward a student-centred learning strategy, which has been proved to be more successful than a teacher-centred approach, particularly for acquiring skills of the 21st Century (Radzali et al., 2018).

Typically, the term "student-centred teaching approach" refers to instructional methods that, among other things, give students the chance to guide learning activities, engage in discussions more actively, create their own learning projects, investigate subjects that interest them, and generally contribute to the creation of their own course of study (Bara & Xhomara, 2020). It covers all pedagogical strategies that refrain from emphasising the position of the teacher as the one who makes decisions, solves problems, or imposes rules in the classroom; instead, consider the teacher to be a consultant, coach, mentor, guide, or facilitator during teaching and learning (Olifer, 2020). In student centred classrooms, the focus of the class is shifted from the teacher to the students and ensures that the students are actively engaged in the lesson and not merely passive recipients of knowledge (Bara & Xhomara, 2020). The foundation of this constructivist educational approach is the epistemological idea that pupils are the creators of their own unique perspectives on ideas and real-world phenomena (Precious & Feyisetan, 2020).

According to Radzali et al. (2018), Student-centred learning prioritises the interests of the students while acknowledging the significance of the students' voice in the learning process and forbids teachers from taking the role of sage on stage in favour of that of a guide by the students' sides. While Teacher-centred learning aims to cover all of the curriculum and demands students to memorise enormous reams of material, Student-centred learning, according to Muganga and Ssenkusu (2019), teaches students the skills necessary to understand the information in a manner that is more significant. Active learning is one of the student-centred techniques, where students solve problems in groups, respond to questions, formulate questions of their own, and debate, clarify, or brainstorm throughout class (Olifer, 2020).

It has been consistently demonstrated that student-centred approaches to instruction are superior to the established teacher-centred model (Ersel, 2018; Precious & Feyisetan, 2020). Bara and Xhomara (2020) conclude that, the most effective method for helping students to effortlessly gain knowledge and retain it is through student-centred learning, which calls for them to take an active role in their own education and set their own pace.

Summary of Literature Review

This literature review showed that, the MR-SR Based PIMCA learning model is a teaching model involving four intervention stages and is grounded on the integrative learning theory and educational psychology's guiding principles, which include behaviourist, humanist, constructivist, and cognitivist learning theories (Poluakan & Katuuk, 2022). The reviewed literature highlighted on the relationships that exist between these theories and the PIMCA model.

Furthermore, it has been pointed out that the MR-SR Based PIMCA model improves students learning outcomes in Physics and enhances their attitude towards the subject. It was also shown that the MR-SR Based PIMCA model essentially seeks the welfare of students and an effective classroom interaction between the teacher and the students. It also helps individuals in cultivating the skills necessary for critical, logical, and creative thinking (Nasra et al., 2021).

Notwithstanding, the implementation of the PIMCA Model, though effective but is not without challenges. Inability to cover much during the instructional period, loss of content coverage since PIMCA model demands a lot of time than other teaching methods like the traditional lecture method, the need to fish out for appropriate resources from the web gives teachers extra burden to prepare for lessons, Lack of trust for the students to construct and formulate theories by themselves, teachers not very familiar with the usage of the PIMCA model are some of the challenges outlined in this section (Poluakan & Katuuk, 2022).

The search recommended that, since many teachers are used to the conventional method in teaching Physics, there is the need for an intense in-service training in order to effectively change and adopt this new method of teaching in the Physics classroom (Reskin et al., 2022).

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter talks about the study area of the research. It also describes the research design and paradigm used. It further explains the population and participants of the study, sample and sampling techniques used to select the sample size for the study.
The chapter further outlines the research instruments used in data collection. It as well discusses the validity and reliability of the research instruments, data collection procedure, the intervention processes and ends with data analysis procedure.

3.1 Study Areas

Both the pilot study and the main research were carried out in the Mampong Municipality and Sekyere South District both in the Ashanti Region of Ghana. Among the 43 districts in Ashanti-Region, Ghana, is the Mampong Municipality and Sekyere South District.

Mampong Municipality, which has Ashanti-Mampong as its capital, is situated in the northern portion of the Ashanti Region. The Municipality spans a region of approximately 23.9 km^2 with 116,632 people living there. Farmers make up the majority of the workforce. Its borders are shared with the districts of Ejura Sekye Dumase to the North, Sekyere Central to the East, Sekyere South to the West, and Sekyere Kumawu to the South. Additionally, it lies between latitudes 60 55N and 70 30N and longitudes 00 05W and 10 30W respectively. According to the Annual Progress Report, the Mampong Municipality is divided into seven Zonal councils, which are made up of the Mampong, Kofiase, Yonso, Mprim, Adidwan, Benim, and Nkwanta (The Republic of Ghana, 2017). With two wet seasons, the Municipality receives 1,270mm of rain on average annually. March through August is when the primary rainy season occurs, and September through November is when the secondary season occurs. The harmattan dry season is the remaining months.

The typical monthly temperature varies from 22°C to 30°C, with an average annual temperature of 27°C. The Mampong Municipality is located in the wet semi-equatorial forest region. The forest vegetation, particularly in the northeast, has been diminished to Savannah as a result of human activity including the production of charcoal, lumbering, and bushfires. The Kogyae Natural Forest Reserve, with a total land size of 115 square kilometres, is the only place where you may find vegetation that is of primary origin. In the south, the land is somewhat low-lying, and it gradually undulates towards the north. The lowest location is 135 meters above mean sea level, while the highest point is around 2400 meters above it. The Kintampo-Bisa ranges have an escarpment that extends from them. Numerous rivers and streams, such as the Sene, Afram, Sasebonso, and Kyirimfa, also drain the area (The Republic of Ghana, 2017).

On the other hand, Sekyere South District, with Agona as its district capital, is situated in the eastern part of Ashanti Region, Ghana. It has a population of 120,076 people and a total size of 770 km^2 (300 sq mi). Tropical forest covers practically the whole Sekyere South district. Agriculture, which employs 46.4% of the district's active population, is its primary economic activity. The most important food and cash crops are vegetables, rice, cassava, cocoyam, plantain, and cocoa (The Republic of Ghana, 2021). Other people engage in local pottery production and Kente weaving, both of which are exported. The majority of the district is located inside a dissected plateau that rises between 800 and 1200 meters above sea level. The Mampong Escarpment, which stretches from Jamasi to Boanim, is the only high ground in the northern part of the region.

The Offin, Oyon, and Abankro are three of the district's major rivers. The district, which covers 584 sq km or 2.4% of Ashanti Region's total land area, borders the following areas: Kwabre East Municipal to the south, Sekyere East to the east, Mampong Municipal to the north, and Afigya Kwabre North District to the west. Agona, the district's capital, is 22 kilometres from Kumasi, the Ashanti region's capital (The Republic of Ghana, 2021). The region has an equatorial climate with a double maximum rainfall regime. The primary wet seasons are from March to July, while the secondary rainy seasons are from September to November. The range of the average annual rainfall is 855mm to 1,500mm. Particularly during the dry seasons, temperatures soar to extremely high levels, with the mean monthly temperature hovering about 27°C. Jamasi, Kona, Wiamoase, Asamang, etc. are a few of the district's major communities. Currently, there are 248 elementary schools, 11 secondary schools, and 1 university in the district. A Map of the study areas is presented in Figure 3.1 below.

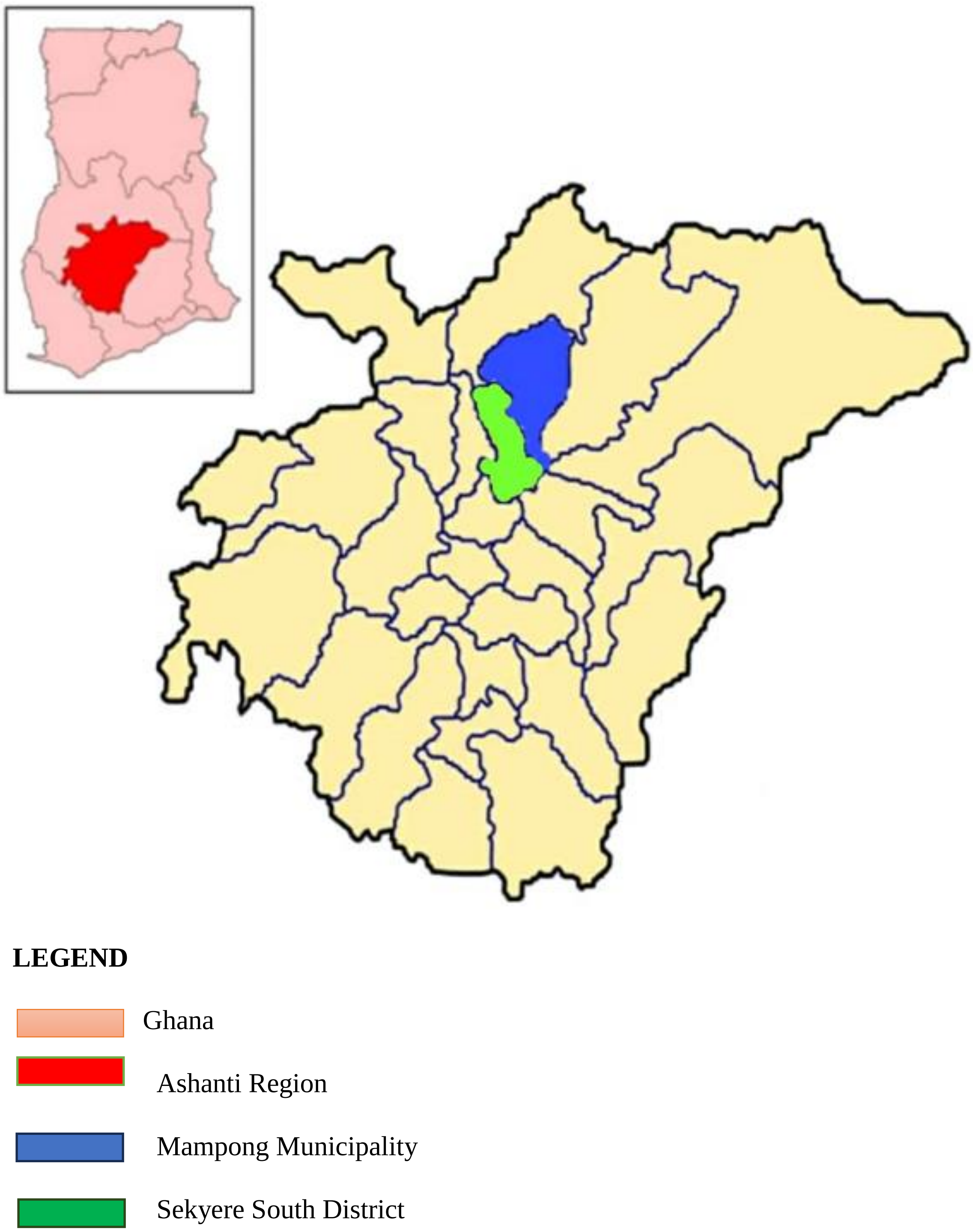

Figure 3.1 Map of the Study Areas

3.2 Research Paradigm

This study employed the positivist Paradigm. The worldview that the positivist paradigm bases its definition of research on what is known as the scientific method of inquiry (Kivunja et al., 2017). The one legitimate means of expanding human knowledge and comprehension as asserted by Cohen (2018) are through experimentation, observation, and reason based on experience. These methods should serve as the foundation for comprehending human behaviour. According to positivism, Ebohon et al. (2021) posit that, there is only one reality and the "scientific" method is the only means of determining reality's objective truth. The goal is to identify pertinent elements, characterise and quantify the factors, clarify how the factors relate to one another, and use the knowledge gained in the companies. The ontological stance of positivism is marked by realism, which is a single, mind-independent reality. Objectivism serves as the methodological pillar, and deductive reasoning is employed, utilising survey or experimentation research (Cohen et al., 2018).

Typically, quantitative research approaches are used, such as questionnaires, focus groups, statistical analysis, sampling, measuring, and scaling (Rehman & Alharthi, 2018). A research study may be judged to have adopted a positivist paradigm by looking for certain characteristics, such as the emphasis on determining and testing causal or associative relationships, the use of quantitative data collection methods, the extensive and intensive citation patterns, and the frequently narrow scope of research claims (Kivunja et al., 2017). Rehman and Alharthi (2018) assert that, the post positivist paradigm is utilised to search for causal relationships in the natural world. It is selected as the favoured worldview for study that seeks to use quantifiable items or facts to explain observations. The findings of this paradigm's research are supported by deductive reasoning, operational definitions, hypothesis formation, testing, computations, extrapolations, and expressions in mathematics. It also seeks to explain and forecast using quantifiable results as a basis (Rehman & Alharthi, 2018).

Determinism, empiricism, parsimony, and generalisability are the four underlying assumptions that Cohen et al. (2018) explain and support these measurable results. By breaking down each of these underlying assumptions, researchers can gain a deeper comprehension of the importance and expectations of research conducted within this paradigm. According to the empiricism assumption, in order for us to study a research problem, in order to test the hypotheses, you have developed and justify the theoretical framework you have chosen for your study, we must be able to collect real empirical facts (Cohen et al., 2018). A researcher's attempts to provide the most economical explanation for the phenomena they study are referred to as parsimony in the Positivist paradigm. Lastly, the generalisability assumption states that findings from a study carried out in a context that adheres to the Positivist paradigm ought to be able to be applied with inductive reasoning in several situations.

Accordingly, Ebohon et al. (2021) postulate that, a positivist researcher has the ability to identify examples of the particular phenomenon they have studied and make generalisations about what might be expected in different regions of the world. Because of these fundamental assumptions, the positivist paradigm encourages the application of quantitative research methods as the basis for the investigator's ability to precisely characterise the parameters and coefficients in the information that is gathered, scrutinised, and interpreted to understand the relationships that are embedded in the examined data. According to Rehman and Alharthi (2018), positivists want to fully understand society in the same way that they do the natural world. Positivism holds that, as events in nature have a cause-and-effect relationship and can be accurately predicted once they are established, the same holds true for the social realm. Since reality has no context, researchers from various eras and locations will come to the same findings regarding a certain phenomena (Rehman & Alharthi, 2018).

3.3 Research Design

The pretest-posttest non-equivalent comparison groups design was used in this study. The evaluation of the students was based on their past knowledge of optics. This allowed for the measurement of the dependent variable both before and after the intervention. Between-group differences before the intervention were measured using the pre-test scores. By demonstrating if the groups differed on the dependent variable prior to the intervention, this could significantly lessen the risk of selection bias (Marczyk et al., 2005).

The simplest case of the pretest-posttest comparison group design has one treatment group and one comparison group (Akhtar, 2016; Marczyk et al., 2005). Prior to the pretest, subjects are assigned to groups or conditions. Each group is measured prior to the intervention and after the intervention. Typically, one group receives a new treatment and the other group receives a treatment that has been used previously or a placebo (Marczyk et al., 2005). The purpose of this design is to allow the investigator to evaluate the new treatment relative to the previously used treatment. The design is classified under the heading of mixed design because there are two independent variables. The between- groups independent variable is the treatment, and the within-subjects or repeated-measures independent variable is change over time from pretest to posttest (Akhtar, 2016).

The intact classrooms that students were allocated to in their individual schools were used without any adjustments in an attempt to prevent class disruption due to randomisation. This study intended to establish the causal linkages between the MR-SR Based PIMCA instructional model and the conventional teaching approach, student attitude, ability and gender variations in performance in the experimental group by comparing the outcomes of the pre- and post-tests scores. The sample was randomly divided into two instructional groups, with one group being assigned as the Experimental group (instructed using the MR-SR Based PIMCA model) and the other being assigned as the Control group (instructed using the Conventional teaching method). Students' performance in Optics and attitude are the dependent variable in this study, and the main independent variables are the MR-SR Based PIMCA model and the conventional teaching approach. A framework of the research design is presented in Figure 3.2 as shown below.

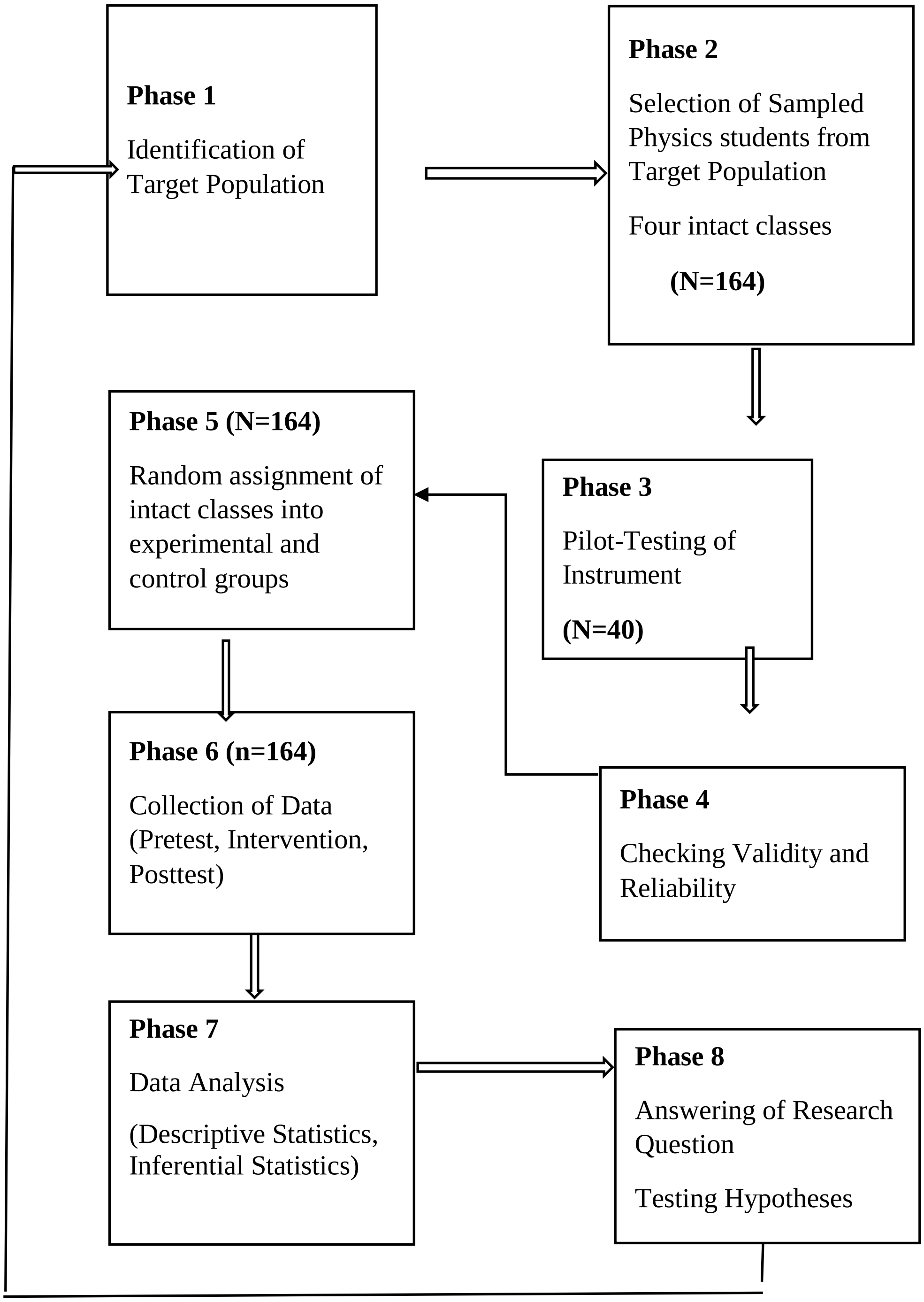

Figure 3.2 A Framework of the study design

As observed from figure 3.2, the process began from identifying the target population to Selection of Four intact classes as sampled Physics students from target population at phase two, research instruments were designed and Pilot-tested at the third phase of which validity and reliability of the test instruments were assessed at the fourth phase. At the fifth phase, the intact classes were grouped into two and randomly assigned experimental and control groups to be instructed using the MR-SR Based PIMCA model and the conventional teaching approach respectively. At the sixth phase, data was collected and analysed at the seventh phase using descriptive and inferential statistics which were used to answer the research question and tested for the hypotheses at phase eight.

3.4 Population

In this study, all Public Senior High School Physics students in the Mampong municipality and Sekyere South District in the Ashanti region of Ghana formed part of the target population. Also, the accessible population comprised of SHS one Physics students of the aforementioned Municipality and District. These schools were chosen based on their gender statuses, courses offered, approval from the various heads and willingness of the Physics teachers to make the work a success.

A total of one hundred and sixty-four (164) students made up of ninety-two (92) males and seventy-two (72) females from the four Senior High Schools in the Municipality and District participated in the study. First year Senior High school Physics students from the selected schools were used. The four schools were identified with letters A, B, C and D.

3.5 Sample and Sampling Technique

Multi-Stage Sampling is what this study adopted. This method was appropriate because the population was too large and widely scattered. When using multistage cluster sampling, the researcher selects a sample over the course of two or more stages due to either the population's excessive size or their difficulty in identifying it (Cohen et al., 2018). For this study, the sampling technique involved six key phases.

Phase 1: All Senior High Schools (SHS) in the Municipality and District offering Physics as an elective subject were purposively selected.

Phase 2: The mixed schools in the study area were also purposively selected. This was due the fact that, gender was considered in the study and there was the need to ignore single sex schools and choose only mixed schools.

Phase 3: The four participating schools from the Mampong Municipality and Sekyere South District were selected using simple random sampling.

Phase 4: Simple random sampling was used to select the intact classes from the participating schools. This is because, each of the participating schools had more than one Physics classes.

Phase 5: The form one class and the topic used for the study were purposively selected because the Optics Concept used in this study is treated in SHS 1.

Phase 6: The Experimental and Control groups were also randomly assigned.

3.6 Participants

The four Participating Schools were divided into Experimental and Control groups, using their intact classes. The Experimental group consisted of the classes of Schools A and B and were instructed through the MR-SR Based PIMCA model whereas the Control group consisted of classes of students from Schools C and D and were instructed through the conventional approach. The Experimental group consisted of seventy-five (75) participants and the control group consisted of eighty-nine (89) participants from two intact classes. The participating students were within the ages of 14 and 18.

All the participants had comparable educational background since they had all passed through the Ghanaian Junior High School education system and passed the Basic Education Certificate Examination (BECE).

The participating students in the experimental group were also divided into high and low-achieving students based on their pre-test results. Twenty-Five students from the MR-SR Based PIMCA group were high achievers, 23 were average achievers and 27 were low achievers. The average achievers were not considered in this study and hence were eliminated leaving the high and low achievers. The procedure for Categorising students into high achievers and low achievers has been explained in Section 4.11.

3.7 Research Instruments

Two research instruments were used in this study, that is the Optics Concept Achievement Test (OCAT) and Optics Learning Attitude Questionnaire (OLAQ). The optics concept test instrument was prepared by the researcher and was pilot-tested in order to assess its validity and reliability. The questionnaire on the other hand was adapted from similar research works to suit the purpose of this research and was pilot-tested as well.

3.7.1 The Optics Concept Achievement Test (OCAT)

The Optics concept Achievement Test (OCAT) was a self-designed test instrument which covered an aspect of optics found under the broad theme of wave motion in the Ghanaian Senior High School Physics Syllabus. Both the pre-intervention and post-intervention tests used the same test instruments. This is done in order to determine if any changes can be connected to the treatment (Appiah-Twumasi, 2016). At the phase of the pre-intervention test, Students' knowledge in some areas of optics was assessed prior to the intervention. This provided evidence that all participating groups were of equal standard and also provided a baseline for grouping the students into high and low achievers. The post-intervention test on the other hand was used to gather information for the study to evaluate the efficacy of the Conventional teaching method and the MR-SR Based PIMCA model on SHS Physics students' academic performance.

The test consisted of two main parts. Students' bio-data such as name, age, school, class and gender were found in the first part. General information on both Section A and Section B were provided in the second part. The optics concept test consisted of 20 items of which 15 were multiple choice questions and the other 5 were theory questions. See Appendix C for the OCAT.

3.7.2 The Optics Learning Attitude Questionnaire (OLAQ)

The OLAQ was a close-ended questionnaire which was adapted from a similar research work from Subia et al. (2018). The OLAQ was divided into 2 parts. The first part contained students' bio-data like the age, class, and gender. The second part contained the actual scale items. The OLAQ is a four-point Likert scale with a range of strongly agree to strongly disagree and was composed of 15 items. The same questionnaire was administered at the pre-intervention and post-intervention stages. This was designed to assess the Experimental students' attitude towards Physics before the intervention. After the intervention and students' exposure to the MR-SR Based PIMCA model, the questionnaire was re-administered to collect to assess the impact of the teaching method on students' attitude in Physics.

3.8 Validity

Afterwards the validity of the instruments was determined. The validity of an instrument determines how accurately it measures the intended parameters. In this study, the content validities of the instruments were determined. Thus, the content validities were determined to assesses whether the items on the instruments were representative of all aspects of the construct (Obilor & Miwari, 2022). Therefore, the instruments were guided by a table of test specifications (see Appendix E). The table of test specification facilitates meaningful weightings of the items in each cell in accordance with the importance attached to them.

Additionally, after designing the instruments, the OCAT and the OLAQ were given to a panel of two Physics educators (experts) from the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), and four SHS Physics teachers, who assessed the items in the OCAT and OLAQ to evaluate their appropriateness to measure the study's variables. Therefore, after the evaluation of the OCAT and OLAQ, by the experts, the content validity of the OCAT was evaluated quantitatively using the Content Validity Ratio (CVR) proposed by Lawshe (1975). The CVR is determined by first finding the Content Validity Index (CVI). According to Rutherford-Hemming (2015), the CVI for each item is calculated by dividing the total number of experts who evaluated the item by the number of experts who rated the item as relevant.

An overall CVI for the entire items is calculated once a CVI has been determined for each item. The CVR is then determined by dividing the overall CVI by the total number of items. Therefore, the CVR for OCAT and OLAQ are presented in Tables 3.1, and 3.2 respectively. Surip et al. (2019) asserts that CVR ranges from -1.000 to 1.000. According to Surip et al., the higher the CVR value, the higher the content validity of a test instrument. Also, positive values indicate that at least half the experts indicated the item as essential.

Tables 3.1 and 3.2 present the Content Validity Index and Content Validity Ratio for the OCAT and OLAQ respectively.

Table 3.1: Content Validity Index and Content Validity Ratio for OCAT

Item	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Agreement	CVI
1	1	1	1	1	1	1	6	1.000
2	1	1	1	1	1	1	6	1.000
3	1	1	1	1	1	1	6	1.000
4	1	1	1	1	1	1	6	1.000
5	1	1	1	1	1	1	6	1.000
6	0	1	1	1	1	1	5	0.833
7	1	1	1	1	1	1	6	1.000
8	1	1	1	1	1	0	5	0.833
9	1	1	1	1	1	1	6	1.000
10	1	1	1	1	1	1	6	1.000
11	1	1	1	1	1	1	6	1.000
12	1	1	1	1	1	1	5	0.833
13	1	1	1	1	1	1	6	1.000
14	0	1	1	1	1	1	5	0.833
15	1	1	1	1	1	1	6	1.000
16	1	1	1	1	1	1	6	1.000
17	1	1	1	1	1	1	6	1.000
18	1	1	1	1	1	1	6	1.000
19	1	1	1	1	1	1	6	1.000
20	1	1	1	1	1	1	6	1.000
CVR								0.967*

***CVR=CVI/20, where CVR=Content Validity Ratio, **CVI=Content**

Validity Index

As seen from Table 3.1, the content validity ratio of the OCAT was 0.967, which indicates a valid instrument per Surip et al.'s interpretation.

Also, Content Validy Ratio (CVR) was calculated for the items on the Optics Learning Attitude Questionnaire (OLAQ), as presented in Table 3.2 below.

Table 3.2: Content Validity Index and Content Validity Ratio for OLAQ

Item	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Agreement	CVI
1	1	1	0	1	1	1	5	0.833
2	1	1	1	1	1	1	6	1.000
3	1	1	1	1	1	1	6	1.000
4	1	1	1	1	1	1	6	1.000
5	1	1	1	1	1	1	6	1.000
6	0	1	1	1	1	1	5	0.833
7	1	1	1	1	1	1	6	1.000
8	1	1	1	1	1	1	6	1.000
9	1	1	0	1	0	1	4	0.667
10	1	1	1	1	0	1	5	0.833
11	1	1	1	1	1	1	6	1.000
12	1	1	0	1	1	1	5	0.833
13	1	1	1	1	1	1	6	1.000
14	1	1	1	1	1	1	6	1.000
15	1	1	1	1	1	1	6	1.000
CVR								0.933*

***CVR=CVI/15, where CVR=Content Validity Ratio, *CVI=Content Validity Index**

As seen from Table 3.2, the content validity ratio of the OLAQ was 0.933, which also indicates a valid instrument per Surip et al.'s interpretation.

3.9 Reliability

The test items for the study were field pilot-tested in a different school in the Sekyere Central District with 40 students who had similar characteristics as the research participants. Since the test instrument (Optics Concept Achievement Test) contained multiple choice and essay test items, the reliability of the pretest scores, was analysed using Cronbach alpha and Cohen's Kappa respectively and the results are presented in Tables 3.3 and 3.4 as shown below.

Table 3.3 Reliability Statistics for multiple choice section of Optics Concept Achievement Test (OCAT)

Cronbach's Alpha	No. of Items
0.780	15

Table 3.4 Reliability for Essay section of Optics Concept Achievement Test (OCAT)

		Value	Asymp. Std. Error	Approx. T^b	Approx. Sig.
Measure of Agreement	Kappa	.844	.064	11.306	.000
N of Valid Cases		40			

The pilot study of this research involved forty (40) Physics students. Using SPSS, the instruments' reliability analysis was statistically evaluated, and a Cronbach alpha coefficient of 0.780 as presented in Table 3.3 was found. Since adequate reliability exists when the correlation coefficient is 0.70 or higher, the Cronbach alpha coefficient exceeding 0.70 is statistically accepted in social and educational research (Cohen et al., 2018). Kappa value which measures the agreement between the two raters was 0.844 at $p=0.00<0.05$ as seen in Table 3.4. This means that the agreement between the two raters was reliable since a Kappa value 0.8 represents very good agreement. Therefore, the assumption of reliability of the covariate was not violated.

3.10 Data Collection Procedure

Data for this research was collected at three phases namely, Pre-intervention, intervention and Post-intervention Phases.

3.10.1 Pre-intervention Phase

First and foremost, ethical consideration was put in place to make sure everything was in order and formalised. An introductory letter from the institution's department of science was used to seek permission from the district and municipal education offices concern. The introductory letter from the department as well as the permission letter from the education offices were used to seek the consent and approval from the heads of the participating school. Heads of department and subject masters were also given prior consent notice of the research. Respondents were briefed on their rights and the expected benefit of the study and were given an informed consent form (see Appendix J) to sign indicating their willingness to be part of the study. Additionally, responders received guarantees of confidentiality and anonymity.

After permission was granted from five schools, four schools were grouped into Experimental one and Control groups, having two schools each. The fifth school was held as a school for the mini study or pilot test. Students in the mini study group were informed and a pilot test was conducted a week after. Forty (40) Physics students participated in this pilot test with 25 males and 15 females. This pilot test helped in validating the test instruments. Adjustments were made for some test items making it more effective and relevant for the study.

The next stage was the pretest stage. Both experimental and control groups were informed to get prepared for the pre-intervention test a week before the said date. Students were tested prior to the intervention using the Optics Concept Achievement Test of which the scripts were marked and analysed later. The purpose of this was to receive data to be able to group students into their ability groups and also know if all the participating schools were on the same standard or performing equally before the intervention. The Optics Learning Attitude Questionnaire (OLAQ) was also administered to the Experimental group prior to the interventions and the data collected were analysed afterwards. This was used to assess experimental groups' attitude towards Physics before their exposure to the reflection content using the MR-SR Based PIMCA learning model.

3.10.2 The intervention phase

The actual intervention for the research commenced a week after the pre- intervention tests were conducted. A well-designed lesson notes containing the content of Reflection of light from the Ghana Education Service (GES) Physics Syllabus was used as a guide for the intervention. Appropriate books and teaching resources were gathered. The same content was used for both groups but using different teaching strategy. The Experimental group was treated using the MR-SR Based PIMCA model whereas the Control group was instructed using the Conventional teaching approach.

The Experimental group (treated with the MR-SR Based PIMCA model) were exposed to the use of multimedia and semiotic resources such as Videos, animations and pictures following the four main MR-SR Based PIMCA intervention steps namely; Presentation, Idea-Mapping, Conceptualisation and assessment (Formative). The resources were projected using a laptop computer and a Bluetooth device that aided audibility of sound. The kind of resource to use at each stage of the lesson was dependent on the nature of the concept being examined. A detailed lesson plan for the MR-SR Based PIMCA model has been provided at Appendix S. The procedures followed throughout the experimental group's intervention phase are shown in Table 3.5.

Table 3.5 Intervention Processes for the Experimental Group.

PHASE	TEACHER/STUDENTS' ACTIVITIES
Phase 1 Teacher clarified objectives and motivated students	Teacher spelt out objectives for the lesson and established learning set.
Phase 2 Presentation	Teacher presented lesson in the form of Videos, animations and pictures on each week's activities based on the lesson objective and the lesson notes
Phase 3 Idea Mapping	Teacher allowed students to define or formulate concepts and theories on their own from the presentations provided.
Phase 4 Conceptualisation	Teacher guides students to restructure and correct their definitions, concept and theories
Phase 5 Assessment	Each students' performance is assessed by the teacher, marked, graded and did corrections with students.
Phase 6 Conclusion	The lesson is concluded and the main points are summed up by the teacher

The Control groups were treated using the Conventional teaching approach commonly used in the Ghanaian schools. In this teacher-centred classroom, the teacher acts as a model in the class where he does most of the talking during instructional delivery. Notes were written on the board after the topic was introduced to the class and students copied them into their notebooks as they were asked to do so. They passively listened to the teacher as he/she explains the notes from the board and students asked their questions after the explanation. A detailed lesson plan for the control has been provided at Appendix T. The steps involved in the intervention phase of the Control group (Conventional) are shown in Table 3.6

Table 3.6 Intervention Processes for the Control Group.

PHASE	TEACHER/ STUDENTS' ACTIVITIES
Phase 1 Introduction	Teacher used lecture method to introduce the lesson and spelt out the objectives to the class.
Phase 2 Development	Teacher explained key points and writes notes on the board for students to copy
Phase 3 Application	Teacher links the lesson to their daily life activities
Phase 4 Evaluation	Teacher uses both oral and written exercises to assess the students based on the objectives.

3.10.3 Post-intervention Phase

After the intervention, the post-intervention test followed. Students were informed to prepare for the test. With the help of the various Physics teachers, both the Experimental and Control groups were tested using the Optics Concept Achievement Test. The Optics Learning Attitude Questionnaire was also administered the MR-SR Based PIMCA group on the same day of the test. The questionnaire was collected and was made ready for analysis. The test scripts were also collected, marked and analysed afterwards.

3.11 Data Analysis Procedure

The data was subjected to descriptive statistical analysis, such as mean, standard error and mean differences and other graphical representations in order to answer the research question. Also, the one-way between groups analysis of covariance (one-way ANCOVA) was used to test for the hypotheses.

One-way between groups ANCOVA involves one independent, categorical variable (with two or more levels or conditions, in this case, the teaching methods, that is, the MR-SR Based PIMCA model and the Conventional teaching method), one dependent continuous variable (in this case, the Posttest Scores), and one or more continuous covariates (in this case, the Pretest scores). This method works well to evaluate the influence of an intervention while controlling for the scores of the pre-test (Cohen et al., 2018). ANCOVA will inform us whether there is a statistically significant difference in the mean scores for both groups after the initial pre-test scores are controlled for. According to Pallant (2011), when you have a two-group pretest-posttest design and the pretest scores are handled as a covariate to "control" for prior variations between the two groups, you can utilise ANCOVA. One-way between groups analysis of covariance (one-way ANCOVA) was used since there was significant differences in academic performance in the pretest scores for both groups. ANCOVA was used in this study in order to control for these differences between the two groups and also controlled for the influence of students’ exposure to the pretest on their posttest scores. In this case, pretest scores were used as covariate to control for its effects on the posttest. In order to ascertain whether there were any significant differences between the outcomes of the Experimental and control groups following exposure to the MR-SR Based PIMCA and the conventional instructions, the acceptable level of probability (p=0.05) was employed as the basis for the report.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the demographic characteristics of the participating students, results and findings of the study. The results are presented based on research questions and hypothesis. Both descriptive and inferential statistics were carried out on the data collected during the research. Statistical Package for Social Sciences (SPSS) for windows, version 20, was used for the analysis. The results are presented based on the following research question and hypotheses.

RQ1. What is the attitude of SHS Physics students towards the learning of optics before and after exposure to the MR-SR Based PIMCA model?

H_{01}. There is no significant difference in academic performance between students instructed using the MR-SR Based PIMCA learning model and those instructed using the Conventional method.

H_{02}. There is no significant difference in academic performance between male and female senior high school students in Physics after exposure to the MR-SR Based PIMCA model

H_{03}. There is no significant difference in academic performance between high and low achieving students in the senior high school after exposure to the MR-SR Based PIMCA model.

4.1 Demographic Characteristics of Students

This section discusses the demographic characteristics of the students. The parameters discussed include test of equivalence of groups before intervention as well as gender and age distribution of students.

4.1.1 Gender Distribution of Students

A total number of 164 students participated in the research. The males out-numbered the females having a total number of 92 students representing 56 % of the total participants, while the females were 72, representing 44% of the total participants. The students were then grouped into Experimental and control groups based on their methods of treatment during the research. The experimental group was instructed through the MR SR- Based PIMCA model (Simply referred to as PIMCA) and the Control group was instructed using the Conventional teaching approach.

The MR-SR Based PIMCA Model had a total of 75 participating students as seen in Figure 4.1, representing 45.7%. 41 were males (54.7 %) and 34 were females also representing 45.3% of the PIMCA Model participating students. The Conventional group consisted of 89 participating students (see Figure 4.1) representing 54.3 % of the total participating students, out of which 51 of the students representing 57.3 % of the Conventional students were males and 38 representing 42.7% were females.

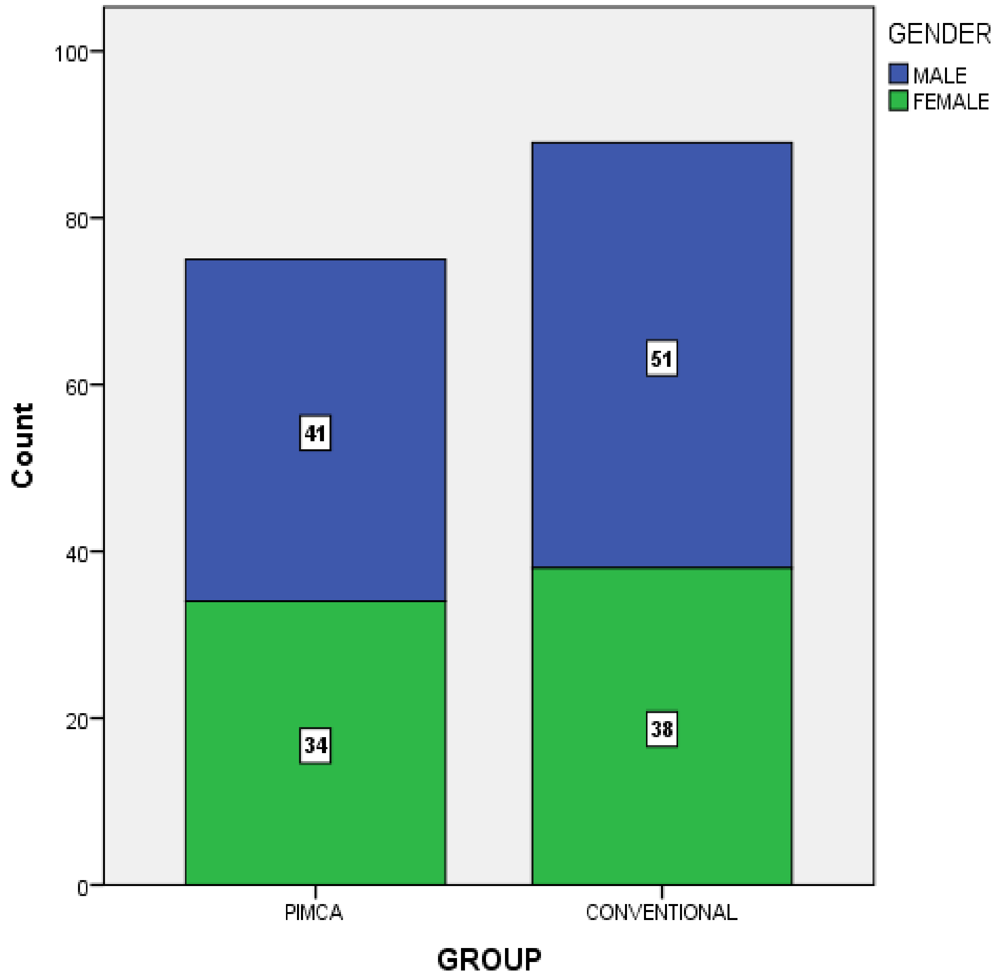

Figure 4.1: Gender Distribution of Participants

1.2 Pretest and Posttest Scores for Experimental and Control Groups

The scores for the pretest and posttest for both groups, thus, MR-SR Based PIMCA and Conventional groups were analysed and their means, standard deviations, minimum and maximum scores were presented as shown in Table 4.1

Table 4.1 Descriptive Statistics of Pretest and Posttest Scores

GROUP		PRETEST	POSTTEST
	N	75	75
	Minimum	1	15
PIMCA	Maximum	11	30
	Mean	10.01	22.97
	Std. Deviation	5.108	3.990
	N	89	89
	Minimum	1	9
Conventional	Maximum	14	27
	Mean	11.20	18.25
	Std. Deviation	5.279	4.533
	N	164	164
	Minimum	1	9
Total	Maximum	14	30
	Mean	10.66	20.41
	Std. Deviation	5.220	4.889

From Table 4.2, both groups obtained a minimum score of one in the pretest. However, the Conventional group obtained the highest pretest score of 14. Also in the posttest, the conventional group obtained the least score of nine, while the MR-SR Based PIMCA group obtained the highest score of 30. As a result, the PIMCA group recorded a mean score of 10.01(SD=5.108) in the pretest and 22.97(3.990) in the posttest, while the conventional group obtained a mean score of 11.20(SD=5.279) and 18.25(SD=4.533) in the pretest and posttest respectively. Overall, the total mean score for all students in the pretest was 10.66(SD=5.220) and 20.41(SD=4.889) in the posttest.

1.3 Test of Normality for Pretest and Posttest Scores for MR-SR Based PIMCA and Conventional Groups

Since parametric analysis were conducted, statistical analyses for normality of the pretest and posttest scores using Kolmogorov-Smirnov and Shapiro Wilk as shown in Table 4.3 as well as graphical representations such as histogram and box plots (Appendix A1-A5) were presented.

Table 4.2 Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest	PIMCA	.082	75	.200*	.969	75	.063
	Conventional	.090	89	.070	.980	89	.201
Posttest	PIMCA	.084	75	.200*	.969	75	.062
	Conventional	.090	89	.072	.976	89	.090

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The MR-SR Based PIMCA model group obtained a Shapiro Wilk test value of 0.969(p=0.063) in the pretest and 0.969(p=0.062) in the posttest as presented in Table 4.3. The conventional group also obtained a Shapiro Wilk test value of 0.980(p=0.201) in the pretest and 0.976(p=0.90) in the posttest. Therefore, the pretest and posttest scores of both the MR-SR Based PIMCA model group and the Conventional group were deemed approximately normal as observed in Table 4.3. These have been graphically presented in Appendixes A1 to A5 (Histograms, Box plots and normal Q-Q plots).

1.4 Entry Characteristics of Participants

Prior to the intervention, a pretest was conducted on all the participating groups and the scores were used as a baseline to check for students' equivalence level in performance and also to group students into high and low achievers. Since the data were normally distributed as shown in Table 4.2, an independent sample t-test as presented in Table 4.3 was conducted to assess the differences between the two groups of students, namely the MR-SR Based PIMCA model and the Conventional groups. However, an independent sample t-test assumes that, the variances in the pretest scores within each group should be equal (Pallant, 2011). Also, the Levene's test statistic, F, which tests for assumption of equal variances between the two groups as seen from Table 4.3 was not significant (F=0.007, p=0.936), implying that the assumption of equal variances was not violated.

Table 4.3: Independent Sample t-test for Pretest Scores of Both Experimental and Control Groups

Group	N	Mean	SD	t	df	p
Experimental	75	10.01	5.108	1.46	162	0.044
Control	89	11.20	5.279			

The mean pretest score and standard deviation of the MR-SR Based PIMCA model were 10.01 and 5.108 respectively. The conventional group also had a mean pretest score of 11.20 and a standard deviation of 5.279. However, this difference was statistically significant (mean diff.= 1.189, t= 1.46, df= 162, p= 0.044) as shown in Table 4.3. Therefore, it can be concluded that there was a significant difference between the two groups prior to the intervention. This means that both groups performed significantly different prior to the intervention.

4.5 Results of Research Question 1

This research question sought to determine the SHS Physics students' attitudes towards optics before and after exposure to MR-SR Based PIMCA model, using a 15-item

Likert-like questionnaire (see Appendix B). The items were used to collect information on SHS Physics students' attitudes towards optics before and after exposure to MR-SR Based PIMCA model. Descriptive statistics of OLAQ before and after intervention of each dimension (mean scores, standard deviations) and overall mean scores were used for the analysis. According to Lovelace and Brickman (2013), the items of a Likert scale are ordinal, but as there is an increase in response options as well as items and sample sizes, the properties of a composite score from a measurement scale, which is composed of the total of several related items, may appear to be much more continuous than categorical. Hence, the scores from the OLAQ analysed using mean scores and standard deviations as measures of central tendency.

As proposed by Lovelace and Brickman (2013), items of the OLAQ were estimated by finding the average of the valuations given to the items that define them. Therefore, for a four-point Likert scale, it is computed as (4+3+2+1)/4 = 10/4 = 2.5. Hence, 2.5 was set as the standard mean score. By interpretation, an overall mean score below the standard mean score of 2.5 suggests a negative attitude towards optics, whilst an overall mean score above the standard mean score of 2.5 suggests a positive attitude. Thus, the greater the mean score, the more positive the attitude and the lesser the mean value, the more negative the attitude of the students towards optics. The results of the analyses are presented in Tables 4.4 and 4.5 as shown below.

Table 4.4: Descriptive Statistics of OLAQ Before Intervention

Dimensions	Items	Mean	Std. Deviation	Total Mean (Std. D)
Leaning Optics (LO)	LO1	1.08	.273	
	LO2	1.07	.251	
	LO3	1.07	.251	1.07(0.13)
	LO4	1.05	.226	
Future participation (FP)	FP1	1.04	.197	
	FP 2	1.08	.273	
	FP 3	1.05	.226	
	FP 4	1.03	.162	1.05(0.11)
Optics Outside Classroom (OOC)	OOC1	1.08	.319	
	OOC2	1.03	.162	
	OOC3	1.04	.197	1.05(0.14)
The Physics Teacher (TPT).	TPT1	1.04	.197	
	TPT2	1.03	.162	
	TPT3	1.04	.197	1.05(0.11)
	TPT4	1.08	.273	
OVERALL TOTAL		1.0531	.06033	

Before exposure to the intervention, Table 4.4 showed that, SHS Physics students obtained a mean score of 1.07(SD=0.13) in “learning Optics” dimension; 1.05(SD=0.11) in “Future Participation” dimension; 1.05(SD=0.14) in “Optics Outside Classroom” dimension; and 1.05(SD=0.11) in “The Physics teacher” dimension. The overall mean score of OLAQ before the intervention was 1.05(SD=0.06).

Table 4.4 shows that the responses to the 15 items by the respondents are spread around Strongly Disagree (SD) and Disagree (D) for the positive items and strongly agree (SA) and Agree (A) for the negative items. The overall mean score of 1.0531 (SD= 0.06033) which is below the standard mean score of 2.5 shows that the respondents had negative attitude towards optics prior to the intervention.

Similarly, SHS Physics students' attitudes towards optics were again measured after the intervention using descriptive statistics of OLAQ scores (mean, standard deviations) after intervention and overall mean score as presented in Table 4.5.

Table 4.5: Descriptive Statistics of OLAQ After Intervention

Dimensions	Items	Mean	Std. Deviation	Total Mean (Std. Deviation)
Leaning Optics (LO)	LO1	3.85	.356	
	LO2	3.75	.572	3.73(0.28)
	LO3	3.45	.684	
	LO4	3.88	.327	
Future participation (FP)	FP1	3.77	.559	
	FP 2	3.72	.583	3.82(0.24)
	FP 3	3.85	.356	
	FP 4	3.95	.226	
Optics Outside Classroom (POC)	OOC1	3.91	.293	
	OOC2	3.79	.444	3.74(0.27)
	OOC3	3.52	.578	
The Physics Teacher (TPT)	TPT1	3.71	.458	
	TPT2	3.77	.452	3.78(0.20)
	TPT3	3.84	.369	
	TPT4	3.80	.403	
OVERALL MEAN		**3.7686**	**0.12531**	

After exposure to the intervention, SHS Physics students obtained a mean score of 3.73(SD=0.28) in "learning Optics" dimension; 3.82(SD=0.24) in "Future Participation" dimension; 3.74(SD=0.27) in "Optics Outside Classroom" dimension; and 3.78(SD=0.20) in "The Physics teacher" dimension. The overall mean score of OLAQ after the intervention, was 3.77(SD=0.12).

As seen from Table 4.5, the responses to the 15 items in OLAQ (see Appendix B) by the respondents are spread around Strongly Agree (SA) and Agree (A) for the positive items and Strongly Disagree (SD) and Disagree (D) for the negative items. The overall mean score of 3.7686 which is above the standard mean score of 2.5 shows that the respondents had positive attitude towards optics after exposure to the intervention.

4.6 Testing of Hypothesis 1

The research hypothesis which states that *"there is no significant difference in academic performance between students instructed using the MR-SR Based PIMCA model and those instructed using the conventional method"* was tested using one-way between groups analysis of covariance (one-way ANCOVA) to determine any significant difference in the posttest scores of the two groups at an alpha level of 0.05, using the pretest scores as covariates. This is because, Table 4.3 showed that, the difference between the two groups in the pretest in the pretest was significant. Therefore, it was appropriate to use ANCOVA in order to control for the differences prior to the intervention, using the pretest scores as a covariate and also to control for the influence of students' exposure to the pretest score on the posttest. However, other assumptions which must be met before using an analysis of covariance (ANCOVA) were tested. The assumptions are;

1. linear relationship between dependent variable (posttest scores) and covariate,
2. homogeneity of regression slope,
3. homogeneity of equal variances,
4. normality of covariate and dependent variable (see Table 4.2), and
5. reliability of covariate, that is, the pretest scores of students (see Table 3.3 and Table 3.4).

Since normality of the covariate and dependent variables, as well as the reliability of the covariate have already been determined, the first three assumptions were therefore tested of which the results are presented in Appendices F, G and H respectively.

4.7 Test for Assumption of Homogeneity of Regression Slope

This assumption, according to Pallant (2011), demands that the relationship between the covariate and dependent variable for each group is the same. Pallant (2011) suggests that, for this assumption to be met, there should be no significant interaction between the covariate and the treatment or experimental manipulation, which is the posttest scores. The results in Appendix G showed that there was no significant interaction ($p=0.843$) between the covariate and the treatment, thus the teaching methods. Therefore, from Appendix G this assumption was not violated.

4.8 Linear Relationship Between Dependent Variable and Covariate

This assumption, as stated by Pallant (2011) requires that the relationship between the dependent variable and the covariate is linear (straight-line). Thus, an observation of a curvilinear relationship represents violation of this assumption, which will reduce the power of the ANCOVA test. As observed in Appendix F there appears to be a straight-line relationship posttest scores and the pretest scores, which indicates that this assumption was not violated.

4.9 Assumption of Equal Variances

This assumption also requires that the variances in posttest scores (dependent variable) between the two groups are equal (Pallant, 2011). This assumption operates on the null hypothesis that, the variances in posttest scores within each group are equal, which means the null hypothesis is rejected if the p-value is less than 0.05. Levene's statistic, ($F=2.582$), which tests that the variances in posttest scores between both groups in an ANCOVA test should be equal, was not significant ($0.055>0.05$) as shown in Appendix H. This implies that this assumption was not violated.

From the foregoing, it can be said that the assumptions of ANCOVA relative to this study were not violated. As a result, it was appropriate to conduct the ANCOVA test, with its descriptive analysis, between the posttest scores of students from both groups, using the pretest scores as a covariate.

Since all the assumptions were not violated, the effect of the MR-SR Based PIMCA model and the conventional approach on the academic performance of senior high school Physics students was analysed using one-way between groups analysis of covariance (one-way ANCOVA) and the results are presented in Table 4.6 as shown below.

Table 4.6: ANCOVA Results Between the Posttest Scores of Both Experimental and Control Groups

Groups	N	Adjusted Mean	Std. Error	F	p	Partial Eta Squared
Experimental	75	21.519	0.404	129.090	.000	0.445
Control	89	18.019	0.371			

Table 4.6 showed that, after controlling for the effect of the pretest on the posttest, there was a significant difference in the posttest scores between the experimental (Adjusted Mean=21.519, std. error=0.404) and control groups (adjusted mean = 18.019, std. error=0.371; $F_{(1, 161)} = 129.090$, $p=0.00<0.05$), with an effect size (partial Eta Squared) of 0.445, implying a large effect size, according to Cohen's indices (Appendix L). Accordingly, the null hypothesis which states that there is no significant difference between students instructed using the MR-SR Based PIMCA learning model and those instructed using the conventional method is rejected.

4.10 Testing of Hypothesis 2

The research hypothesis which states that "*there is no significant difference in academic performance between male and female SHS Physics students instructed using MR-SR Based PIMCA learning model*" was tested using one-way between groups analysis of covariance (one-way ANCOVA) to determine any significant difference in the posttest scores of both gender groups at an alpha level 0.05, using the pretest scores as covariates. This is because, students were already exposed to the test items at the pretest stage and also, there was significant difference between both gender groups in the pretest (see Appendix I). Therefore, it was appropriate to use ANCOVA in order to control for the differences prior to the intervention, using the pretest scores as a covariate.

Also, other assumptions (linear relationship between covariate and dependent variable, homogeneity of regression slope, assumption of equal variances) which must be met before using an analysis of covariance (ANCOVA) were tested and were found not to be violated (see Appendix J, K and L).

The difference between the two groups was tested for its significance using one-way between groups analysis of covariance and the results are presented in Table 4.7 as shown below.

Table 4.7: Results of ANCOVA on Posttest Scores of Male and Female SHS Physics Students Taught Using MR-SR Based PIMCA Model

Gender	N	Adjusted Mean	Std. Error	F	p
Males	41	21.144	.540	.319	.574
Females	34	21.091	.595		

Table 4.7 showed that, there was no significant difference between male (Adjusted Mean=21.144, std. error=0.540) and female (adjusted mean = 21.091, std. error=0.595; $F_{(1, 72)} = 0.319$, $p=0.574>0.05$) gender groups on the posttest scores of students taught using MR-SR Based PIMCA Model. This means that the estimated marginal mean difference between male and female SHS Physics students was not significant.

Accordingly, we do not have enough evidence to warrant the rejection of the null hypothesis which states that "there is no significant difference between male and female senior high school students' academic performance in Physics after exposure to the MR-SR Based PIMCA model**"**.

4.11 Testing of Hypothesis 3

This research question states that *"There is no significant difference in academic performance between high and low achieving students in the senior high school after exposure to the MR-SR Based PIMCA model".*

A one-way between groups analysis of covariance (ANCOVA) as presented in Table 4.8 at a significant level of 0.05 was used to test this hypothesis since there was a significant difference in pretest scores between both ability groups (see Appendix R). Students in the experimental group were grouped into groups based on their ability levels inferred from their pretest scores.

In categorising students into high achievers and low achievers, the students were first grouped into three using 33rd percentile (with pretest scores ranging from 0.00 through to 7.00), 66th percentile (with pretest scores above 7.01 through to 12.16), and 100th percentile (with pretest scores above 12.17 through to 20). Students who scored from the 33^{rd} percentile (7.00) or below were classified as low achievers, those who scored above the 33^{rd} percentile (7.00) through to the 66^{th} percentile (12.16) were classified as medium or average achievers and those who scored above the 66^{th} percentile (12.16) through to the highest or the 100^{th} percentile (20) were classified as high achievers. The average achievers were eliminated since they were not considered in this study and was left with the high and low achievers.

The participating students in the experimental group were also divided into high and low-achieving students based on their pre-test results. Twenty-five students from the MR-SR Based PIMCA group were high achievers, 23 were average achievers and 27 were low achievers. The average achievers were not considered in this study and hence were eliminated leaving the high and low achievers.

Prior tests of the assumptions of analysis of covariance were carried out to ensure no violation of assumptions of linearity, homogeneity of regression slope, as well as homogeneity of variances (see Appendices M, N and O).

This difference between the two groups was tested for its significance using one-way between groups analysis of covariance and the results are presented in Table 4.8 as shown below.

Table 4.8: ANCOVA Results of Posttest Scores for High Achievers and Low Achievers Taught Using MR-SR Based PIMCA Model

Ability Group	N	Adjusted Mean	Std. Error	F	p
High Achievers	25	23.317	1.105	.044	.835
Low Achievers	27	22.892	1.031		

As observed in Table 4.8, There was no significant difference in posttest scores of both ability groups (high and low-achievers) who were exposed to MR-SR Based PIMCA model ($F_{(1, 49)} = 0.44$, $p=0.835>0.05$). This implies that the adjusted mean difference between the two ability groups (0.425) was not significant.

Accordingly, we do not have enough evidence to warrant the rejection of the null hypothesis which states that "There is no significant difference between the academic performance of high and low achieving students in the senior high school Optics after exposure to the MR-SR Based PIMCA model".

4.12 Discussion of Findings

This study sought to assess the comparative effect of MR-SR Based PIMCA Model and Conventional teaching method on the academic performances of SHS Physics students in Optics. The students sampled for this study were divided into two groups, thus, experimental (taught using MR-SR Based PIMCA Model) and control group (taught using the conventional teaching method). The results of the study are discussed below according to the research question and hypotheses.

4.12.1 Discussion of results of Research Question 1

"What is the attitude of SHS Physics students towards the learning of optics before and after exposure to the MR-SR Based PIMCA model?"

Physics students who were instructed through the PIMCA model exhibited improved attitudes towards the learning of Optics, as measured by their Optics Learning Attitude scores, using the Optics Learning Attitude Questionnaire (OLAQ). Before the intervention, a mean score of 1.0531 (SD= 0.06033) was attained whiles a mean score of 3.77(SD=0.12) was attained after the intervention. This seems to agree with the general conception that individuals can change their attitude and disposition about subjects through student-centred teaching methods. For example, Guido (2013), noted that the extent to which learners learn depends on their level of motivation and attitudes which can be stimulated by the nature of the learning environment and the instructional methods employed by the teacher.

The relative higher levels of attitude by students in the MR-SR Based PIMCA model class may also be explained, at least in part, by the fact that student-centred lessons promote better understanding than teacher-centred lessons. For example, Wendorf (2018) noted that, it has been demonstrated time and time again that student-centred approaches to instruction are superior to traditional teacher-centred ones. According to Wendorf, lessons that are centred around the needs of the students help them become proficient in the material being taught, retain it for a longer period of time, or understand it deeply. They also help them develop critical thinking and creative problem-solving abilities, as well as positive attitudes towards the subject matter.

The integrated approach of presentation, idea-mapping, conceptualization, and assessment enhanced students' attitudes towards the teaching and learning of optics by making the learning process more engaging and accessible. Through dynamic presentations, students were introduced to the complexities of optics concepts in a visually appealing and simplified manner. Nasra et al. (2021) assert that, this method helps to demystify challenging concepts and showcased the real-world applications of a concept, making the subject more interesting and relevant to students' lives.

Idea-mapping and conceptualization further contribute to this positive shift in attitude by empowering students to take control of their own learning (Reskin et al., 2021). Idea-mapping allows students to visually organize and connect concepts, facilitating a deeper understanding and retention of information. This process not only helps students to clarify their thoughts but also encourages them to explore relationships between different phenomena, fostering a sense of discovery and creativity (Poluakan & Katuuk, 2022). The conceptualization phase, where students actively engage with the teacher to form their understanding, promotes critical thinking and problem-solving skills. By encouraging students to ask questions, experiment, and apply concepts in new contexts, they become more confident in their ability to grasp complex ideas. This active involvement in the learning process transforms feelings of intimidation or apathy towards optics into enthusiasm and self-efficacy.

Finally, the assessment component of the PIMCA model reinforces a positive attitude by providing students with regular feedback on their progress, highlighting areas of strength and identifying opportunities for improvement (Koming et al., 2021). This ongoing evaluation helps students see tangible evidence of their learning journey, boosting their confidence and motivation. Additionally, by incorporating a variety of assessment methods, Tokolang et al., (2021) stated that, students are evaluated in a manner that aligns more closely with their individual learning styles, making the assessment process feel more fair and less daunting. Together, these elements of the PIMCA framework create a supportive learning environment that not only enhances students' understanding of optics but also improves their overall attitude towards the subject, making them more likely to engage deeply and persist in their studies.

4.12.2 Discussion of results of Hypothesis 1

"There is no significant difference in academic performance between students instructed using the MR-SR Based PIMCA learning model and those instructed using the Conventional method."

In an attempt to find evidence to accept or refute this hypothesis, the posttest estimated marginal mean scores of experimental and control groups were compared. It was found from the ANCOVA results that, after exposure to the treatments, students in the experimental group, who were taught using MR-SR Based PIMCA Model performed significantly better than students in the control group ($F_{(1, 161)} = 129.090$, $p=0.00<0.05$), with an effect size (partial Eta Squared) of 0.445. In effect, the MR-SR Based PIMCA Model was found more effective to improve SHS Physics students' academic performances in Optics.

This finding was consistent with the findings of previous studies (Hartati et al., 2021; Koming et al., 2021; Lampeang et al., 2021; Poluakan & Katuuk, 2022). Students who were instructed using the MR-SR Based PIMCA Model performed better than students who were instructed using the conventional teaching method because during Physics lessons, Physics students in the experimental group had the opportunity to observe a number of presentations using semiotic resources, which enabled them to conceptualise optics concepts better than their colleagues who were taught using the conventional teaching method where learners only listened and copied notes from the teacher while he speaks to the whole class in a lecture format. Koming et al. (2021) concluded that the MR-SR Based PIMCA learning model does an outstanding job of enhancing comprehension of the convex lens concept. Hartati et al. (2021) also came to the conclusion that the experimental class research on the material for optical loop instruments using the MR-SR Based PIMCA learning model in the Physics education study program generally showed a positive effect, indicating that the application of this learning model can best improve student learning outcomes in optics and on optical loop instrument material. The research from Hartati et al. (2021) indicated that, the best way to alternate teaching Physics in the classroom is by integrating multimedia and semiotics using the MR-SR Based PIMCA Learning Model.

The usage of multiple resources helped majority of SHS Physics students in the MR-SR Based PIMCA Model group understand optics concepts from different perspective since providing students with more diverse representations by broadening the variety of external representations affects students’ cognitive abilities, offer special advantages when learning difficult new concepts, and makes concepts easier to comprehend, thereby adapting the lessons to suit each student.

The MR-SR Based PIMCA model enhances students' academic performance in optics, and other complex subject, more than conventional teaching methods for several reasons. According to Patol et al. (2021) each component of this model contributes to a deeper understanding and retention of material:

Presentation involves delivering content in a structured format, often utilizing multimedia resources, demonstrations, and lectures. It caters to various learning styles (visual, auditory, etc.) and helps in making abstract concepts more tangible. In optics, which is visually intensive, presentations can make a concept like reflection of light easier to comprehend. Idea-Mapping helps students organize and relate concepts visually. This technique is especially beneficial in a subject like optics, where understanding the relationships between concepts is crucial. Idea-maps facilitate a better integration of new knowledge with existing knowledge, promoting deeper learning. This step involves students actively engaging with the material to form their own understanding of the concepts (Poluakan & Katuuk, 2022). It often involves activities like problem-solving, designing experiments, or applying concepts to novel situations. In optics, conceptualization helps students move beyond rote memorization to a more profound grasp of how principles manifest in real-world applications.

Also, teacher guidance at the Conceptualization stage helps students to better understand the concept being taught. Learners receive information accompanied by instructions from the teacher who functions as a facilitator so that scaffolding functions can take place (Poluakan & Katuuk, 2022). At this stage, Patol et al. (2021) state that, ensuring that no incorrect concepts are built, the immature idea mapping is repaired and built into the correct concept. The concepts of the ideas that were developed earlier should are clarified at this point so that the formation of an incorrect concept understanding is prevented. Again, the Assessment (formative) stage provides immediate feedback to both students and instructors about the level of understanding achieved (Herrero et al., 2021). In subjects like optics, where practical skills are as important as theoretical knowledge, assessments can be tailored to measure a broad range of competencies, from conceptual understanding to application and analysis.

Compared to traditional teaching methods, which often rely heavily on passive learning and rote memorization as asserted by Radzali et al. (2018), the integrated approach of the PIMCA model promotes active learning, critical thinking, and practical application skills essential for mastering complex subjects like optics. By engaging with the material in diverse ways, students are more likely to develop a robust, flexible understanding of the subject matter, which is reflected in improved performance.

4.12.3 Discussion of results of Hypothesis 2

"There is no significant difference in academic performance between male and female senior high school students' academic performance in Physics after exposure to the MR-SR Based PIMCA model."

In testing for this hypothesis, the posttest estimated marginal mean scores of male and female SHS Physics students who were exposed to the MR-SR Based PIMCA model's treatment were compared. The ANCOVA results showed that, there was no significant difference in the academic performance between male and female SHS Physics students in Physics after exposure to the MR-SR Based PIMCA model intervention ($F_{(1, 86)} = 0.319$, $p=0.574>0.05$), with an effect size (partial Eta Squared) of 0.004. As a result, it could be said that the usage of the MR-SR Based PIMCA model was effective in helping bridge the gender gap in Physics performance. This was in accordance with the findings of Koming et al. (2021) and Mayampoh et al. (2021).

Since concrete representations aid in the construction of more abstract representations, Koming et al. (2021) found that, all students regardless of gender, have the opportunity to access the content for better understanding. Mayampoh et al. (2021), also found that, both male and female Physics students in the MR-SR Based PIMCA class stand the chance to perform approximately equally and that could be ascribed to students' exposure to new learning materials (Semiotic Resources).

The use of an integrated model like the MR-SR Based PIMCA model in the teaching and learning of optics can play a significant role in bridging the performance gap between male and female students. This model's multifaceted approach caters to diverse learning styles and preferences, which is crucial in creating an inclusive learning environment (Mayampoh et al., 2021). For instance, Hartati et al. (2021) propound that, presentations that utilize both visual and auditory elements can address the varied ways students absorb information. By providing multiple entry points to the material, this approach ensures that all students, regardless of gender, can find a method that resonates with their personal learning style, thereby enhancing their understanding and retention of complex Physics concepts.

Idea-mapping and conceptualization further contribute to leveling the playing field. Idea-mapping encourages students to visually organize their thoughts and see the connections between concepts, which supports both analytical and holistic thinkers (Poluakan & Katuuk, 2022). This method can particularly benefit female students, who, according to some educational research, may excel in tasks that involve relational thinking and visualization. Conceptualization, on the other hand, involves active engagement with the teacher where students are assisted so scaffolding function can take place. By fostering an active learning environment where students are encouraged to explore, question, and apply concepts, the framework supports experiential learners and can help reduce any performance disparities by engaging all students in a way that aligns with their strengths (Takwe, 2019).

Lastly, the assessment component of the PIMCA model is key to ensuring equitable performance among male and female students. By employing a variety of assessment methods, educators can provide multiple avenues for both male and female Physics students to demonstrate their understanding and mastery of optics. By valuing different types of intelligence and skills can help mitigate gender biases in performance, enabling both male and female students to excel.

4.12.4 Discussion of results of Hypothesis 3

"There is no significant difference in academic performance between high and low achieving students in the senior high school after exposure to the MR-SR Based PIMCA model."

ANCOVA test was carried out on the posttest scores of both the high and low achieving students in the MR-SR Based PIMCA group, comparing their estimated marginal mean scores. Findings with respect to this hypothesis revealed that there was no significant difference between high achieving and low achieving students instructed using MR-SR Based PIMCA model ($F_{(1, 49)} = 0.44$, $p=0.835>0.05$), with an effect size (partial Eta Squared) of 0.001. As a result, it could be said that the MR-SR Based PIMCA model did not discriminate among students, but it gave all students equal platform to perform equivalently irrespective of their abilities.

This is because lessons were adapted to students' needs and abilities, using appropriate teaching and learning resources and techniques, adaptive to the needs of time thereby helping low achieving students to catch up with their high achieving counterparts. Appropriate use of the constructivist student centred teaching methods has a great tendency of helping low ability students do better in the Physics classroom. This is in accordance with the work of Vanlaar et al. (2016) who found that, low-achieving students can improve their academic performance and catch up with their high-achieving peers in the Physics classroom when teachers adopt effective learner centred instructional strategies. Yang et al. (2020) also, found that, effective leaner centred learning experiences that emphasise higher-order competencies are crucial because they have the potential to assist students become more academically successful and so close the achievement gap.

The MR-SR Based PIMCA model inherently supports differentiated learning, which is crucial in bridging the gap between high and low achieving students. By integrating a variety of teaching methodologies and tools, the model caters to a wide range of learning preferences and abilities. For example, Mamengko et al. (2021) postulated that, presentations can be tailored to introduce basic concepts in a clear, accessible manner for those who might struggle, while also incorporating more advanced, thought-provoking elements to challenge higher achievers. This method ensures that all students, regardless of their starting point, can engage with the material at an appropriate level, fostering a deeper understanding and appreciation of optics.

The use of idea-mapping and conceptualization within the PIMCA framework further aids in leveling the academic field between high and low achievers. Idea-mapping allows students to visually organize and connect concepts, which can be particularly beneficial for low achieving students who might find abstract concepts in optics challenging to grasp (Nasra et al., 2021). This visual representation of knowledge helps in making complex ideas more tangible and accessible. On the other hand, the conceptualization process, which encourages students to apply concepts in practical and often creative ways, provides an opportunity for high achievers to explore the subject matter more deeply. These strategies not only cater to the diverse needs of students but also promote an active and engaging learning environment that stimulates curiosity and motivation across the board.

Assessment stage of the PIMCA model ensures a fair and comprehensive evaluation of student performance, recognizing different strengths and learning outcomes (Hartati et al., 2021). This approach allows low achievers to showcase their knowledge and skills in ways that traditional exams might not capture, while also providing high achievers with the opportunity to extend their learning and demonstrate higher-order thinking and application skills (Koming et al., 2021). By valuing a wide range of competencies and learning styles, the PIMCA model supports a more equitable learning environment, where both high and low achieving students have the opportunity to succeed and excel in the study of Optics.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter entails the summaries of the findings of this study. Also, conclusions, recommendations, and suggestions have been made, based on the findings, for further research work.

5.1 Summary of the Study

In this study, the effect of MR-SR Based PIMCA model and Conventional teaching method were investigated in the Mampong Municipality and Sekyere South District using 164 SHS Physics students. The sampled students were assigned into experimental and control groups randomly using their intact classes. The experimental group (N=75) was instructed using the MR-SR Based PIMCA model, while the control group (N=89) was exposed to the conventional teaching method. The main focus of this research was to compare the academic performance of SHS Physics students instructed through the conventional approach and those instructed through the MR-SR Based PIMCA model. Also, the attitude of Physics students in the experimental group was tested before and after the intervention.

After exposure to MR-SR Based PIMCA Model, students demonstrated positive attitudes towards the teaching and learning of optics. This was shown by the overall mean scores of OLAQ before the intervention (mean=1.0531, SD=0.06033) which was below the standard mean score of 2.5 and after the MR-SR Based PIMCA model's intervention (mean=3.7686; SD=0.12531) where the mean score was above the standard mean of 2.5. Therefore, it can be concluded that the employment of MR-SR Based PIMCA Model could help change students' negative attitude towards the teaching and learning of optics to a positive one.

Also, it was revealed that prior to the intervention, students in both groups performed approximately different. After the intervention, the MR-SR Based PIMCA model was significantly effective than the conventional teaching method in enhancing Physics students' academic performances. Specifically, after the intervention, the estimated marginal mean score of the MR-SR Based PIMCA model group was 21.591 in the posttest, with a standard error of 0.404 while the mean score of the conventional group was 18.019 in the posttest with a standard error of 0.371. This means that the employment of the MR-SR Based PIMCA model in the teaching and learning of optics was more effective in the Physics classroom.

Lastly, in this current study, neither achievement results were affected by gender or ability. For example, all students, irrespective of their gender, benefited in about the same margin, from the use of MR-SR Based PIMCA Model having a mean difference of 0.053. Also, the results revealed that, there was no significant difference ($F_{(1, 49)}$ = 0.44, p=0.835>0.05) between the high achieving students (Mean=23.317, standard error=1.105) and low-achieving students (Mean=22.89, Standard error=1.031) with regard to the use of MR-SR Based PIMCA Model.

5.2 Conclusions

As a result of the findings of this study, it is appropriate to conclude that the MR-SR Based PIMCA learning Model was more effective and beneficial than the conventional teaching approach in the teaching and learning of optics in the Senior High Schools in the Mampong Municipality and Sekyere South District. This is because, Within the confines of this research, the interventional instruments premeditated to improve upon students' appalling performance in optics concepts yielded positive outcomes. The employment of MR-SR Based PIMCA Model in the teaching and learning of optics in this study personalised the lessons to individual students using multiple representations and semiotic resources through four interventional stages where the needs of all students were considered.

It was found from this research that, all students, irrespective of gender learned and achieved optics concepts at about equal levels. It was also found that, both high and low achieving students in the experimental group performed equally after the intervention. Again, students developed more positive attitudes towards the teaching and learning of optics when they were exposed to the MR-SR Based PIMCA model. In view of this, the MR-SR Based PIMCA model has been accorded the ability to improve Physics students' academic performance in optics, reduce the disparity between male and female students' achievement in optics, bridge the gap between high and low achieving students in optics and as well improve students' attitudes towards the teaching and learning of optics in the Senior High School.

Therefore, it is appropriate to conclude that, the use of multiple representation and semiotic resources through the four PIMCA intervention processes (namely;

Presentation, Idea-Mapping, Conceptualisation, Assessment) in the Physics classroom is effective in enhancing academic performance and attitude of students in optics irrespective of gender or their abilities.

Results from this study also support the conclusion that both the teacher and the students have important responsibilities to play in boosting students' academic performance in Physics concepts. Instead of acting as a sage on stage, the Physics instructor should act as a learner among learners and be viewed as a mentor by the students' sides throughout instruction. He should be viewed as a coach and facilitator who encourages students to study on their own rather than just as an authoritative figure who spoon-feeds information to them. Therefore, it is important to provide students with the essential tools so they can participate completely in the entire teaching and learning process.

1.3 Recommendations

The findings of this study led to the following recommendations:

1. It is recommended that Physics teachers should adapt lessons to the needs of students through the use of multiple representations. It has been found that, students learn optics concepts better when different presentations are used to explain the same concept during instructional delivery. This will bring the understanding of the optics concepts to the level of all students, thus, causing students to perform regardless of entry backgrounds.
2. Also, as this study revealed a positive effect of MR-SR Based PIMCA model over the conventional teaching method, it is recommended that in-service training and workshops should be organised by the Ghana Education Service for Physics

teachers in order to help them acquire the skills needed to implement the MR-SR Based PIMCA model in Physics classrooms.

3. Additionally, in order to improve the academic performance and attitudes of Physics students, teacher training institutions like Colleges of Education and Universities are urged to guide in-service teachers toward the adoption of effective instructional strategies like the MR-SR Based PIMCA model. This model places a greater emphasis on the student than the teacher.
4. Physics teachers are also encouraged to incorporate semiotic resources such as YouTube videos, animations, graphs, and images of optics contents during the teaching and learning of optics.

5.4 Suggestions for Further Research

It was suggested that, studies on the MR-SR Based PIMCA model should be conducted using other research designs that would allow for randomisation.

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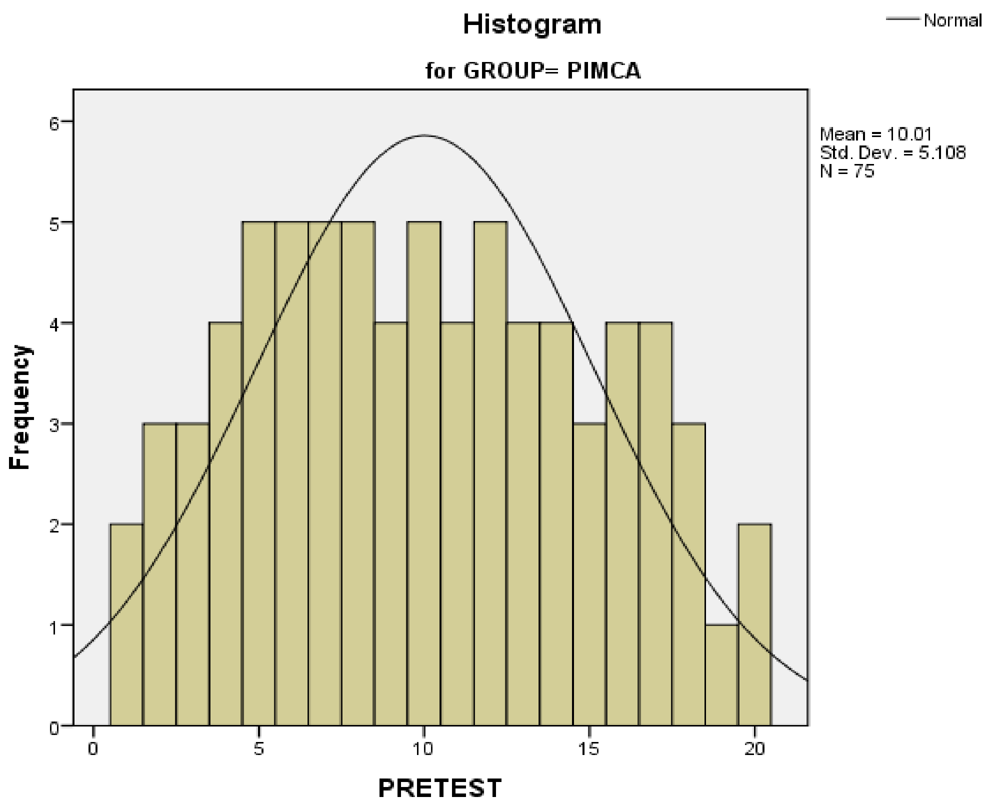
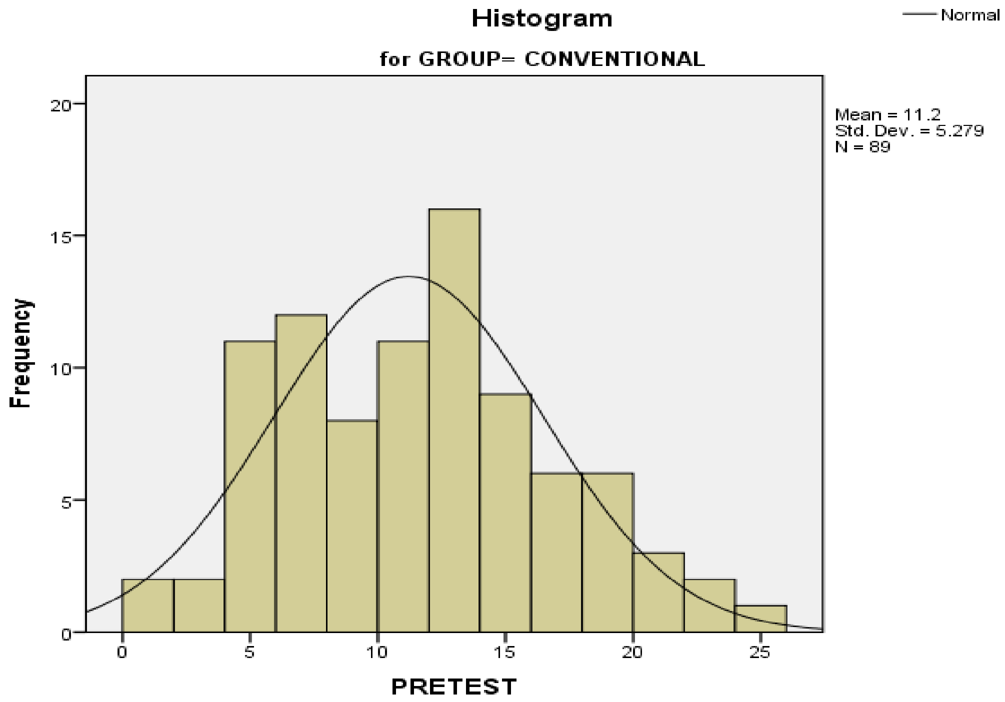
APPENDICES

APPENDIX A1

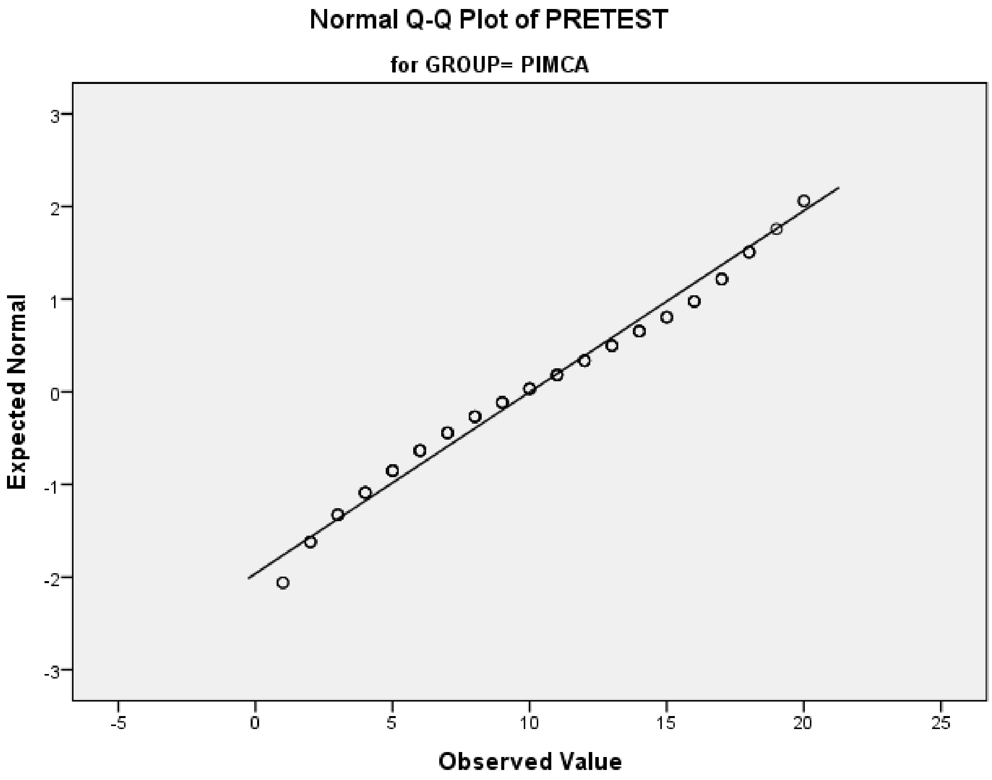
Histogram Plots of pretest scores for the experimental and control Groups

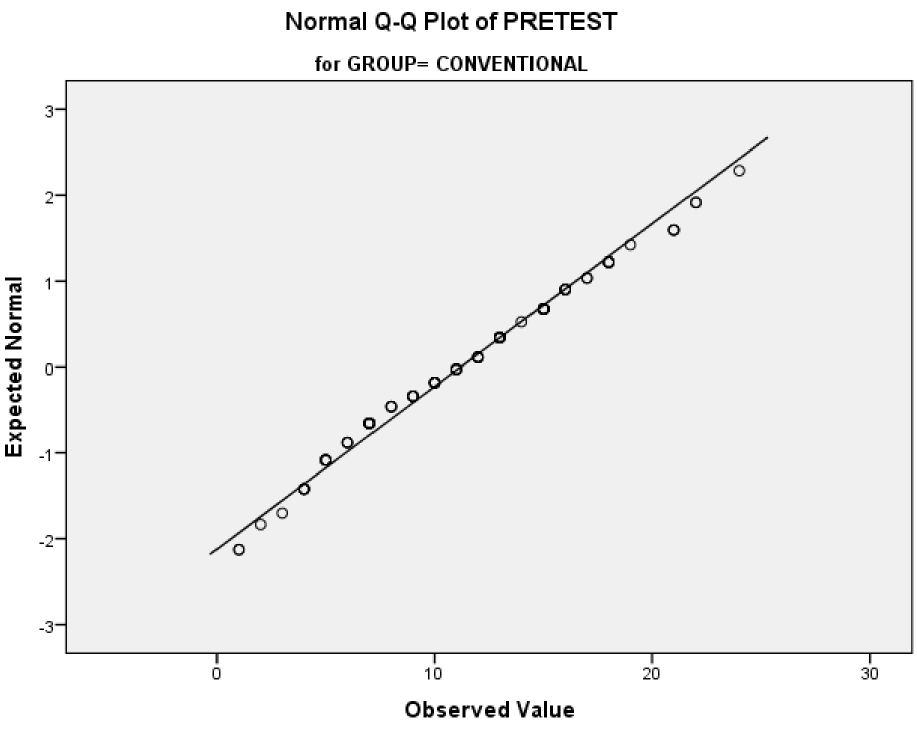




APPENDIX A2.

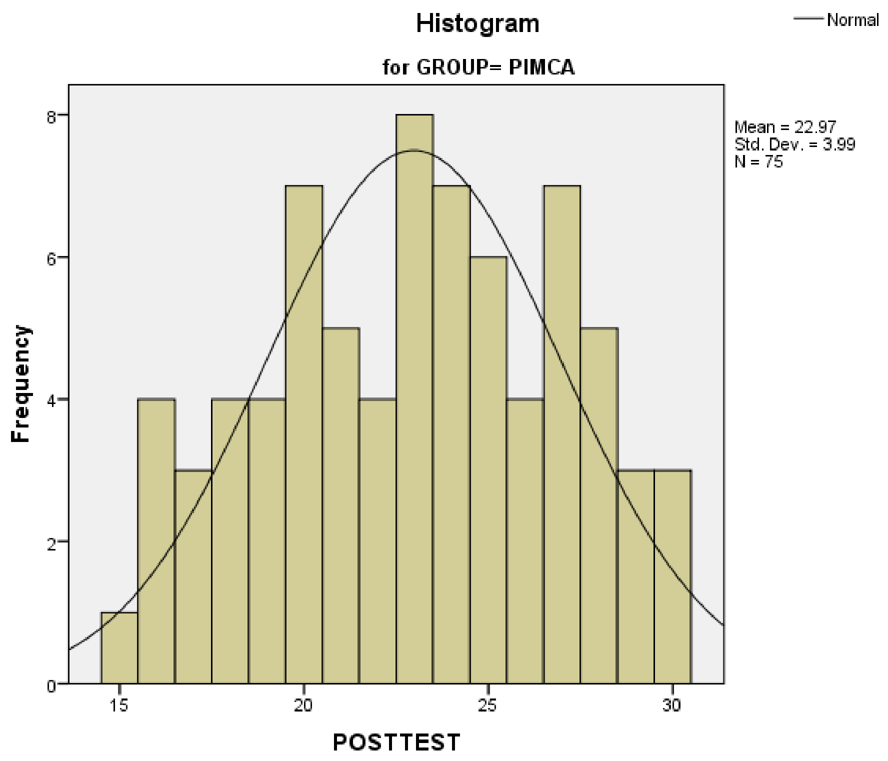
Q-Q plots of pretest scores for the experimental and control Groups

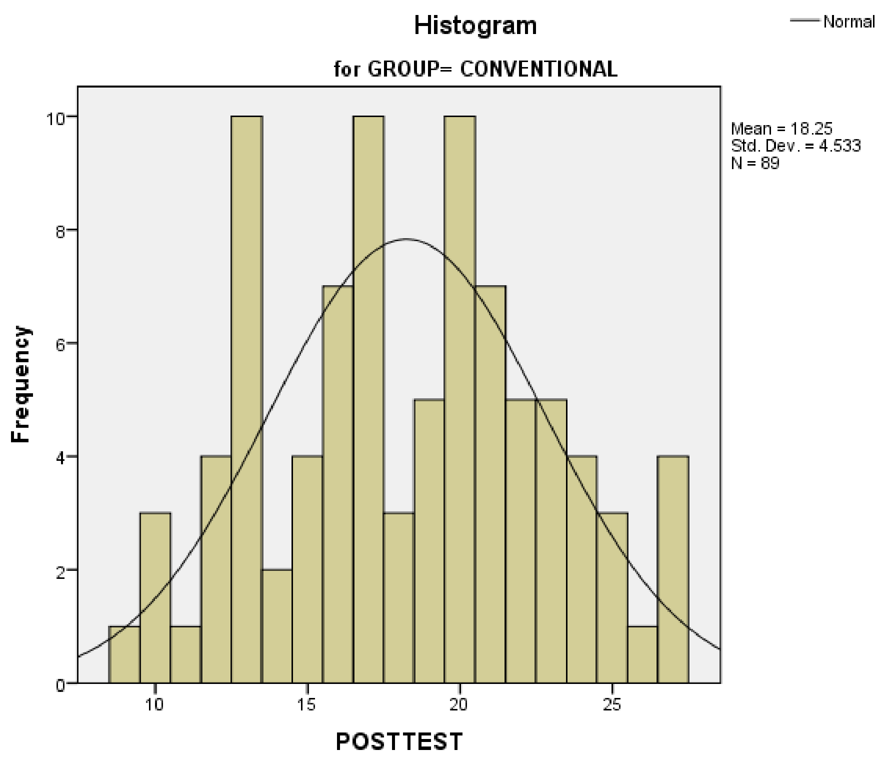




APPENDIX A3:

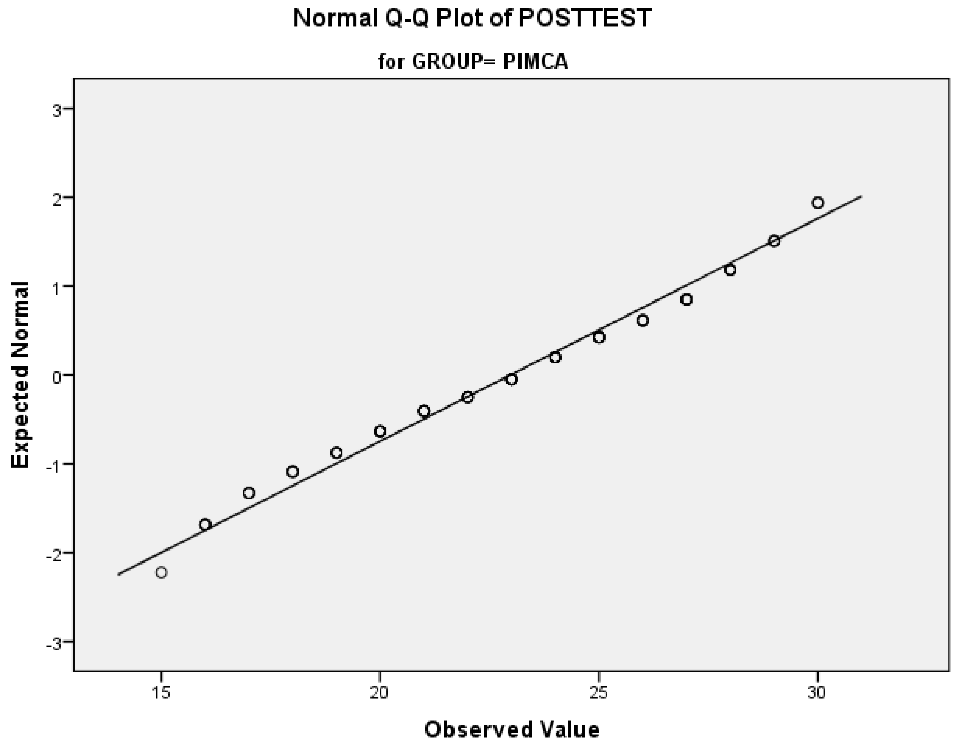
Histogram plots of Posttest scores for the experimental and control Groups

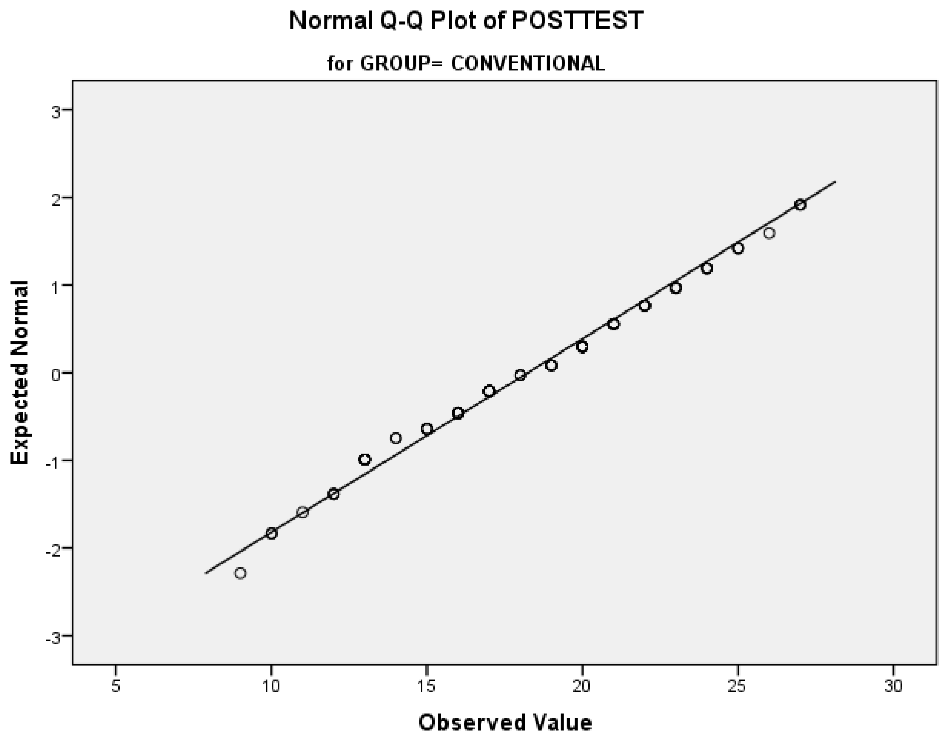




APPENDIX A4

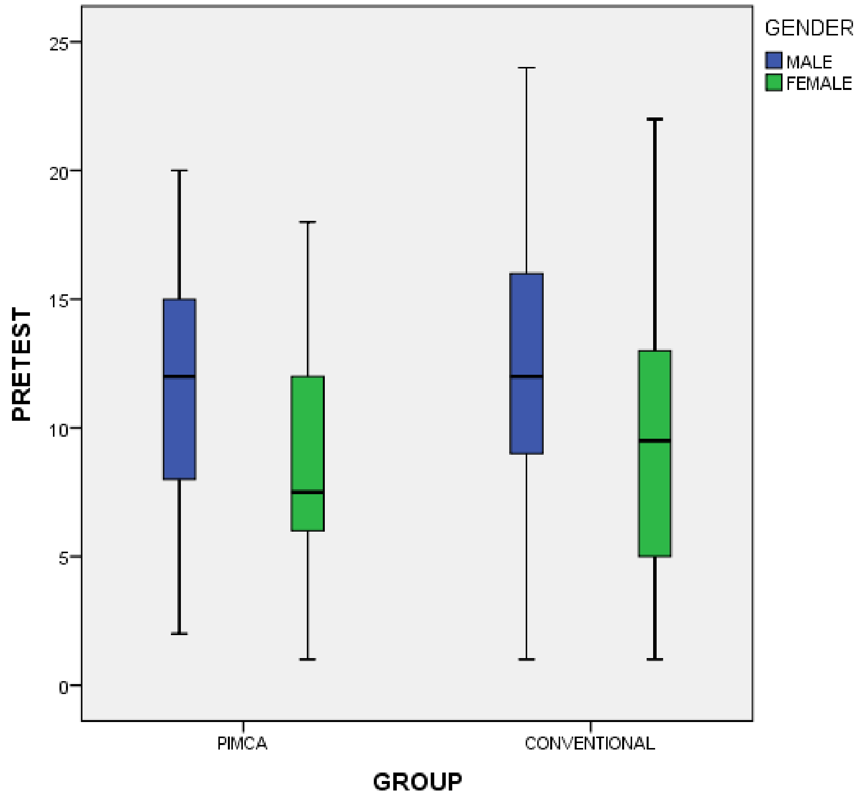
Q-Q plots of Posttest scores for the experimental and control Groups

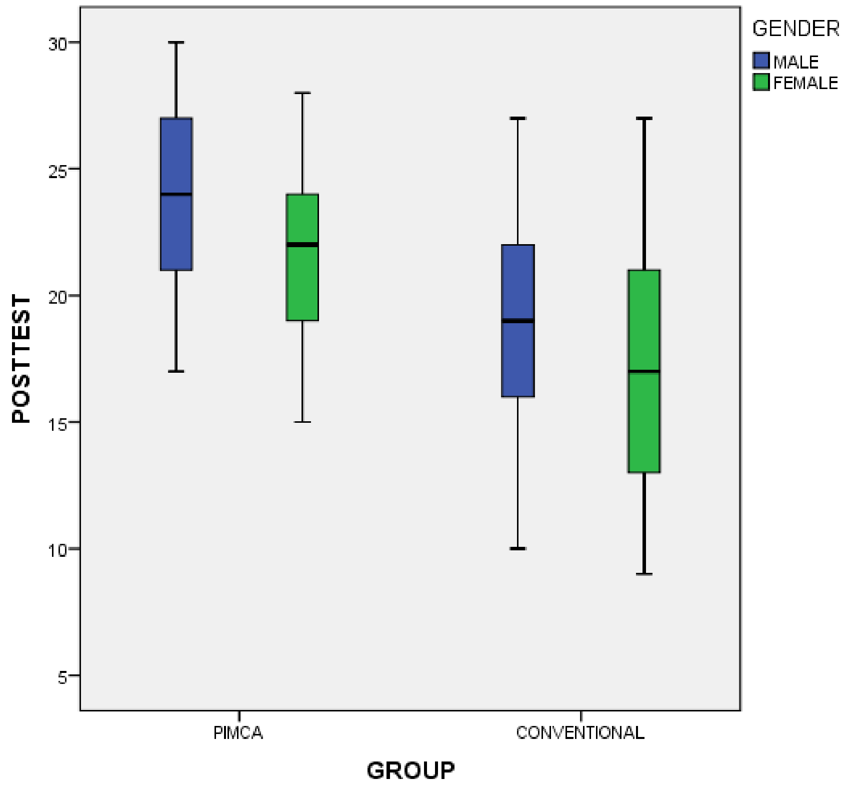




APPENDIX A5

Box Plots of pretest and posttest scores for the experimental and control Groups





APPENDIX B

OPTICS LEARNING ATTITUDE QUESTIONNAIRE (OLAQ)

This questionnaire seeks to investigate Senior High School Students' attitudes towards Physics in some selected municipalities and districts in the Ashanti Region of Ghana. Please answer the following questions as accurately as possible by ticking [√] in the box corresponding to whatever your choice is. Your response is for academic purposes only and will be held confidential.

Dimension	S/N	Items	Strongly Agree	Agree	Disagree	Strongly Disagree
Learning Optics (LO)	**LO1**	I look forward to my next Physics lessons				
	LO2	I get good marks in Physics assignments/quizzes.				
	LO3	I do not like to have more Physics lessons in school.				
	LO4	I easily learn Physics concepts.				
Future participation (FP)	**FP1**	I would like to become a Physics teacher				
	FP2	I would like to have a job working with Physics				
	FP3	I would like to become Physicist.				
	FP4	I would not like to study Physics at university.				
Optics outside classroom	**OOC 1**	I like reading Physics journals and books				

(POC)	**OOC 2**	I would like to do more Physics activities outside school.				
	OOC 3	Physics home works are not exiting				
The Physics Teacher	**TPT1**	I feel relaxed when my Physics teacher is in class.				
(TPT)	**TPT2**	I do not enjoy my Physics teacher's teaching.				
	TPT3	My Physics teacher uses a combination of teaching aids while teaching				
	TPT4	My Physics teacher does not encourage critical thinking.				

APPENDIX C

THE OPTICS CONCEPT ACHIEVEMENT TEST (OCAT)

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENURIAL DEVELOPMENT

DEPARTMENT OF INTEGRATED SCIENCE EDUCATION

OPTICS CONCEPT ACHIEVEMENT TEST

POST-INTERVENTION TEST DURATION**: 30 minutes**

School:

………………………………………………………………………………………

Age: ☐ **Class:** ☐ **Gender: Male** **Female** ☐

GENERAL INSTRUCTIONS: This test has been grouped in two sections, namely section A and section B. Please answer ***all*** questions in both sections of the test.

SECTION A

The following questions are followed by options Lettered A-D. Choose the correct answer from the options below by circling it.

1. Which of the following is a type of reflection?
   a. Incident reflection
   b. Irregular reflection
   c. Molecular reflection
   d. Normal reflection
2. When two or more rays meet or appear to meet, a/an ……..……….. is formed.
   a. character
   b. image

c. light

d. object

3. If an object is placed in front of a mirror at a distance of 6cm, what will be the distance between the mirror and the image?

   a. 2cm

   b. 3cm

   c. 6cm

   d. 12cm

4. ……………..…. are formed by the actual intersection of two or more rays from an object.

   a. Erect images

   b. Lateral images

   c. Optical images

   d. Real images

5. The image produced in a camera is an example of ………

   a. erect images.

   b. lateral images.

   c. real images.

   d. virtual images.

6. In scattered reflection, the surface of reflection is…………

   a. blur.

   b. rough.

   c. sharp.

   d. smooth.

7. An image on a plane mirror is laterally inverted which implies that ……….

a. it cannot be formed on a screen.

b. it is difficult to see with the naked eye.

c. its left becomes right and right becomes left.

d. its object appears to be virtual.

8. The angle of incidence is ………….……. the angle of reflection.

a. double of

b. equal to

c. half of

d. less than

9. Light waves …………

a. can travel through a perfect vacuum.

b. can travel through magnetic fields only.

c. require air or another gas to travel through.

d. require an electric field to travel through.

10. When all parallel rays incidenting on a surface are reflected through the same angle,……..

a. angular reflection occurs.

b. irregular reflection occurs.

c. scattered reflection occurs.

d. specula reflection occurs.

11. The angle of incidence is represented by the symbol…

a. d

b. g

c. i

d. r

12. A/An………. is formed on the screen of the plane mirror.

   a. character
   b. image
   c. object
   d. shadow

13. One characteristic of a virtual image is that,

   a. it can be formed on the screen.
   b. it cannot be formed on the screen.
   c. it is formed by the actual intersection of two or more rays from an object.
   d. it is formed in a camera.

14. ……… reflection is the reason for the ability to observe most illuminated surfaces from an angle.

   a. Angular
   b. Diffused
   c. Specular
   d. Regular

15. The reflected light ray is always in the plane, which is defined by the …………. to the surface and the incident ray.

   a. Angle
   b. axis
   c. beam
   d. normal

SECTION B

ESSAY QUESTIONS

Answer ***all*** questions in this section by providing your answers in the spaces provided below.

1. a. Define the term Reflection of light. (2 marks)

…………………………………………………………………………………………

…...……………………………………………………………………………………...

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

b. Briefly explain why the letters on the front of an ambulance are reversed. (3 marks)

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

……………………………………………………………………………………..……

………………………………………………………………………………………..

c. State the two laws of reflection. (4 marks)

………………………………………………………………………………………..

………………………………………………………………………………………..

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………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

2. a. With the aid of a diagram, briefly explain how light is reflected on a plane mirror. (3 marks)

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

b. Explain briefly the distance that exist between you and your image if you stand in front of a plane mirror. (3 marks)

…………………………………………………………………………………………

……..……………………………………………………………………………………

……………..……………………………………………………………………………

.…………………….……………………………………………………………………

…………………………...………………………………………………………………

…………………………………..…………………………………………………………

………..…………………………………………………………………………………

THANK YOU.

APPENDIX D

INTRODUCTORY LETTER FROM THE FACULTY OF SCIENCE EDUCATION

AKENTEN APPIAH-MENKA UNIVERSITY
of Skills Training and Entrepreneurial Development

FACULTY OF SCIENCE EDUCATION
DEPARTMENT OF INTEGRATED SCIENCE EDUCATION
P.O. Box 40, Asante Mampong   0270001890, 0502972415

M/DISE/ADM/STU/01/08   NOVEMBER 28, 2022

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

INTRODUCTORY LETTER FOR MR. SIMON TANKO

We write to introduce Mr. Simon Tanko, who is an M.Phil. (Science Education) student of this Department. Mr. Tanko is working on a project titled "A comparative study of the MR-SR Based PIMCA model and the conventional teaching method on the academic performance of Senior high School physics students" and would like to collect data from your institution for a period of six (6) months to enable him complete his dissertation, which is a requirement for graduation.

We would be grateful if you could offer him the needed assistance. We count on your usual cooperation.

Thank you.

Yours faithfully,

DR. EBENEZER E. MENSAH
(AG. HEAD OF DEPARTMENT)

HEAD
DEPT. OF INTEGRATED SCIENCE
FACULTY OF SCIENCE EDUCATION
COLLEGE OF AGRIC EDUCATION
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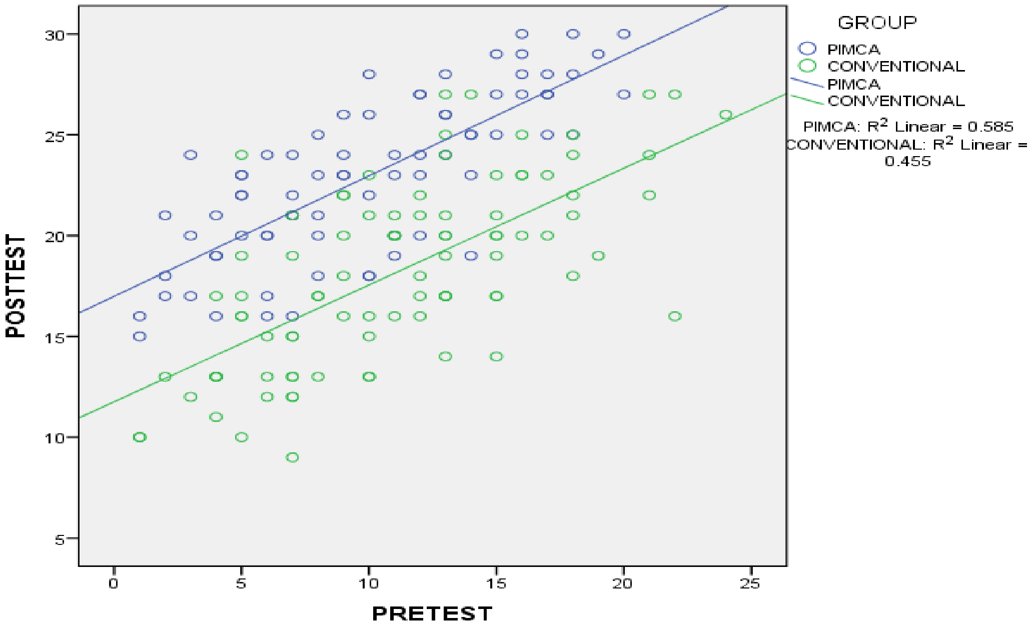
APPENDIX E

TABLE OF TEST SPECIFICATION ON REFLECTION OF LIGHT

Content	**Knowledge**	**Comprehension**	**Application**	**Total**
Definition of Reflection of light	3	2		5
Laws of Reflection	2	2		4
Types of Reflection	3	1		4
Images	3		1	4
Characteristics of plane mirror images	1	3	4	8
TOTAL	12	8	5	**25**

APPENDIX F

Results of linear relationship between the dependent variable and the covariate of SHS Physics students taught using MR-SR Based PIMCA Model and Conventional Teaching Method



APPENDIX G

Results of Test of Homogeneity of Regression Slope on covariate (pretest scores) and dependent variable (posttest scores) of SHS Physics students taught using MR-SR Based PIMCA Model and Conventional Teaching Method

Dependent Variable: POSTTEST

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2421.673[a]	3	807.224	87.625	.000
Intercept	6473.166	1	6473.166	702.672	.000
Group	214.321	1	214.321	23.265	.000
Pretest	1496.348	1	1496.348	162.431	.000
Teaching Method* Pretest	.365	1	.365	.040	.843
Error	1473.955	160	9.212		
Total	72203.000	164			
Corrected Total	3895.628	163			

APPENDIX H

Results of Test of Assumption of Homogeneity of Variances on Posttest Scores of SHS Physics students taught using MR-SR Based PIMCA Model and Conventional Teaching Method

Dependent Variable: POSTTEST

F	df1	df2	Sig.
2.582	3	160	.055

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

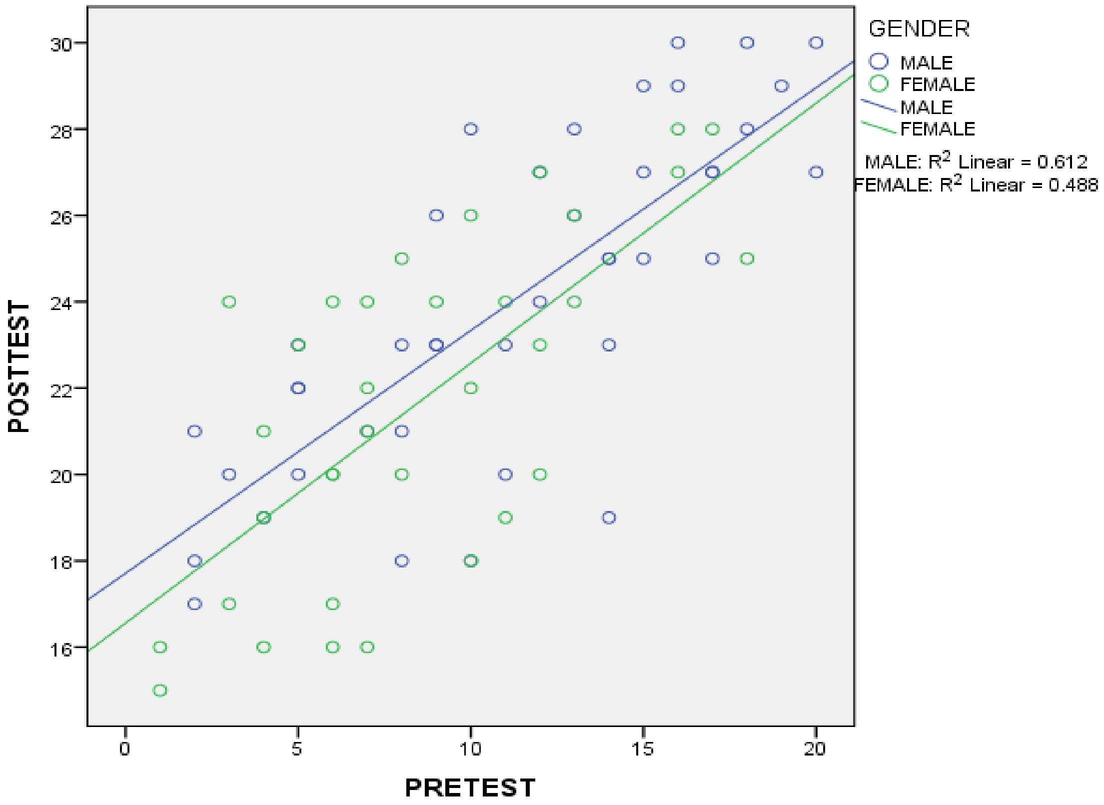
APPENDIX I

Results of Independent Sample t-test on Pretest Scores of Male and Female SHS Physics students Taught Using MR-SR Based PIMCA Model

Gender	N	Mean	SD	t	df	p
Males	34	10.37	5.257	1.881	73	0.042
Females	41	8.29	4.049			

APPENDIX J

Linear Relationship between covariate (pretest scores) and dependent variable (posttest scores) of male and female SHS Physics students taught using MR-SR Based PIMCA Model



APPENDIX K

Results of Test of Homogeneity of Regression Slope on covariate (pretest scores) and dependent variable (posttest scores) of male and female SHS Physics students taught using MR-SR Based PIMCA Model

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	700.688[a]	3	233.563	34.746	.000
Intercept	4257.158	1	4257.158	633.322	.000
Gender	4.826	1	4.826	.718	.400
Pretest	564.158	1	564.158	83.928	.000
Gender * Pretest	.659	1	.659	.098	.755
Error	477.259	71	6.722		
Total	40761.000	75			
Corrected Total	1177.947	74			

APPENDIX L

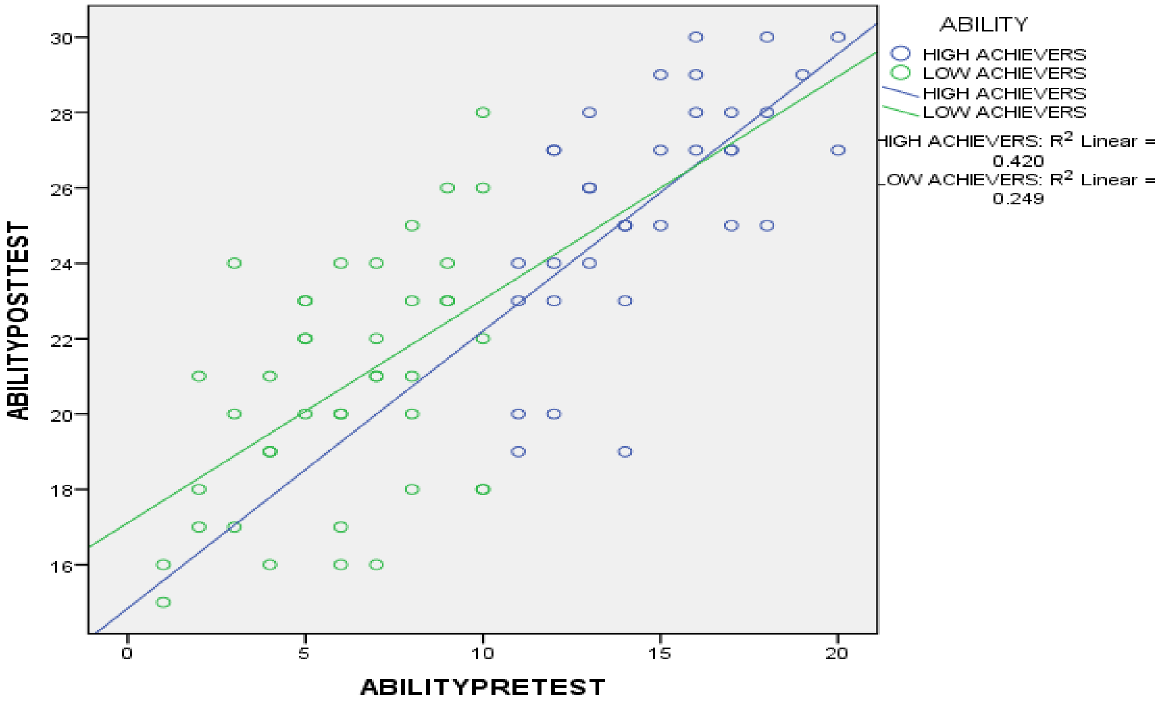
Results of Test of Assumption of Homogeneity of Variances on Posttest Scores of male and female SHS Physics students taught using MR-SR Based PIMCA Model

F	df1	df2	Sig.
.077	1	87	.783

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

APPENDIX M

Linear Relationship between covariate (pretest scores) and dependent variable (posttest scores) of high achieving and low achieving SHS Physics students taught using MR-SR Based PIMCA Model



APPENDIX N

Results of Test of Homogeneity of Regression Slope on covariate (pretest scores) and dependent variable (posttest scores) of High and Low Achieving SHS Physics students taught using MR-SR Based PIMCA Model

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	694.983[a]	3	231.661	34.056	.000
Intercept	936.488	1	936.488	137.672	.000
Ability	4.709	1	4.709	.692	.408
Abilitypretest	230.496	1	230.496	33.885	.000
Ability*Pretest	2.684	1	2.684	.395	.532
Error	482.963	71	6.802		
Total	40761.000	75			
Corrected Total	1177.947	74			

APPENDIX O

Results of Test of Assumption of Homogeneity of Variances on Posttest Scores of High and Low Achieving SHS Physics students taught using MR-SR Based PIMCA Model

F	df1	df2	Sig.
1.636	1	73	.205

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

APPENDIX P

Cohen's d indices

Effect Size	Interpretation
≤ 0.2	Small effect
≤ 0.5	Medium effect
≤ 0.8	Large effect

Source: Cohen et al. (2018)

APPENDIX Q

Informed Consent Form

1. I have had the research explained to me, and I have read the information sheet.

2. I agree to participate in the research as described.

3. I acknowledge that:

- **a.** I understand that my participation is voluntary, and that I am free to withdraw from the project at any time.
- **b.** The project is for the purpose of research. It may not be of direct benefit to me.
- **c.** The privacy of the personal information I provide will be safeguarded.
- **d.** The security of the research data will be protected during and after completion of the study.

4. If you voluntarily agree to participate in this experimental study, check I agree, else check I do not agree.

I agree ☐ **I do not agree** ☐

APPENDIX R

Independent Sample t-test on Pretest Scores of High and Low Achieving SHS Physics students Taught Using MR-SR Based PIMCA Model

Group	**N**	**Mean**	**SD**	**t**	**df**	**p**
High Achievers	25	15.92	2.159	20.147	50	0.000
Low Achievers	27	4.56	1.908			

APPENDIX S

Lesson Plan for the MR-SR Based PIMCA Model

Lesson Objectives: By the end of the lesson, student will be able to

1. Define Reflection of Light
2. State the Laws of reflection
3. Explain at least one type of reflection

Semiotic Resources	**Stages/ Content/ Time**	**Teacher Activity**	**Student Activity**	**Core point**
	Introduction (5 minutes)	Teacher introduces the lesson by asking students how they are able to see that their hairs were well combed before coming to school	Students responded by saying; I looked through a mirror	
YouTube Video, images	Stage 1 **Presentation stage** (10 minutes) 1. Definition of Reflection of light 2. Laws of reflection 3. Types of reflection	Teacher projects a YouTube videos as well as images of the concepts using a laptop computer	Students watched attentively	

	Stage 2 **Idea-Mapping** (10 minutes)	Teacher asks students to formulate and note down concepts from the presentations.	Students formulated and noted down concepts as they watched the presentations	
	Stage 3 **Conceptualisation** (20 minutes)	Teacher asks students the concepts they have formulated and assists them correct and formulate rightful concepts	Students voiced out their concepts, asks for clarification and noted down key points	**Reflection of Light** Reflection of light is the bouncing back of light by an object. Shiny surfaces (mirrors) or highly polished surfaces are good reflectors. **Laws of Reflection** **Law 1:** The incident ray, the reflected ray and the normal and the normal at a point of incidence all lie in the same plane. **Law 2:** The angle of incidence is equal to the angle of reflection (i=r)

				Types of Reflection There are two types of reflection. They are: 1.Regular/Specula reflection 2.Irregular/diffuse/ scattered reflection **Regular/Specula reflection** This occurs when the surface of the reflection is smooth or highly polished. Example is mirror. Regular reflection occurs when all parallel rays incidenting on a surface are reflected through the same angle and the image produced is clear and well defined.

				Irregular/diffuse/ scattered reflection This occurs when 1. The surface of reflection is rough 2. Most if the light rays incidenting on the surface are absorbed 3. Incident parallel rays are reflected in different directions or scattered It forms images that are not well defined
	Stage 4 Assessment (10 minutes)	Teacher asks students to answer these questions in their exercise books **1.**What is reflection of light **2.**State the Laws of reflection **3.**explain any one type of reflection		

	Conclusion (5 minutes)	Teacher concludes the days lesson and brings it to a close		

APPENDIX T

Lesson Plan for the Control Group

Lesson Objectives: By the end of the lesson, student will be able to

1. Define Reflection of Light
2. State the Laws of reflection
3. Explain at least one type of reflection

Teaching Resources	Activity/ Step/ Time	Teacher Activity	Students' Activity	Core Point
	Step 1 Introduction (10 Minutes)	Teacher introduces the lesson by asking students how they are able to see that their hairs were well combed before coming to school	Students responded by saying; I looked through a mirror	
Mirror, Torchlight	**Step 2** Development Definition of Reflection of Light (10 Minutes)	Teacher guides students to define Reflection of Light as he demonstrates using a mirror and a torch.	Students paid attention and participated in the lesson	**Reflection of Light** Reflection of light is the bouncing back of light by an object. Shiny surfaces (mirrors) or highly polished surfaces are good reflectors.

Chart	Laws of Reflection (10 Minutes)	Teacher displays a chart explaining the Laws of reflection on the board as he assists students in stating them	Students observed carefully and stated the laws of reflection	**Laws of Reflection** **Law 1:** The incident ray, the reflected ray and the normal and the normal at a point of incidence all lie in the same plane. **Law 2:** The angle of incidence is equal to the angle of reflection (i=r)
chart	Types of Reflection (10 Minutes)	Teacher helps students to explain the laws of reflection as he displays a chart on the board.	Students participated in the lesson as they observed and explained the laws of reflection	**Types of Reflection** There are two types of reflection. They are: 1.Regular/Specula reflection 2.Irregular/diffuse/ scattered reflection

				Regular/Specula reflection This occurs when the surface of the reflection is smooth or highly polished. Example is mirror. Regular reflection occurs when all parallel rays incidenting on a surface are reflected through the same angle and the image produced is clear and well defined. **Irregular/ diffuse/ scattered reflection** This occurs when 1. The surface of reflection is rough 2. Most if the light rays incidenting on

				the surface are absorbed 3. Incident parallel rays are reflected in different directions or scattered It forms images that are not well defined
	Conclusion (10 Minutes)	Teacher summarises the days lesson and brings it a close as he allows students to ask their questions	Students listened attentively and asked their questions	
	Evaluation (10 Minutes)	Teacher evaluates the lesson by asking the following questions: **1.**What is reflection of light **2**.State the Laws of reflection **3**.explain any one type of reflection	Students responded by answering them in their exercise books	