

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT**

**COMPARATIVE EFFECTS OF 5E, DIFFERENTIATION, AND
CONVENTIONAL TEACHING METHODS ON PHYSICS STUDENTS'
ACADEMIC PERFORMANCE IN THERMAL PHYSICS**

KENNETH DARKO ATEKO

NOVEMBER, 2023

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT**

**COMPARATIVE EFFECTS OF 5E, DIFFERENTIATION, AND
CONVENTIONAL TEACHING METHODS ON PHYSICS STUDENTS'
ACADEMIC PERFORMANCE IN THERMAL PHYSICS**

BY

KENNETH DARKO ATEKO

(8211920027)

**A Thesis Submitted to the School of Graduate Studies, Akenten Appiah-Menka
University of Skills and Entrepreneurial Development in Partial Fulfillment of the
Requirements for the Award of a Master of Philosophy Degree in Science
Education**

NOVEMBER, 2023

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.

Kenneth Darko Ateko

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 Appia-Menka University of Skills and Entrepreneurial Development.

Dr. Isaac Owusu-Mensah (Principal supervisor)

Sign..... **Date**.....

Rev. Dr. George Oduro-Okyireh (Co-supervisor)

Sign **Date**.....

ABSTRACT

In this study, the comparative effect of 5E Instructional Model, Differentiated Instruction and conventional teaching method on Senior High School (SHS) Physics students' academic performances in Thermal Physics was investigated. Employing a quasi-experimental pretest/posttest non-equivalent control group design, 291 SHS 2 Physics students were employed from six intact classes from 3 randomly selected Senior High Schools in the Mampong Municipality and Sekyere South District. The instrument used for data collection was Thermal Physics Concepts Test (TPCT). The hypotheses were tested using independent sample t-tests, one-way ANCOVA and two-way ANCOVA at $\alpha=0.05$. The results indicated that, SHS students taught using 5E Instructional Model performed better ($M=16.59$, $SD=5.168$) than those taught using conventional teaching method ($M=13.34$, $SD=5.010$; $t_{(191)}=4.437$, $p=0.000<0.05$). Similarly, SHS students taught using Differentiated Instruction performed better ($M=19.12$, $SD=5.766$) compared to the conventional teaching method ($M=13.34$, $SD=5.010$; $t_{(188)}=7.362$, $p=0.000<0.05$), and also compared to the 5E Instructional Model ($F_{(1,196)}=34.833$, $p=0.000$), after introducing the interventions. However, there was no significant difference in academic performance between male and female SHS Physics students taught using Differentiated Instruction (mean difference= 0.233 , $p=0.765$) and 5E Instructional Model (mean difference= 0.75 , $p=0.532$), but a significant difference in academic performance between male and female SHS Physics students taught using conventional teaching method (mean difference= 8.284 , $p=0.000$). It was therefore recommended, amongst others that SHS Physics teachers should consider Differentiating their students in order to tailor Physics lessons to all students, which will help them perform better in Thermal Physics.

ACKNOWLEDGEMENTS

I could not have finished this work without the support, and dedication of my supervisors, family, friends, and colleagues, to whom I am most grateful, and who deserve my appreciation. First, and foremost, my genuine appreciation goes to my supervisors, Dr. Isaac Owusu-Mensah and Rev. Dr. George Oduro-Okyireh for their guidance, valuable comments, suggestions, and advice given to me during the period of this work.

Furthermore, my thanks go to Dr. Eric Appiah-Twumasi, who has taken me as his son, for his assistance and selfless attitude to help young graduates reach the pinnacle of the educational ladder. Also, to my diligent mother, Gifty Adomako, who provided extraordinary support and guidance in adverse times during this study. Finally, to Reverend Emmanuel Owusu Boakye for his spiritual backing and encouragement throughout this study, and also, any other person who contributed to the successful completion of the work.

DEDICATION

This work is dedicated to my mother, Gifty Adomako and my siblings: Theophilus Mante Ateko Darko and Sheilla Aboagyewaa Ateko Darko.

TABLE OF CONTENTS

DECLARATION.....	ii
ABSTRACT	iii
ACKNOWLEDGEMENTS	iv
DEDICATION	v
LIST OF TABLES	xiv
LIST OF FIGURES	xvi
ABBREVIATIONS	xvii
CHAPTER ONE.....	1
INTRODUCTION	1
1.0 Overview	1
1.1 Background to the Study	1
1.2 Statement of the Problem	9
1.3 Main Objective of the Study	11
1.4 Specific Objectives of the Study	11
1.5 Research Hypotheses	12
1.7 Significance of the Study	12
1.8 Justification of the Study.....	13
1.9 Delimitations of the Study	13
1.10 Limitations of the Study	14
1.11 Operational Definition of Terms	15
1.12 Organisation of the Study	15
CHAPTER TWO.....	17

LITERATURE REVIEW	17
2.0 Overview	17
2.1 Theoretical Review of the Study.....	17
2.2 Conceptual Framework of the Study.....	28
2.3 Conceptual Review of the Study’s Variables.....	31
2.3.1.5 Evaluation Phase.....	35
2.3.2 The Concept of Differentiated Instruction	35
2.3.6.1 Students’ Difficulties in Thermal Physics.....	59
2.4 Empirical Review of the Study.....	61
2.6 Summary of Literature Review	68
CHAPTER THREE	70
METHODOLOGY	70
3.0 Overview	70
3.1 Study Areas	70
3.2 Research Paradigm.....	73
3.3 Research Design.....	74
3.4 Population	78
3.5 Sample.....	78
3.6 Sampling Technique.....	79
3.7 Data Collection Instrument	80
3.8 Validity of the Instrument	82
3.9 Pilot testing of the Instrument	85
3.10 Reliability of Research Instrument.....	86

3.11	Data Collection Procedure	87
3.12	Data Analyses Procedure	94
3.13	Ethical Considerations	96
CHAPTER FOUR		98
RESULTS AND DISCUSSION		98
4.0	Overview	98
4.1	Gender Distribution of Participants	98
4.2	Pretest and Posttest Scores for 5E Instructional Model, Differentiated and Conventional groups	99
2.4	Pretest and Posttest Scores of Male and Female SHS Physics Students Within All Groups	101
4.4	Data Distribution of Pretest and Posttest Scores for All Groups	103
4.5	Preliminary Analysis of Pretest Scores of SHS Physics Students Within All Groups	105
4.6	Difference Between the Use of 5E Instructional Model and Conventional Teaching Method in the Teaching and Learning of Thermal Physics	107
4.7	Difference Between the Use of Differentiated Instruction and Conventional Teaching Method in the Teaching and Learning of Thermal Physics	109
4.8	Difference Between the Use of 5E Instructional Model and Differentiated Instruction in the Teaching and Learning of Thermal Physics	111
4.9	Difference Between the Use of 5E Instructional Model, Differentiated Instruction and Conventional Teaching Method on Male and Female SHS Physics Students in the Teaching and Learning of Thermal Physics	114

4.10	Discussion of Findings	120
CHAPTER FIVE	.....	128
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	.....	128
5.0	Overview	128
5.1	Summary of Findings	128
5.2	Conclusions	130
5.3	Recommendations	131
5.4	Suggestions for Further Research	132
REFERENCES	.....	133
APPENDICES	.....	163
Appendix A: Thermal Physics Concept Test (TPCT)	.....	163
Appendix B1	.....	170
Histogram Distribution of Pretest Scores of 5E Instructional Model Group	.....	170
Appendix B2	.....	170
Normal Q-Q Plot for Pretest Scores of 5E Instructional Model Group	.....	170
Appendix C1	.....	171
Histogram Distribution for Posttest Scores of 5E Instructional Model Group	.....	171
Appendix C2	.....	171
Normal Q-Q Plot for Posttest Scores of 5E Instructional Model Group	.....	171
Appendix D1	.....	172
Histogram Distribution for Pretest Scores of Differentiated Instruction Group	.....	172
Appendix D2	.....	172
Normal Q-Q Plot for Pretest Scores of Differentiated Instruction Group	.....	172

Appendix E1	173
Histogram Distribution for Posttest Scores of Differentiated Instruction Group	173
Appendix E2	173
Normal Q-Q Plot for Posttest Scores of Differentiated Instruction Group.....	173
Appendix F1	174
Histogram Distribution for Pretest Scores of Conventional Group	174
Appendix F2	174
Normal Q-Q Plot for Pretest Scores of Conventional Group	174
Appendix G1.....	175
Histogram Distribution for Posttest Scores of Conventional Group	175
Appendix G2.....	175
Normal Q-Q Plot for Posttest Scores of Conventional Group.....	175
Appendix H1.....	176
Box Plots for Pretest and Posttest Scores for 5E Instructional Model, Differentiated Instruction, and Conventional Groups	176
Appendix H2.....	176
Box Plots for Pretest and Posttest Scores for Male and Female Students in 5E Instructional Model, Differentiated Instruction, and Conventional Groups.....	176
Appendix I1	177
Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Conventional Group.....	177
Appendix I2	177

Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Conventional Group.....	177
Appendix J	178
Results of One-Way ANCOVA on Posttest Scores of 5E Instructional Model Group and Conventional Group.....	178
Appendix K1	179
Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Differentiated Instruction Group and Conventional Group.....	179
Appendix K2.....	179
Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Differentiated Instruction Group and Conventional Group	179
Appendix L	180
Results of One-Way ANCOVA on Posttest Scores of Differentiated Instruction Group and Conventional Group.....	180
Appendix M1	181
Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Differentiated Instruction Group	181
Appendix M2	181

Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Differentiated Instruction Group	181
Appendix N.....	182
Results of Levene's Test of Equality of Error Variances of Posttest Scores Between 5E Instructional Model Group and Differentiated Instruction Group.....	182
Appendix O.....	183
Results for Two-Way Between Groups Analysis of Variance of Male and Female Pretest Scores Within All Groups.....	183
Appendix P1	184
Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Male and Female SHS Physics Students Within All Groups	184
Appendix P2	184
Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Male and Female SHS Physics Students Within All Groups	184
Appendix Q.....	185
Results for Levene's Test of Equality of Error Variances of Male and Female SHS Physics Students Within All Groups	185
Appendix R.....	186
Student's Interest Inventory.....	186
Appendix S	188

Learning Style Questionnaire	188
Appendix T	192
Informed Consent Form.....	192
Appendix U.....	193
Introductory Letter	193
Appendix V.....	194
Formula for Eta Squared.....	194

LIST OF TABLES

Table 2.1: Summary of Gardner’s Eight Intelligences.....	18
Table 3.1: Participants’ Distribution According to School and Gender.....	78
Table 3.2: Stages of Multi-Stage Sampling Technique Used in this Study	79
Table 3.3: Content Selection of Thermal Physics Concept Test	82
Table 3.4: Calculated Content Validity Index and Content Validity Ratio for TPCT ...	84
Table 3.5: Internal Consistency for “Section A” of TPCT.....	86
Table 3.6: Results for Inter-Rater Reliability of “Section B” of TPCT	87
Table 3.7: Thermal Physics Content Taught to All Groups	90
Table 3.8: Intervention Activities for 5E Instructional Model Group.....	91
Table 3.9: Intervention Activities for Differentiated Instruction Group	92
Table 3.10: Intervention Activities for Conventional Group	93
Table 4.1: Descriptive Statistics of Pretest and Posttest Scores of 5E Instructional Model (5E), Differentiated Instruction (DI) and Conventional Groups	100
Table 4.2: Descriptive Statistics of Pretest and Posttest Scores of Male and Female SHS Physics Students Within All Groups	102
Table 4.3: Test of Normality for Pretest and Posttest Scores of 5E Instructional Model (5E), Differentiated Instruction (DI) and Conventional Groups.....	104
Table 4.4: Results for Test of Homogeneity of Variances on Pretest Scores for All Groups.....	106
Table 4.5: Results of One-way Between Groups Analysis of Variance on Pretest Scores for All Groups	106

Table 4.6: Results for Test of Homogeneity of Variances on Posttest Scores of 5E Instructional Model Group and Conventional Group	108
Table 4.7: Results of Independent Sample t-test for Posttest Scores of 5E Instructional Model and Conventional Groups	108
Table 4.8: Results for Test of Homogeneity of Variances on Posttest Scores for Differentiated Instruction Group and Conventional Group	110
Table 4.9: Results of Independent Sample t-test on Posttest Scores of Differentiated Instruction and Conventional Groups	111
Table 4.10: Results of One-Way Analysis of Covariance on Posttest Scores for 5E Instructional Model Group and Conventional Groups.....	113
Table 4.11: Descriptive Statistics of Adjusted Posttest Mean Scores of 5E Instructional Model Group and Differentiated Instruction Group	114
Table 4.12: Results of 2 by 2 Between Groups Analysis of Covariance of Male and Female SHS Physics Students Within All Groups.....	116
Table 4.13: Descriptive Statistics of Male and Female SHS Physics Students' Adjusted Posttest Scores Within All Groups.....	118
Table 4.14: Simple Effect Analysis of Posttest Scores of Male and Female SHS Students Within All Groups	119

LIST OF FIGURES

Figure 2.1:	Conceptual Framework of the Study.....	29
Figure 3.1:	Geographical Map of Study Areas.....	72
Figure 3.2:	Flowchart of the Study Design.....	77
Figure 4.1	Gender Distribution of Participants.....	99
Figure 4.2:	Estimated Marginal Means Plot of Posttest Scores of TPCT For Male and Female SHS Physics Students for 5E Instructional Model, Differentiated Instruction and Conventional Groups.....	117

ABBREVIATIONS

BSCS	:	Biological Science Curriculum Study
CVI	:	Content Validity Index
CVR	:	Content Validity Ratio
OECD	:	Organisation for Economic Cooperation and Development
SHS	:	Senior High School
STEM	:	Science, Technology, Engineering and Mathematics
TPCT	:	Thermal Physics Concepts Test
UNESCO	:	United Nations Educational, Scientific, and Cultural Organisation.
WAEC	:	West African Examinations Council
WASSCE	:	West African Senior School Certificate Examination.
ZDP	:	Zone of Proximal Development.

CHAPTER ONE

INTRODUCTION

1.0 Overview

The chapter highlights a background to the study, delineates the problem investigated, outlines the purpose of the study, as well as the specific objectives of the study. Also, the hypotheses are outlined in this chapter. It goes on to highlight the significance of the study, details its boundaries or delimitations, and lists its various limitations. In conclusion, this chapter provides definitions for words used throughout this study and an overview of the overall organisation of the study.

1.1 Background to the Study

The advancement of science and innovation has occurred in nations that have invested in their human resources (Amankona et al., 2018). Therefore, when its citizens are highly educated, every nation may advance. It is general knowledge that modern development now relies heavily on education in science and technology. As a branch of science, Physics as a study includes the nature of matter and energy, as well as how they interact and their measurements. Physics research has had, and continues to have, a significant influence on society at large. This is because Physics-related concepts, abilities, and attitudes are frequently used in numerous scientific and technical advancements. For instance, advancements in renewable energy are greatly assisting the world, and it is hoped that they will increase in Ghana to complement other sources and help the country meet its energy needs. Solar energy is one particular example of renewable energy since it can be converted into useful forms like electrical energy for residential use, machinery, and basic equipment.

The concepts and uses of Physics are universal. Physical actions like walking, lifting things, seeing, and taking pictures are all impacted by the concepts and applications of Physics (Ministry of Education, 2010).

Ogunleye and Babajide (2016) also acquiesce that, numerous inventions, including the creation, use, and application of integrated circuits as well as the creation and use of machines and other devices, have been made possible thanks to our understanding of Physics. It also explains the working of telephones, refrigerators, heaters, and cookers as well as the development of gas turbine, thermonuclear, and hydroelectric power plants. Therefore Physics is a particularly important branch of science in this setting, and understanding its ideas and developing its skills is essential in the highly advanced society of the 21st century (Sanchez & Ponce, 2020).

Thermal Physics is studied as one of the major concepts in the Ghanaian Senior High School (SHS) Physics curriculum (Ministry of Education, 2010). Thermal Physics, according to the Ministry of Education (2010) is a field of science that deals with heat and temperature. In general, the study of Thermal Physics is the energetic study of the statistical properties of physical systems. It encompasses the relationship between heat and work and the interaction between microscopic particles. Its importance stems from its capacity to describe how the world functions, including the dispersion of heat in the earth's atmosphere, and its connection to weather and climate, even in these days where global climate has been fraught with challenges. Also, small-scale everyday applications such as cooking, automobile engines, refrigerators, incandescent lights, and antifreeze require an

understanding of Thermal Physics. Thermal Physics begins with the fundamentals of heat and temperature and investigates the first and second laws of thermodynamics from a statistical standpoint, in terms of the number of microstates corresponding to a certain macrostate (Garg, Bansal & Ghosh, 2012). This means that Thermal Physics deals with large number of particles. Examples of these particles include the air in a balloon, the water in a lake, the electrons in a chunk of metal, and the photons (that is, the electromagnetic wave packets given off by the sun). Thus, anything large enough to be seen with the naked eye or even under a traditional microscope can be considered a subject of Thermal Physics. Practically all contemporary Physics and the significant technological issues we face in this century depend on our ability to comprehend Thermal Physics (Blundell & Blundell, 2010).

The part of Thermal Physics studied in high school include temperature, its measurement and temperature changes, as well as heat and heat transfer (Ministry of Education, 2010). Considering the relevance of Thermal Physics, as discussed, it is expected that the academic performances of students in public examinations would be on the increase. Contrary to this, indices from research reports and from examinations such as those organised by the West African Examinations Council (WAEC) showed students' poor performance in Thermal Physics. According to Blundell and Blundell (2010), students frequently find these topics challenging, which is also reflective in the WAEC chief examiners' reports in 2017, 2018, 2019 and 2020.

A perusal through the chief examiners' reports from the West African Examinations Council (WAEC) revealed that “many candidates had difficulty in solving problems on resistance and gas thermometers (WAEC, 2017 p. 322)”. Also, in 2018, it was stated that candidates demonstrated difficulty in solving heat problems, and also exhibited insufficient knowledge in the concept of heat transfer (WAEC, 2018, p. 368). Similar challenges recurred in 2019 and 2020, where candidates again found it difficult to solve heat problems, and also appeared to possess less amount of knowledge in some heat concepts according to the chief examiners (WAEC, 2019, p. 381; 2020, pp.493-494). In 2021, the chief examiner reported, concerning problems under Thermal Physics that, “most of the candidates could not explain what a calorimeter is, and also only few candidates, among the very few that opted, could solve heat problems” (WAEC, 2021, pp. 446-447). It is therefore imperative to take immediate action to address this issue of low academic performance in Thermal Physics, which has been the subject of research for many years, before it gets out of control in the near future.

Motivated by the situation of the consistent poor academic performances of students, researchers have delved into the possible causes of this problem, and have reported that ineffective instructional methods employed by teachers strongly hamper the academic performances of students (Appiah-Twumasi et al., 2022; Buabeng et al., 2014; Chibwana & Rajamehala, 2022; Coffie et al., 2020; Garzón-Agudelo et al., 2020; Njiru & Karuku, 2015; Opore et al., 2018; Quansah et al., 2022), as well as gender differences (Andam et al., 2019; Assem et al., 2023; Ngari et al., 2018; Wrigley-Asante et al., 2023). In this regard, Djajalaksana et al. (2013) revealed that, what students do in the classroom has the

propensity to impact on all the domains of human learning (cognitive, affective and psychomotor domains). Therefore, the majority of students need numerous opportunities to interact with the material or put their new skills into practice in order to learn it.

According to the Organisation for Economic Cooperation and Development (OECD), classroom atmosphere has an impact on students' learning outcomes (OECD, 2018). This is also evident in Ghana as studies (Assem et al., 2023; Azigwe et al., 2016; Bonney et al., 2015; Kwaah & Palojoki, 2018) reveal the poor academic performances students obtain in Physics as a result of inappropriate instructional methods employed by teachers.

Learning is often presented in this dualism of either student-centered learning (constructivist perspective about learning and instruction) or teacher-centered learning (direct transmission perspective about learning and instruction) (Felder & Brent, 2017; Olifer, 2020; Serin, 2018). However, research has shown that there is a paradigm shift from the “conventional teacher-centered teaching” to the “contemporary learner-centered teaching”, for the fact that the learner-centered teaching have evidently improved the performance of learners more than the “conventional teacher-centered teaching” (Appiah-Twumasi, 2020; Bara & Xhomara, 2020; Radzali et al., 2018; Siddiqui & Khatoun, 2013; Tebabal & Kahssay, 2015). In view of this, the Ghanaian educational system demonstrates full support to the learner-centered teaching, after a review of the Physics syllabus designed for SHS in Ghana indicated that teachers should employ “teaching and learning activities that maximise student participation in lessons and avoid rote learning and drill-oriented

methods to enhance the cognitive, affective and psychomotor domains of knowledge” (Ministry of Education, 2010, p.vi).

However, there was no specific student-centered teaching method suggested in the syllabus to be considered in the teaching of Physics at the SHS, as Heinich et al. (2002), as well as Marcourt et al. (2022) argue that, not all teaching methods are appropriate to teach all concepts. Hence, diverse teaching and learning strategies and methods which support learner-centered approach have been suggested by researchers to improve learners’ understanding of scientific concepts. Among these learning strategies include the 5E Instructional Model (Abdulraheem et al., 2018; Appiah-Twumasi et al., 2021; Bybee, 2018) and Differentiated Instruction (Awofala & Lawani, 2020; Obafemi, 2022; Salar & Turgut, 2021).

The Biological Science Curriculum Study’s (BSCS) 5E Instructional Model was developed by a team led by Roger Bybee as the main investigator (Borah, 2020). Its five phases are engagement, exploration, explanation, elaboration, and evaluation. This methodology is frequently mentioned as the 5E Instructional Model or the 5Es. Each stage serves a particular purpose and aids in the development of the students' comprehension of scientific and technological information, attitudes, and skills as well as the teacher's ability to provide a cogent lesson plan. As a result, by using the 5E Instructional Model programs, units, and lessons are organised and sequenced. Once internalised, it can also help science teachers with the numerous split-second choices they face in the classroom (Bybee et al., 2006).

The 5E Instructional Model according to Bybee (2018) promotes students' active participation in the instructional processes. The effectiveness of employing 5E Instructional Model as a teaching method is supported by studies conducted by Appiah-Twumasi et al., (2021), Sam et al., (2018) and Bunkure (2019) who showed that, the application of the 5E Instructional Model improves retention, motivation, knowledge transfer and sustains learners' interest in the teaching and learning process.

Differentiated Instruction is also another learner-centered approach to teaching, which can be thought of as the modification of teaching and learning procedures, to address a range of learners' characteristics such as students' readiness levels, interests, and learning styles. Thus, in differentiation, teachers proactively alter curricula, teaching strategies, resources, learning activities and students' works to meet the varied needs of individual students in order to maximise each student's learning opportunities in a classroom (Tomlinson et al., 2003). Research has shown that Differentiated Instruction evidently affects learners' academic performances positively, as revealed by studies conducted by Kotob and Abadi (2019), Awofala and Lawani (2020), Kamran et al. (2019), and Nurasiah et al. (2020).

The result of a classroom instruction, according to Lare and Abegunrin (2014), is academic performance, which measures how well a student has met the instructional objectives. Thus, Spinath (2012) argues that, academic performance is a good indicator of a person, a group, or a country's level of intellectual education. To Spinath (2012), there are three key factors which affect academic performance of students. These are, the learner's characteristics, (intelligence, motivation, and personality), the setting for learning that replicates the conditions for learning to which the student is subjected, which include the

instructional approaches, the types of instructional media etc., and the nature of the overall educational system (e.g., early, late, or no separation into educational tracks). Therefore, if individuals and societies are going to do well, academic performance cannot be overlooked with the broad goal of improving each learner's performance according to their capabilities.

In this study, the moderating effect of gender on 5E Instructional Model, Differentiated Instruction, and the conventional teaching method was examined. The selection of this variable was made because there exist a performance gap between male and female Physics students at all levels of education (Abuh, 2021; Andam et al., 2019; Kalender et al., 2019; Morgan & Aboagye, 2022; Olusola et al., 2020; Takwe, 2019; Wrigley-Asante et al., 2023). Aina and Akintunde (2013), as well as Wilson et al. (2016) revealed that male Physics students performed better than their female counterparts in Physics. Equally, Apata (2013) discovered that in general, male students' performance in Physics are superior than those of their female peers. However, Jugović (2017) and Olusola et al. (2020) found that females obtained a higher performance in Physics than males. Given the lack of agreement on the subject of gender and Physics, and more significantly, the necessity to pique the attention of girls, as well as enhancing their performance in Physics and other Physics-related fields, it is necessary, as Babajide and Folasade (2013) as well as Kalender et al., (2019) suggested, to test out such novel teaching approaches, which maintain gender-neutral classroom environment, to determine their impact on both male and female students' performance in the sciences, in particular, Physics, amongst which are 5E Instructional Model and Differentiated Instruction.

The above background has necessitated this research, to undertake a comparative study of two learner-centered approaches to teaching, thus, “5E Instructional Model” and “Differentiated Instruction” with the conventional teaching method, as well as their comparative effect on gender in the teaching and learning of Thermal Physics.

1.2 Statement of the Problem

The study of Thermal Physics is crucial to the development of science and a nation’s economy. Thermal Physics explains how the world functions, including the dispersion of heat in the earth's atmosphere, and its connection to weather and climate (Georgiou & Sharma, 2012). However, Physics students exhibit difficulties in concepts relating to Thermal Physics, notably heat, temperature and heat transfer (Blundell & Blundell, 2010; Budiarti et al., 2017; Leinonen et al., 2013; Obafemi & Aderonmu, 2022; Saricayir et al., 2016; Winarti et al., 2017). Chief examiners from WAEC in recent years have noticed and reported that many candidates had difficulty in solving problems on resistance and gas thermometers, difficulty in solving heat problems, exhibited insufficient knowledge in the concept of heat transfer, and inability to explain a calorimeter (WAEC, 2017; 2018; 2019; 2020; 2021).

In their study, Appiah-Twumasi et al. (2021) reported high percentages of Physics students’ misconceptions about heat, temperature and heat transfer concepts, which leads to low academic performance in Physics. Similarly, Awudi and Danso (2023) also revealed that, Physics students exhibited misapplication of heat and heat transfer concepts. The performance of Physics students in the Mampong Municipality and Sekyere South District

regarding Thermal Physics is not different from the international and local perspectives highlighted. For example, a field survey in the Mampong Municipality revealed that, about 70% of 2022/2023 SHS 3 final year Physics students in their mock exams, failed to attempt questions relating to Thermal Physics, while students who attempted struggled to provide appropriate answers (Field Survey, 2023).

This poor academic performances in Thermal Physics have been reported to be due to the abstract nature of the concepts (Awudi & Danso, 2023; Blundell & Blundell, 2010), which stems from teachers' inability to select suitable instructional methods for their lessons (Appiah-Twumasi, 2020; Assem et al., 2023; Buabeng et al., 2014). In search of effective instructional methods, researchers have reached a consensus that teaching approaches that place the learner at the center of the instructional process greatly improve the understanding, as well as the academic performance of students (Abdulraheem et al., 2018; Boakye & Nabie, 2022; Donkoh et al., 2021; Kamran et al., 2019; Nurasiah et al., 2020). Accordingly, the SHS Physics syllabus encourages Physics teachers to employ such approaches in their Physics lessons (Ministry of Education, 2010). However, the SHS syllabus was short of the specificity regarding which student-centered instructional methods are to be considered by teachers.

The 5E Instructional Model (Appiah-Twumasi, et al., 2021; Bunkure, 2019; Sam et al., 2018) as well as the Differentiated Instruction (Awofala & Lawani, 2020; Kamran et al., 2019; Nurasiah et al., 2020) have been touted to enhance students' academic performances in Physics concepts more than the conventional teaching method. Nevertheless, there exists

paucity of research in the literature regarding their comparative study, especially in the Ghanaian context, on SHS Physics students' academic performances in Thermal Physics, as well as their impact on gender. Therefore, the need to compare the 5E Instructional Model and Differentiated Instruction to the conventional teaching method to determine which will greatly help Physics educators as the quest to improve students' academic performance continues.

1.3 Main Objective of the Study

The overall aim of this study was to determine the comparative effects of 5E Instructional Model, Differentiated Instruction and Conventional teaching method on Senior High School Physics students' academic performance in Thermal Physics.

1.4 Specific Objectives of the Study

The study specifically sought to:

1. Determine the difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and those taught using conventional teaching method.
2. Determine the difference in academic performance between SHS Physics students taught Thermal Physics using Differentiated Instruction and those taught using conventional teaching method.
3. Determine the difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and those taught using Differentiated Instruction.

4. Determine the difference in academic performances between male and female SHS Physics students taught Thermal Physics using each of 5E Instructional Model, Differentiated Instruction, and conventional teaching method.

1.5 Research Hypotheses

From the research objectives stated, the following null hypotheses were formulated and tested:

H₀₁: There is no significant difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and those taught using conventional teaching method.

H₀₂: There is no significant difference in performance between SHS Physics students taught Thermal Physics using Differentiated Instruction and students taught using conventional teaching method.

H₀₃: There is no significant difference in performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and students taught using Differentiated Instruction

H₀₄: There is no significant difference in academic performances between male and female SHS Physics students taught Thermal Physics using each of 5E Instructional Model, Differentiated Instruction, and conventional teaching method.

1.7 Significance of the Study

Firstly, the results of this study should inform Physics teachers, who are the major stakeholders when it comes to curriculum development and implementation, about the need

to select and adopt appropriate teaching method to teaching Thermal Physics which will significantly improve the performance of students. Furthermore, the results of this study should inform curriculum developers and other stakeholders in curriculum planning to advocate and organise frequent training workshops for in-service teachers who do not have much knowledge and skills in employing learner-centered approaches to teaching. Lastly the results of this study should inform higher institutions (colleges of education and universities) who train teachers to focus more on equipping trainee teachers with the skills in using some learner-centered approaches to teaching.

1.8 Justification of the Study

Literature is replete with studies regarding 5E Instructional Model and also Differentiated Instruction. However, in the Ghanaian Physics teaching context, it appears paucity of comparative studies can be identified in the existing literature regarding 5E Instructional Model, Differentiated Instruction and conventional teaching method, which will inform Physics educators about the appropriate instructional approach which must be employed in order to maximise the academic performance of Physics students, given the limited time and other resources at their disposal.

1.9 Delimitations of the Study

There are several concepts in the Physics syllabus that students exhibit low level of understanding in, but because all the difficult concepts could not be covered in this study due to limited time, this research focused on Thermal Physics concepts which includes heat, temperature and its measurement, thermal expansion and heat transfer. These

concepts were considered because they were the major concepts identified by researchers, as well as the chief examiners for WAEC, where SHS Physics students encounter much difficulty. Secondly, because a quasi-experimental design was employed in this study, not all schools in Mampong Municipality and Sekyere South District could participate in this study. Therefore, only three Senior High Schools from Mampong Municipality and Sekyere South District were selected to participate in this study.

Thirdly, the study focused on SHS 2 Physics students because as outlined in the Ghanaian Physics syllabus, Thermal Physics is taught in year 2 at the SHS level. Also, the study was delimited to only cognitive domain (academic performance) of human learning. The affective domain (attitude, motivation, self-efficacy, perceptions, etc.) and psychomotor domain (skills, movement, coordination and the use of motor skills) were not assessed in this study. Lastly, a quantitative research methodology was used in this study, and solely numerical data was gathered through achievement tests.

1.10 Limitations of the Study

One significant limitation in this study was that the use of quasi-experimental design prevented random assignment of participants into experimental and control groups, making it difficult to draw generalised conclusions about causal relationship between the intervention and an outcome. Therefore, the conclusions were carefully drawn to not generalize to other groups. Secondly, the violation of the assumptions of one-way between groups analysis of covariance for hypotheses 1 and 2 led to the use of independent samples

t-test. As a result, there is a likelihood the pretest had minimal influence on the posttest performance.

1.11 Operational Definition of Terms

5E Instructional Model: A learning cycle model which involves five stages, thus, engagement, exploration, explanation, elaboration, and evaluation, which provides students the opportunities to be actively involved in instructional process.

Conventional teaching method: Direct teaching from a teacher whose main responsibility is to impart knowledge to students while they sit passively listening and copying notes.

Differentiated Instruction: A method of teaching wherein instructors proactively modify lesson plans, instructional techniques, materials, learning exercises, and student assignments to accommodate each student's unique needs.

Academic Performance: This is the knowledge or skills that a student has learned that are evaluated by the teacher using the student's scores in a test or assignment based on the instructional objectives or national educational standards.

Gender: The male or female sex, especially when considered in terms of cultural and social differences instead of biological ones.

1.12 Organisation of the Study

This study is organised into five chapters, each chapter discusses an aspect of the study. Chapter one presents the background to the study, statement of the problem, main objective as well as the specific objectives of the study. Research questions, hypotheses, significance of the study, delimitations, limitations, abbreviations and definition of terms are also presented in chapter one. Literature related to this study was reviewed in the chapter two

which includes conceptual review, theoretical review and review of empirical studies. Chapter three discusses the research design, population, sampling procedure, data collection instrument, data collection procedures, data processing and analysis, and ethical considerations. With chapter four, there is the presentation and discussion of the results obtained. Lastly, chapter five presents the findings, conclusions and recommendations based on the results obtained. Chapter five ends with suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter presents a review of literature that relates to this study. This includes theoretical review of the study, which are theory of multiple intelligences and constructivism theory. It also highlights the conceptual framework of the study, after which the conceptual review of the study's variables (5E Instructional Model, Differentiated Instruction, conventional teaching method, academic Performance, gender and Thermal Physics) is presented. The empirical review of the Study is also presented in this chapter. The chapter ends with a summary of the literature.

2.1 Theoretical Review of the Study

The theories that underpin this study are constructivism and the theory of multiple intelligences. Differentiated Instruction is rooted in the theories of multiple intelligence and constructivism (Ferrier, 2007; Thakur, 2014; Wenning & Vieyra, 2020) while 5E Instructional Model is rooted in constructivism (Bybee, 2019).

2.1.1 Theory of Multiple Intelligences

Howard Earl Gardner propounded the theory of multiple intelligences by asserting that schools should provide "individual-centered education" with curricula that are adjusted to the needs of each learner, as opposed to relying on a homogeneous curriculum (Gardner, 1999). According to Gardner, this involves assisting the learners in strengthening their

lower-level intelligences. Based on this theory, Gardner claimed that there are eight ways that a person's intellect can be expressed, as described in Table 2.1.

Table 2.1: Summary of Gardner’s Eight Intelligences

Type of Intelligence	Description	Learning skills
Linguistic intelligence	Marked by comfort with words and languages.	Reading, taking notes, paying attention to lectures, participating in discussions, and debating.
Mathematical Intelligence	Relates to numbers, inductive and deductive reasoning, abstractions, and reasoning.	Learn best by rearranging and classifying various objects in their environment, and working with abstract patterns
Spatial Intelligence	Characterised by the capacity to mentally picture things and to position and control three-dimensional space in order to address issues.	Better understand concepts when they are taught using pictures, diagrams and other visual aids.
Bodily-kinesthetic Intelligence	Characterised by movement and doing.	Learning is maximised through the use of manipulatives and physical activities
Musical Intelligence	It is manifest in greater sensitivity to sounds, rhythms, tones, and music.	Frequently employ melodies or rhythms to absorb and recall information.
Naturalistic Intelligence	Individuals with this type of intelligence coexist peacefully with the natural world.	Enjoy learning outside through activities such as observing nature, field trips, etc.
Interpersonal Intelligence	Involves realising how to interact and work cooperatively with others.	Learning is enhanced through cooperative games, group projects and debates, dramatic exercises, or role playing
Intrapersonal Intelligence	Involves becoming more adept at managing and interacting consciously with one's inner world of emotions and thoughts.	Learning becomes meaningful through individual projects, reading thought-provoking literature, keeping a journal, and engaging in imaginative activities and games

Source: (Gardner, 1999)

Thus, the underlying premise of the theory is that learners possess a variety of intelligences rather than just one (Lunenburg & Lunenburg, 2014). However, Şener and Çokçalışkan (2018) makes the notion that although each person has a variety of intelligences, some are more pronounced in some individuals.

Though the eight intelligences are separate from one another due to the fact that different people experience the development of each one at a different pace and to a different extent (Yavich & Rotnitsky, 2020), they are nevertheless intimately related as Yaghoob and Hossein (2016) argue. As a result, when a person improves in one area of intelligence, their overall intelligence quotient (IQ) may also increase (Fayazi-Nasab & Ghafournia, 2016; Shearer, 2018). Therefore, researchers including Kumalasari et al. (2017) and Yanti et al. (2018) suggest that children should be encouraged to use all of their intelligences. In the views of Moran et al. (2006), this can be achieved by enhancing the learning environment with suitable learning resources and activities that allow students to interact personally with the content and in a way that piques their interest, as opposed to simply absorbing it in an abstract, decontextualised fashion. These experiences according to Moran et al., (2006), provide diagnostic information. That is, teachers can assess student performance to identify the reasons of misunderstandings and determine ways to help students develop better understandings.

It is common knowledge that the cornerstone for healthier, happier, and brighter learners is building a rich, caring, and stimulating environment full of engaging objects, toys, games, and books. These kinds of experiences have taught many students that there are

many different methods to study practically anything (Winarti et al., 2019). This means that, teachers must have a thorough understanding of their students' personalities in order to successfully teach them, and they must adapt their lesson plans to suit the unique needs of each student. Studies (Abdi et al., 2013; Winarti et al., 2018; Yurt & Polat, 2015) have shown that the theory of multiple intelligences can be used to support a lesson as well as identify and understand the students.

2.1.1.1 Relationship Between Differentiated Instruction and Theory of Multiple Intelligences

The theory of multiple intelligences provides teachers with a greater understanding of and ability to meet learners' various learning preferences (Timmins, 2019). Every learner has the potential for each of these intelligences, so the onus is on teachers to encourage and assist students in growing their individual intelligences (Yanti et al., 2018). Hence, through Differentiated Instruction, teachers organise and design activities for students of different cognitive levels, taking into account their varied learning styles, individual learning abilities, and their academic levels, in a way that both supports learners' strong areas of intelligence and at the same time lets them make use of all of their intelligences (Thakur, 2014). By so doing, the teacher tailors the instruction to suit the unique needs of the learners, as Şener and Çokçalışkan (2018) suggest that all students, not only those who can read, write, or do calculate well, can participate in lessons if teachers are aware that there are diverse intelligence types in their classes. By so doing students will learn according to their strengths, causing them to produce enhanced performances.

2.1.2 Constructivism Theory

The constructivist perspective is grounded in the works of prominent educational psychologists such as Jean Piaget and Lev Vygotsky along with the writings of Jerome Bruner and John Dewey (Hodgson, 2017). Constructivism recognises that people actively participate in the creation of knowledge, as opposed to passing along knowledge and recording what others have said (Khadidja, 2020). Constructivism is a significant, contemporary theory that can be used to enhance conceptual change in science education. According to the constructivism theory, learners' conceptions of knowledge come about as a result of their efforts to create their own personal interpretations of their experiences (Applefield et al., 2001). In other words, students can draw inferences about the numerous events taking place in the world by examining their own real-life experiences. This, Khadidja (2020) avers, is the basic tenet that sets constructivism apart from other learning theories. But this active construction of knowledge by the learner, according Fernando and Marikar (2017), can be bifurcated between two polar approaches, viz; cognitively and socio-culturally.

2.1.2.1 Cognitive Constructivism

One major source of inspiration for cognitive constructivism is thought to be the work of Piaget (Khadidja, 2020), who believes that in an effort to make sense of the world around them, children will actively construct and form “schemas”, which are mental frameworks that organise and interpret information (Piaget, 1976). This construction is done out of their actions with the environment, both physically, that is, actually manipulating an object, and mentally (enlarging and/or refining existing internal schema) (Kola, 2017). In constructing

the knowledge, the experiences the child has throughout life will be incorporated into their preexisting schemas, a process which Piaget (1976) named “assimilation”. As new experiences and information do not fit into a schema, the child must therefore, adjust their ways of thinking through a process known as “accommodation”, in order to make room for new knowledge or to make sense of their surroundings (Umida et al., 2020).

Thus, when fresh information contradicts what the learners have already learned, “disequilibrium” or imbalance results (Piaget, 1976). In this way, Piaget viewed learning as an active process of continuing “adaptation” or transformation. In other words, learners adjust by constantly rearranging the knowledge and experiences they acquire throughout their daily lives. Hence, through the process of accommodation, a new schema is constructed into which the information can be assimilated and “equilibrium” (the cognitive balancing of new information with existing knowledge) can be temporarily recreated (Huang, 2021). Through the creation of disequilibrium, the internal motivation of the learner is therefore enhanced to reshape pre-existing knowledge, thus leading to learning (Poonam, 2017).

By implication, a problem that increases disequilibrium, however the student finds intriguing, and is capable of solving with some effort and support, must be the setting in which the teacher presents new information (Khadidja, 2020). In other words, instead of giving them pre-packaged information, teachers should encourage students to discover information themselves via natural interactions with their surroundings. This, according to Saleem et al. (2021) and Applefield et al. (2001), can be achieved through asking questions,

making investigations and evaluation and other socially mediated discovery-oriented learning activities.

Also, Mohammed and Kinyo (2020) are of the opinion that with the help of assimilation and accommodation, each learner's cognitive schemas are continuously updated to take advantage of fresh information. As a result, there will never be a situation in which two people are equally prepared for an experience, and learning will always take place in a variety of ways. Here, teachers are encouraged to consider how various learners approach tasks and other activities. For example, teachers might spend some time learning about each student's preferences, dislikes, areas for improvement, and areas for strength in order to deliver education that produces excellent outcomes (Khadidja, 2020).

2.1.2.2 Socio-Cultural Constructivism

The socio-cultural constructivism, heavily influenced by Lev Vygotsky (Hodgson, 2017), is founded on the premise that through their abilities to interact socially and communicate with their classmates, children can pick up the cultural norms of society (Huang, 2021). In other words, by interacting with others and their surroundings, people construct their own meanings. As a result, knowledge is a creation of humans that is shaped by social structures and cultures. Therefore, social constructivists espouse that, the formation of knowledge requires a group of individuals with similar linguistic and cultural backgrounds. Accordingly, children are said to acquire their information in collaboration with their peers, instructors, and other school personnel, with the instructor playing a role as a facilitator or guide (Appiah-Twumasi & Osei, 2018; Hodgson, 2017). This means that when teachers

are planning lessons in the classroom, greater consideration must be given to student engagement, debating, and sharing among students and teachers. Consequently, by engaging in practical activity, a child develops meaning on an intra-personal level, and speech links this meaning to the interpersonal reality that the child and her/his culture share (Hodgson, 2017). That is, to arrive at a new, socially validated version of truth, students compare their interpretation of reality with that of the teacher and other students. Vygotsky therefore emphasises that the most crucial aspect of a learner's psychological development is social contact with cultural artifacts. These cultural artifacts may include all of the objects we use, thus, from the most basic—like a pen, book, ruler, or table—to the most complex—like language, customs, or beliefs (Shabani et al., 2010).

Vygotsky (1978) proposed that children enter into the classroom with the ability to perform certain tasks by themselves (known as actual development), and what the child is able to do because of the guidance of others, who are more competent than the child (known as the level of potential development). The distance between these stages is what Vygotsky calls the “zone of proximal development” (ZPD). According to Vygotsky, what a student does in groups or with support, they will eventually do independently. In order to identify the learner's present and future learning, Vygotsky argued that a ZPD should be established. According to Vygotsky (1978), once the learner adjusted and altered the means of support utilised interpersonally, they would be used intrapersonally. Accordingly, the characteristics of the cooperation that produce the proximal level and establish the standards for the learner's future, autonomous performance are fundamental to the ZPD.

In view of this, educators can employ many scaffolding approaches like breaking down the activity into manageable pieces, offering instructions, cues, examples, questions, handouts and diagrams (Hodgson, 2017; Khadidja, 2020; Saleem et al., 2021). Nevertheless, Khadidja (2020) cautions that teachers should be aware that using the same scaffolding approaches in various contexts is not advisable because it depends on the situational factors such as the work type, the learner's level, the available time, etc. Vygotsky, like Piaget (1976), opine that, learners should be continually challenged with assignments that involve information and abilities that are just beyond their present level of competence. This is consistent with the ZPD, and therefore, reflects their motivation and builds on prior accomplishments to boost learner confidence (Vygotsky, 1994).

It is therefore apt to conclude that, in constructivism, rote memorization is not encouraged, and that the learner is seen as someone who constructs and transforms knowledge. To construct, in this context, means that in order to make meaning of new experiences, a learner must actively work to connect them to what is already known and understood or held to be true about a certain topic (Bhattacharjee, 2015). Therefore, the instructional process must be designed, with students' personal efforts to understand the concepts being fundamental. Also, instead of acting as teachers or classroom instructors must change to become facilitators (Hodgson, 2017). A "facilitator", according to Hodgson (2017), assists the student in creating their own understanding of the subject matter, in contrast to a "teacher" who delivers a didactic lecture covering the subject. Therefore, as a facilitator, the teacher helps students to develop and evaluate their understanding by coaching, mediating, prompting and supporting them (Umida et al., 2020).

2.1.2.3 Relationship Between 5E and Constructivism

In the first phase of the 5E Instructional Model (engagement), students can brainstorm prior knowledge to determine what they already know and to spot misconceptions. This is similar to the constructivism idea. According to Piaget (1976), the existing knowledge acts as a foundation on which the new information is either integrated into it through the assimilation process or restructured to alter the schema through the accommodation process. Bybee et al. (2006) note that this phase aggressively involves students in their learning intellectually through activities that capture their interest. As a result, students experience a cognitive conflict and attempt to either assimilate the new information into their pre-existing mental structures or reorganise in order to acquire or accommodate new knowledge.

Students can observe, investigate, develop theories, test them, record the results, and interact with others while working on the second phase, which is the exploration phase. As a result, new knowledge must be integrated into existing mental structures or made to make room for it, leading to the process of equilibration. Students gain a solid understanding of the phenomenon by being involved in these activities (Martín & Bybee, 2022). As they collaborate in teams, students develop a foundation of shared experiences that help them when sharing and communicating. As a facilitator, the teacher offers resources and directs the learners' attention.

Students can briefly explain concepts, procedures, and skills to the teacher and their peers during the third phase (explanation). Equilibration continues throughout this period, and

misconceptions can be cleared up (Omotayo & Adeleke, 2017). By doing this, the instructor aids in the development of students' ZPDs, in line with Vygotsky's (1978) theory.

In the fourth phase students are given the opportunity to expand on the principles on the topics. Students have the opportunity to apply what they have learned in this phase to their everyday lives, which also aids in solidifying their understanding of concepts and reducing misunderstandings (Ergin, 2012). Students get the chance to evaluate their knowledge and skills after receiving teacher input during the fifth phase, which is called evaluation. As a result, the 5E Instructional Model is helpful in promoting meaningful learning, which is justified by the findings of this study.

2.1.2.4 Relationship Between Differentiated Instruction and Constructivism

Differentiated Instruction, with its emphasis on adjusting teaching to individual needs, is in alignment with constructivist principles. In a constructivist classroom, students are encouraged to explore and build their understanding at their own pace using their already existing knowledge (Amineh & Asl, 2015), and Differentiated Instruction supports this by assessing students' readiness, interests and learning styles prior to the instruction and providing tailored resources and activities (Pozas et al., 2020). Students' readiness levels according to Pozas et al. (2020) provide the teacher with their prior levels of understanding regarding the subject matter. Also, their interests and learning styles help the teacher acting as a facilitator, to provide students with the appropriate resources so that under the guidance

of the teacher, they can actively construct their knowledge of the subject being taught (Kótya-Nagy, 2023).

As they work along their interests and learning styles, students become motivated to learn even when they are presented with challenging real-world situations (Brunello & Brunello, 2022), a state which Piaget (1976) called “disequilibrium”. Therefore, students’ persistence to construct knowledge along their readiness levels, interests and learning styles in a collaborative manner leads to ignoring old knowledge they possess about the subject matter (accommodation), since it is not consistent with new knowledge, or modify old knowledge so that it matches with new knowledge (assimilation) (Marghitan et al., 2016).

Also, the teacher, through the determination of students’ readiness levels, interests and learning styles in a differentiated classroom becomes aware of students’ actual level of development (Thakur, 2014). Therefore, to help students learn the more difficult tasks, the teacher can differentiate instruction accordingly, and through the establishment of a collaborative environment, the teacher and more knowledgeable peers help less knowledgeable students develop the academic skills they need to learn independently (level of potential development) (Ogundeji, 2022). This helps to enhance students’ ZPDs as theorised by Vygotsky (1978).

2.2 Conceptual Framework of the Study

The study was guided by the principle that, the integration of student-centered teaching method will affect students’ academic performance. This was supported by the

constructivism theory and the theory of multiple intelligences. Students learn better when the teaching and learning is centered on the learner, allowing the learning situation to bring the best out of the students as they interact with the materials, and at their actual level of performance, putting in mind their individual learning styles, under the controlled guidance of the teacher. Figure 2.1 therefore conceptualises the relationship between the teaching methods (5E Instructional Model and Differentiated Instruction) and students' academic performances in Thermal Physics.

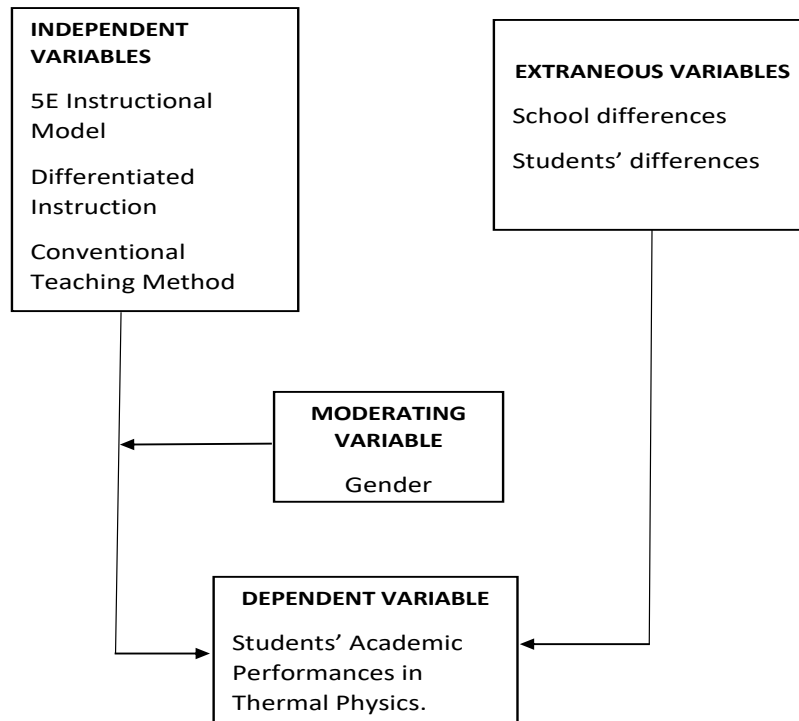


Figure 2.1: Conceptual Framework of the Study

The conceptual framework illustrates how the moderating variable, dependent variables, and independent factors interact to produce the desired student results in the teaching and

learning of Thermal Physics. The independent variables (instructional methods) for this study were the 5E Instructional Model, Differentiated Instruction and conventional teaching method, while the dependent variable was students' academic performance in Thermal Physics.

Learning experiences and outcomes may also be influenced by the gender of the learner as shown in Figure 2.1. Therefore, gender was introduced in this study in order to statistically control for its variation. This is a moderating variable which needed to be controlled for. A moderating variable, according to Leavy (2017) is a variable that influences how strongly and/or in which direction the dependent and independent variables are related. That is, it provides the researcher with information about who, when, or under what conditions a relationship will last (Namazi & Namazi, 2016). This is called an interaction effect, as seen in the analysis for hypothesis 4 (see Table 4.12). Thus, in this study, gender was controlled to account for its effect on the causal relationship between teaching methods and students' academic performances in Thermal Physics.

Moreover, there are a number of factors which may influence the learning outcomes (dependent variable) that were not measured. These are called extraneous variables (Leavy, 2017). In this study, to control for the extraneous variables such as school differences, schools of same category (category C) were used. Also, individual students' prior academic performances were measured through pretest in order to control for students' academic differences. However, other unmeasured differences in students which would affect the results of the study were also controlled statistically using analysis of covariance.

2.3 Conceptual Review of the Study's Variables

2.3.1 The Concept 5E Instructional Model

The 5E Instructional Model is one of the learning cycles that can be applied in science classes to improve practices and create science curricula based on cognitive psychology and structural approach (Cakır, 2017). The 5E Instructional Model, also known as the BSCS (Biological Science Curriculum Study) 5E Instructional Model was developed by a team led by Rodger Bybee in 1987 (Boakye & Nabie, 2022). The model is a learning cycle, which according to Bunkure (2019), refers to series of stages or phases which enable students to learn from experience. This method (learning via learning cycles) uses interactions with classmates and the environment to help students redefine, organise, examine, and change any false concepts they currently have. The 5E Instructional Model consists of five phases, in which every phase begins with the letter “E”, hence the name (Sadeeque et al., 2021). The five phases of the model, according to Sadeeque et al. (2021) include; engagement, exploration, explanation, elaboration, and evaluation.

2.3.1.1 Engagement Phase

Through the use of brief exercises that foster curiosity and elicit past knowledge, the instructor examines the students' prior knowledge while assisting them in becoming immersed in a new idea (Bybee, 2018). During this stage, Ahmad et al. (2018) aver that, getting learners interested and paying attention is crucial. That is, assisting the pupils in focusing on a scenario or problem that incorporates the knowledge and skills that the lesson aims to cultivate in the students. This can be achieved using techniques such as posing a question, a challenge, or presenting a conflicting occurrence. According to Bybee (2018),

if students look baffled and expressing wonder, they are likely to be engaged in a learning situation. As a result, the lesson plan should challenge misconceptions, connect past knowledge to the material being covered, and focus students' attention on the objectives of the activities (Omotayo & Adeleke, 2017). This, Martín and Bybee (2022) highlighted, is essential for memory updating – which, according to Lee et al. (2017), entails alterations in the way memories are related to one another to create meaning and direct recall. Martín and Bybee (2022) also acquiesce that the “engagement phase” has a big impact on learning and conceptual transformation in that, it encourages students' motivation. This means that students' cognitive engagement is necessary if they will pay attention to information, activate past knowledge, check understanding, and persevere with the learning activity.

Within the engagement phase are the contextual engagement and the cognitive engagement (Martín & Bybee, 2022). Students participate in the contextual engagement by understanding the posed situation's practical ramifications, or, more specifically, by appreciating its usefulness, which helps in motivating them in the learning process. The cognitive engagement, on the other hand, is founded in the interest that frequently develops when students discover that their present theories do not adequately explain an observation that perplexes them, and as a result, it is a result of the cognitive dissonance or cognitive conflict (Martín & Bybee, 2022). In this way, students become motivated to learn new concepts and ideas.

2.3.1.2 Exploration Phase

In the exploration phase students are given a shared set of tasks throughout exploration experiences (guided inquiry activities), which allow for the identification of present concepts (misconceptions), processes, and skills as well as the facilitation of conceptual change (that is, building new explanations that make sense to them) (Ünlü & Dökme, 2022). For instance, students can complete laboratory exercises or any appropriate hands on activity that will enable them to draw on existing knowledge to develop fresh concepts and debate their interpretations (Choirunnisa et al., 2018). This, as suggested by Choirunnisa et al. (2018), can be done in small groups or whole class, and as a facilitator, the teacher's roles include guiding and encouraging students' thought processes, clarifying explanations with questions, and proposing paths that might advance the group toward the learning objective(s).

Also, Siwawetkul and Koraneekij (2020) added that it is the teacher's responsibility to provide sufficient materials and equipment, explaining the relevant history of the subject matter, and clearing up any misunderstandings. After that, the teacher takes a back seat and turns into a coach, helping the learners as they expand their skills, clarify their comprehension, and start to reassemble scientific notions (Bybee, 2018). The exploration phase, according to Bybee (2018) is done to facilitate the integration of students' existing knowledge with the newly acquired material, utilizing activities like guided inquiry-based learning tasks that encourage critical thinking and sense-making. This is in contrast to learning that is solely dependent on transmission, in which the student frequently assumes the role of a passive learner.

2.3.1.3 Explanation Phase

During the explanation phase, students are given the chance to demonstrate their conceptual knowledge, processing skills, or behaviours (Muhammad et al., 2019), which focuses their attention on a specific area of their engagement and exploration activities (Omotayo & Adeleke, 2017). Moreover, during the explanation stage, teachers can come in to formally present a scientific concept, method, or skill, while students discuss how well they have grasped the idea (Dodge, 2017). Students may be led to a greater understanding by the teacher's explanation, which according to Bybee et al. (2006), is an important aspect of this stage. Under the direction of the teacher, the student's explanation can advance knowledge creation and position it for potential use in the future in pertinent circumstances (Sotáková & Ganajová, 2023).

2.3.1.4 Elaboration Phase

The elaboration phase is where students' understanding of concepts and skills are applied to new experiences or new activities (Rodriguez et al., 2019). As a result, students acquire new knowledge, useful skills, and a more thorough understanding of the material (Bahadir & Melih, 2022). Therefore, the goal is to make it easier for knowledge and skills to be applied in similar but different and novel circumstances. The promotion of deeper comprehension by exposing learners to various contexts may be due to their increased propensity to abstract the key elements of ideas and to create a flexible model of knowledge (Martín & Bybee, 2022).

2.3.1.5 Evaluation Phase

The evaluation phase presents teachers and students with the opportunity to gauge how the lesson objectives have been attained (Bekteshi et al., 2022). That is in the evaluation phase, an activity that tests each student's comprehension is used to assess the knowledge and skills they have acquired. Such activities include administration of tests or implementing other assessment methods to ascertain each students' level of understanding and abilities (Appiah-Twumasi et al., 2021). According to Appiah-Twumasi et al. (2021), the evaluation phase helps students to get feedback on the appropriateness of their explanations and abilities. Bybee (2018) adds that, the “evaluation phase” of the instructional model is meant to be a summative test administered at the conclusion of a unit, however, there should undoubtedly be some informal and ongoing evaluation.

2.3.2 The Concept of Differentiated Instruction

Differentiated Instruction according to Wenning and Vieyra (2020) came to the forefront of education in the late 1990s, spearheaded by Carol Ann Tomlinson. A key tenet of Differentiated Instruction is that students should have their unique needs taken into account when developing instructional strategies (Salar & Turgut, 2021). Therefore, it is a student-centered approach (Tomlinson et al., 2003), which can be employed by teachers to meet the needs of their students. This means that, with the help of their teachers, students are free to select the material they want to study, the method they want to use to acquire it, and the way they want to apply what they have learned when using this method (Wenning & Vieyra, 2020). The term “differentiation” refers to a wide range of teaching techniques and lesson modifications that educators utilise to train a varied set of students with diverse

learning needs in the same classroom or learning environment (Kotob & Abadi, 2019). It is common knowledge that modern day students enter the classroom with diversities which the teacher should put into consideration when planning classroom instruction. Characteristically, Kotob and Abadi (2019) noted some of these differences and they include their prior knowledge, learning styles, aptitudes, motivation and interests, as well as the speed at which they are learning and even their language skills. As a result, students will need diverse ways to process knowledge, apply what they learn, and even demonstrate what they have learned. Therefore, in their attempt to contribute to the definition of Differentiated Instruction, Wenning and Vieyra (2020) explain that, students in a differentiated classroom are given the same learning objectives but they may use different routes to get there. The ramification is that, students often perform better when encouraged to learn in circumstances that are difficult and accommodate their unique requirements and learning preferences (Kotob & Abadi, 2019).

Thakur (2014) is of the view that due to different learning abilities, an instructional method may help improve the performance of some students while for others, it may not cause any improvement. Therefore, students will likely achieve more satisfying performance if they are offered responsive settings and training as revealed studies including those conducted by Danso (2018) and Balgan et al. (2022). In spite of the fact that different students may acquire standards (lesson objectives) in different ways, differentiation aims to meet each student where they are while still holding them to the same standards (Awofala & Lawani, 2020). This therefore calls for the need for teachers to be reactive and adopt more effective teaching strategies that will be suitable for every learner in the classroom.

Tomlinson et al. (2003) suggest five key elements that are differentiated in the classroom, and they include content, process and product, affect, and learning environment. These elements are differentiated according to the students' characteristics which are readiness, interest and learning styles.

2.3.2.1 Characteristics of Students Based on Which Teachers Can Differentiate Instruction

According to Tomlinson et al. (2003), there are three student characteristics, that teachers can respond to when differentiating their instructions. These are students' readiness, interests and learning styles. The three characteristics are presented in the following sub-sections.

2.3.2.1.1 Readiness

Awofala and Lawani (2020) define readiness in this context as the degree to which a student currently possesses the required information, understanding, and skills related to a concept. Thus, one can say that knowing the readiness levels of the students helps the teacher to know the learning or knowledge gaps of what the teacher is intending to teach, and plans the lesson accordingly. In fact, Tomlinson and Eidson (2003), explain that, if teachers are oblivious of students' learning gaps or ignore the fact that students already know the subject which is yet to be taught, it will be exceedingly challenging to maximise their potential, hence expanding the learning of the students. The purpose of readiness differentiation, according to Ogundeji (2022), therefore, is to make the task slightly challenging for children at a particular stage of development before giving them the

assistance they need to succeed at the new level of effort. Since each student will naturally differ in their readiness to learn specific concepts and abilities at specific times (Brunello & Brunello, 2022), it behooves on the teacher to make the necessary readiness modifications to ensure that each learner experiences consistent academic growth.

2.3.2.1.2 Interest

Awofala and Lawani (2020) describes the interest as topics that evoke a student's attention, involvement and curiosity. That is, what a student finds engaging to study about, contemplate, and do (Tomlinson & Eidson, 2003). In order to engage students, a teacher must therefore make connections between needed material and their interests, thereby increasing the students' motivation to learn. By drawing links between subjects that students already find interesting, relevant, and important, Tomlinson and Eidson (2003) conclude that, differentiating instructions based on learners' interest aims to help students connect with new knowledge, understanding, and abilities.

2.3.2.1.1 Learning Style

The learning style is a student preferred mode of learning (Brunello & Brunello, 2022). An individual's learning profile, according to Tomlinson and Eidson (2003), is influenced by their learning style, intelligence preference, gender, and culture. Learning style differentiation therefore seeks to broaden students' effective learning options while assisting them in learning in the ways that work best for them (Thakur, 2014).

According to Tomlinson et al. (2003), learning styles theory suggests that factors like light, temperature, seating arrangements, demand for concentration, degree of learner mobility, time of day, and perceptual mode have an impact on learning by pointing to individual preferences related to categories like environment, emotions, interactions, and physical needs. It is based on these categories, that Şener and Çokçalışkan (2018) suggest that, learners can be grouped into auditory learners (learning through what the teacher only says), visual learners (learning by watching the teacher and reading everything he or she writes on the board), kinesthetic learners (learning by doing something with what is being discussed) and verbal learners (learning by discussing the concept to truly understand what has been taught).

2.3.2.2 Elements of Differentiated Instruction

Tomlinson and Eidson (2003) identify five key elements of the instruction that can be differentiated, and these are content, process, product, affect and learning environment. The elements of Differentiated Instruction according to Tomlinson and Eidson (2003) are presented in the following sub-sections.

2.3.2.2.1 Differentiating Content

The content is what the student needs to learn. Awofala and Lawani (2020), explain the content as the knowledge students need to acquire in the classroom including concepts, generalisations, principles and skills. That is, the information that is taught and delivered to the students. Teachers can differentiate content based on how learners obtain important information, that is according to the students' characteristics, which include; students'

readiness, interests and learning styles (Brunello & Brunello, 2022). By implication, the same topics should be covered in class with every student, but the level of difficulty should be adjusted to accommodate students with different abilities. In other words, the main subject matter of the lesson should cover the learning objectives established by the institution or the state's educational standards. However, Taylor (2015) is of the view that some students in the class may not have any prior knowledge of a lesson's contents, while others may merely have a passing understanding of them or may already be familiar with the material. In this case, the teacher's job, according to Ismajli and Imami-Morina (2018) is to differentiate the material by creating tasks for distinct groups of students that cover the different levels of Bloom's taxonomy, a classification of six levels of cognitive behaviour moving from lower-order thinking skills to higher-order thinking skills. The six levels are remembering, understanding, applying, analysing, evaluating, and creating (Bloom et al., 1973). Tomlinson and Eidson (2003) therefore suggested some methods which can be used to differentiate the content. These strategies are summarised in subsections 2.3.2.2.1.1 to 2.3.2.2.1.3.

2.3.2.2.1.1 Strategies for Differentiating Content According to Students' Readiness

According to Tomlinson and Eidson (2003), there are diverse ways through which a teacher can differentiate content according to students' readiness. These include; provision of texts and additional resources for a range of reading abilities, reteaching the material to any struggling students, provision of more advanced pupils with extended study groups. According to Tomlinson and Eidson (2003), teachers can consider talking about concepts or abilities, but also putting them into practice, offer audio-recorded resources, add to and

reinforce lectures and explanations with videotapes, provide important lists of vocabulary when taking notes.

2.3.2.2.1.2 Strategies for Differentiating Content According to Students' Interests

There are also strategies suggested by Tomlinson and Eidson (2003) in differentiating content according to students' interests. These are; establishing interest centers to promote in-depth study of various subjects, offering a vast array of resources pertaining to a plethora of student interests, selecting lessons and material guided by students' questions and topics, incorporating illustrations and examples according to the interests of the students.

2.3.2.2.1.3 Strategies for Differentiating Content According to Students' Learning

Profile

In differentiating content according to students' learning profile, Tomlinson and Eidson (2003) suggest that teachers can present learning materials in visual, auditory and kinesthetic formats, make use of examples, applications, and illustrations from a variety of intelligences, apply ideas, models, and depictions from a variety of cultures and societies, as well as from both genders.

It is worth noting that, if the material is too difficult or too easy, Tomlinson et al. (2003) acquiesce, students will fall behind and lose motivation. This concept is consistent with Vygotsky's Zone of Proximal Development (ZPD), which is the difference between a learner's actual mental age and the maximum level at which they can perform in a given domain.

2.3.2.2.2 Differentiating Process

The process, according to Brunello and Brunello (2022), is how students take in, comprehend, or apply the new ideas or skills. Thus, one can say that, the process is how the teacher presents the information to the students. The process, according to Awofala and Lawani (2020), is a crucial stage in Differentiated Instruction since it is during this time that children learn and require varied levels of support, groupings, and learning tempos. Therefore, when teachers differentiate process, it enables students to give the same output or product in a variety of ways (Kotob & Abadi, 2019). Here, the teacher provides support to students while they learn at their own pace. This means that the process refers to the various meaningful activities which students will engage themselves in during the lesson in order to help them own the knowledge which they have acquired, and Tomlinson and Eidson (2003) explain that, an activity is meaningful if it requires learners to apply certain knowledge and abilities in order to comprehend a key concept or principle, motivating students to stick with a task despite its challenges by piquing their interest in it. That is, students must engage in critical thinking, problem-solving, and information utilization in order to move beyond merely "passing back information" and get an understanding of how and why things operate.

The major goal of differentiating the instructional process, Pham (2012) concludes, is to give every lesson to learners purpose and relevance in a situation that is academically rich. Tomlinson and Eidson (2003) suggest that differentiating the process of an instruction should be done according to learners' characteristics (readiness, interests and learning

profiles), using different strategies, as summarised in sub-sections 2.3.2.2.2.1 to 2.3.2.2.2.3.

2.3.2.2.2.1 Strategies for Differentiating Process According to Students' Readiness

In differentiating process according to students' readiness, Tomlinson and Eidson (2003) suggest that teachers can employ tiered activities, which are tasks with varying degrees of difficulty but the same learning objectives as their focus. Also, teachers can provide a range of literate and sophisticated resource materials, give second language learners resources in their mother tongue, as well as change the pace at which students complete their assignments (Tomlinson & Eidson, 2003).

2.3.2.2.2.2 Strategies for Differentiating Process According to Students' Interests

Differentiating the process of the teaching and learning according to students' interests can also be done through making use of discussion and work groups based on interests, giving learners the opportunities to focus on particular facets of a topic they find interesting by using the Jigsaw cooperative technique, creating assignments that demand a variety of interests in order to finish successfully and encouraging students to create some of the classroom activities or to assist in creating them (Tomlinson & Eidson, 2003).

2.3.2.2.2.3 Strategies for Differentiating Process According to Students' Learning Profiles

In differentiating the process according to students' learning profiles, instructors can consider give students a choice in how they express what they have learned, encouraging

students to work individually or in groups, and create classroom tasks and assignments that investigate various points of view regarding problems and topics.

2.3.2.2.3 Differentiating Product

The product refers to the demonstration of students' learning (Awofala & Lawani, 2020). That is, what knowledge, skills and abilities students have acquired following the instruction. Therefore, in differentiating the product, the teacher assesses and evaluates what the learners understand and how successfully they can use the knowledge they have acquired. A variety of assessment tools can be used for the evaluation, allowing students to reflect on their learning and demonstrate how they can apply abstract ideas to real-world scenarios (Thakur, 2014).

Some ways to differentiate the product according to Kotob and Abadi (2019), include, written examination and product assignments like projects. However, Thakur (2014) suggests that in order to give students the greatest chance to prove that they understand the subject, some teachers may combine written assessments with product assignments like projects. But with regards to written assessments or tests, Tomlinson and Eidson (2003) explain that, the ability of a student to demonstrate how much he or she has learnt should be enabled by the tests rather than hindered by them. As a result, some students might have to tape-record their test responses. Some students also might require hearing test or questions read aloud. Some also might require more time to complete their answers to questions. This means that in differentiating the product of an instruction, diverse strategies

can be used, of which few of them are listed in sub-sections 2.3.2.2.3.1 to 2.3.2.2.3.3 as suggested by Tomlinson and Eidson (2003).

2.3.2.2.3.1 Strategies for Differentiating Product According to Students'

Readiness

According to Tomlinson and Eidson (2003), the product of the teaching and learning can be differentiated by making use of tiered product assignments, providing opportunities for optional, in-class mini-workshops covering a range of topics related to product development (e.g., crafting effective research questions, obtaining material online, conducting interviews, proofreading materials), and using critique groups based on similar levels of readiness.

2.3.2.2.3.2 Strategies for Differentiating Product According to Students'

Interests

According to Tomlinson and Eidson (2003), in differentiating product according to students' interests, students should be encouraged to exhibit essential skills, knowledge, and understanding in relevant, highly interesting subjects. Also, teachers should permit students to communicate their knowledge, comprehension, and skills in a variety of media or formats, as well as giving students the chance to conduct independent research under the supervision of a teacher or mentor as necessary.

2.3.2.2.3.3 Strategies for Differentiating Product According to Students'

Learning Profiles

When students' learning profiles are considered, teachers can differentiate the product of the teaching and learning by encouraging students to work on product development in groups or on their own. Teachers can also offer options for products in visual, auditory, and kinesthetic modes, provide analytic, creative, and practical product options, and making sure there are links between the product assignments and various student cultures and communities.

2.3.2.2.4 Differentiating "Affect"

Another important component of Differentiated Instruction is the students' feelings about their learning and their emotions (Tomlinson & Eidson, 2003). The term "affect" according to Awofala and Lawani (2020) refers to feelings and affections that are a result of a concept or experience. According to Pozas et al. (2020), students have shared affective needs when they arrive in school, and they require a sense of physical and mental safety and security. However, despite the similarity of their affective mileposts (Sönmez, 2017), the paths each student takes to get there can vary greatly (Tomlinson & Eidson, 2003).

According to Sönmez (2017) students' emotions and moods are shaped by their past experiences, and how they react to both the present and the past has an effect on how motivated they are to study and work in groups as well as how they perceive themselves. Hence, adapting the learning environment to meet the students' emotional requirements is what is meant by differentiating students' "affect" (Awofala & Lawani, 2020).

Some measures taken by the classroom teacher to enhance the classroom's affective environment according to Tomlinson and Eidson (2003) include the following; modeling respect, assisting learners in becoming increasingly more conscious of and appreciative of the similarities and differences amongst their classmates, encouraging learners to develop active listening skills so they can hear not just what is being said, but also the meaning behind it and its ramifications, seeking out and taking advantage of appropriate opportunities to praise every student, celebrating growth, and assisting students in becoming empathetic toward all classmates.

In view of the above, one can say, and as Awofala and Lawani (2020) explain, that the “affect” is shaped by learning environment, that is the “climate” of the classroom. So, Tomlinson and Eidson (2003) refer to the teacher's role here as “weather-maker”. This means it is the responsibility of the teacher to make sure that every student in the classroom develop a sense of self-efficacy through their affective needs.

2.3.2.2.5 Differentiating Learning Environment

The learning environment is described by Kótya-Nagy (2023) in terms of both the obvious and hidden classroom structures that allow the teacher and the students to collaborate in ways that are advantageous to each individual student and the class as a whole. According to Awofala and Lawani (2020), the flexible organisation of time, resources, and space in the classroom, as well as the atmosphere therein, make up the learning environment.

In terms of space, the teacher, in collaboration with the students, thinks about rearranging the furniture to make room for work by individuals, small groups, and large groups, as well as how they might create space for calm contemplation, movement, and discussion (Awofala & Lawani, 2020).

To make decisions related to classroom materials or resources, teachers and students consider factors such as availability of materials and supplies be in the classroom, the appropriateness of materials and supplies for their tasks at a given time, as well as the guidelines to follow in sharing materials and supplies when there are not enough to go around.

With regards to time, Tomlinson and Eidson (2003) aver that some learners will not be able to advance without further guidance from the teacher. Some will do their work more quickly than others (even when the work is appropriately challenging), while some will require more time for a few tasks. Thus, according to Tomlinson and Eidson (2003), to enable flexible use of time, teacher and students consider factors such as the right time to work in whole class or in smaller groups or independently, when and how to work with or without direct teacher supervision, how to provide help to students when in need and the teacher is busy.

2.3.3 The Concept of Conventional Teaching Method

Olifer (2020) asserts that, before the adoption and acceptance of placing the student at the center of the instructional process, the teacher-centered paradigm was the norm, which is

why it can be referred to as conventional or traditional method. The term conventional teaching method therefore describes the traditional method of instruction, which typically involves the teacher dispensing information to students through the use of lectures or narration and minimal discussions (Appiah-Twumasi, 2020). That is, with this method, the teacher orally delivers the content and answer questions from the students. Here, the main focus is on recalling and applying knowledge of facts, rules, and learning theories, where instruction is delivered in a way that encourages learners to sit still and listen (Appiah-Twumasi, 2020; Tularam, 2018). This stands to reason that, in a conventional classroom, the teacher controls and modifies the flow of knowledge. However, according to Murphy et al. (2021), students are expected to use assignments and homework to further their comprehension of a subject outside of the classroom. In this instance, the instructor serves as the students' primary resource and only provides in-person instruction, who then determines students' comprehension through standardized tests and examinations. Therefore, the location, timing, and speed at which students learn are fixed in this approach.

Researchers including Sawant and Rizvi (2015), Achor et al. (2019), Appiah-Twumasi (2020), Djami and Kuswandon (2020), have noted some shortcomings of the conventional teaching method, amongst which include rote learning or memorization, lack of problem-solving skills, lack of critical thinking skills, less inclusivity, where lessons are not modified to suit every learner in the classroom, as well as competition and individualistic learning among learners, where students only study to pass tests and examinations and aim to prevail as best students among their colleagues. However, Abah (2020) argues that classroom instruction cannot completely do away with the conventional teaching method

but maintains that classroom teachers should improve education by incorporating all strategies and techniques that are most suitable for specific situations and offer the best possibility of reaching predefined objectives. In line with Abah's (2020) position, Altun (2023) also noted that when it comes to imparting a lot of knowledge in a short period of time, the traditional teaching approach is more effective. Additionally, teacher-centered education is sometimes thought of as being more orderly and predictable, which can be advantageous for students who have trouble learning on their own.

2.3.4 The Concept of Academic Performance

According to Noemy et al. (2017) academic performance is the quantifiable result of the learning process, as determined by the assessments made by the teachers using impartial test evaluations. Ampofo and Osei-Owusu (2015) and Balogun et al. (2020) also defined academic performance as the measure of a student's ability to complete a particular piece of classwork in a formal educational context. From these definitions, it is apt to say that academic performance is the evaluation of a student's accomplishment in various academic disciplines. This means that academic performance is the marks a student gains at the end of a course or a lesson. Therefore according to Zheng and Mustapha (2022), academic performance is not equal to academic achievement.

Though both academic performance and academic achievement measure the outcomes of a student's learning, academic achievement is the sum of a student's ability to complete and reach a particular level following a course of study or training (Zheng & Mustapha, 2022), that is, the outcomes of students' academic progress as a result of their cumulative

learning. This means that academic achievement is the evaluation of a student's overall performance over their academic career, while academic performance refers to the overall examination score in a subject or a course. In other words, if a student does not perform well in the individual lessons of a course or a subject, there is the likelihood to have poor academic achievement. An example of academic achievement is a student's WASSCE results earned at the end of the final year examination, while that of academic performance is a student's score or grade in a class test or an end of term or semester examination. Therefore, if a student persistently performs poorly internally, there is a high probability to achieve abysmal final year results externally during their WASSCE. For the purpose of this study, academic performance was used.

According to Bloom et al. (1973), any educational objective should center on three main domains of human learning, viz, cognitive, affective and psychomotor domains. The cognitive domain entails the intellectual abilities of the learner, that is information processing, knowledge construction and application, problem solving, and conducting research; the affective domain refers to the values, interests and feelings, that is the way that we handle things emotionally towards the subject and the learning process; while the psychomotor domain talks about the gross and fine motor skills acquired throughout the learning process (Hoque, 2016). Therefore, Zheng and Mustapha (2022) assert that, in measuring academic performance, the teacher should take into account how all the domains of learning will be measured to obtain a comprehensive understanding of the students' learning outcomes.

2.3.4.1 Academic Performance Assessment in Ghana

In Ghana, the major measures of academic performance at the SHS is end of semester examination (Ministry of Education, 2010). Other tools for assessing academic performance include class exercise, mock tests, field examination, homework and projects. According to the Ministry of Education, performance can be assessed before, during and after the instruction, but must align with the instructional objectives.

2.3.5 The concept of Gender

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) defines the term “gender” as the wide range of socially constructed roles and relationships, personality traits, attitudes, behaviours, beliefs, and relative power and influence that society assigns to males and females on a separate basis (UNESCO, 2020). Therefore, when someone is referred to by their gender, it alludes to the expectations that society has of them based them being male or female. Thus, according to UNESCO (2020), gender is an all-encompassing factor in the sense that it may be used to explain every other factor that cuts over multiple categories, including race, class, age, ethnicity, etc.

According to Bertrand (2020), gender roles are acquired through socialisation processes, therefore one can say that political, economic, legal, cultural, and traditional institutions all play a part in institutionalising gender systems, which Lindqvist et al. (2021) emphasised that, they are modifiable rather than fixed. This means that cultures can change the roles that are expected of the male and female populations as they change and evolve.

Since male and female both fall under the category of gender, according to UNESCO (2020), both gender groups should be concerned with and involved in the development of gender equality in every facet of life. To UNESCO, gender equality means a person's opportunities, rights, and duties do not rely on whether they are male or female at birth. That is, ensuring that males and females are treated equally when making plans and decisions including giving their opinions, interests, needs, and priorities equal weight. These factors can differ greatly due to the diverse positions and responsibilities that men and women hold. When using a gender perspective, the system that determines gender roles and responsibilities, access to and control over resources, and decision-making potentials is the focus rather than on specific females and males (Ablaza, 2021). Therefore, it is imperative that classroom teachers choose activities that will provide male and female students with equal access and opportunities for conceptual understanding.

Secondary school populations are typically the focus of research on gender variations in academic achievement rather than communities of younger students (Buchmann et al., 2007). Also, as noted by Tetteh et al. (2018), the development of formal education in Ghana reveals a persistent effort to provide males and females with equal educational opportunities. This is because, male enrollment substantially outpaces female enrollment in science and technology, making the gender difference in Physics even more conspicuous (Wurah-Norgbey, 2019), and not only in enrollment, but also in academic performances and achievements (Wrigley-Asante et al., 2023). Therefore, females' contributions to science education are limited as a result of the underrepresentation of women in the fields of science and technology. This has an adverse impact on the younger generations because

there are not enough women working in science to act as role models for young girls and women who want to major in science. Therefore, Tetteh et al. (2018) accentuated that, the Ghanaian culture today appears to be adequately persuaded of the value of girls' education, and focus appears to be shifting to tackling gender stereotyping in the decision-making process for academic disciplines and occupations.

2.3.5.1 Gender and Students' Academic Performances in Physics

Studies on academic performance in Physics reveal that there exists a gender gap with respect to male and female students. The existence of this gender gap in academic performance in Physics is revealed with conflicting evidences in the literature. For instance, Aina and Akintunde (2013) employed a descriptive survey to determine male and female college of education students' performance in Physics in Kwara State, Nigeria. The data collected were students' results from first year to final year in four colleges. It was found that the mean score and standard deviation of male performance were 52.76 and 9.95 respectively, while mean score and standard deviation of females were 50.22 and 11.10 respectively. Aina and Akintunde's (2013) finding revealed that the calculated t-value of 0.221 was less than the tabulated t-value of 0.249. This evidence concluded that male Physics students outperformed their female counterparts.

On the contrary, Olusola et al. (2020) also conducted a study to determine academic performance between male and female final year Physics students' from 2013 to 2017 in Ekiti State, Nigeria. Twenty-seven thousand, three hundred and seventy six students were sampled for the study from all of the local government areas in Ekiti State, with 12,927

male students and 14,449 female students. The results indicated that the mean score of male students (47.44) was less than the mean score of female students (55.14) with a mean difference of (7.7). A t-test analysis showed that the calculated t-value (12.73) was higher than the tabulated t-value (1.96) at $p < 0.05$ level of significance, indicating a rejection of the null hypothesis. As a result, it was concluded by Olusola et al. (2020) that between 2013 and 2017, female students significantly outperformed male students in the May/June WAEC examination in the subject of Physics.

In Ghana, Wrigley-Asante et al. (2023) assessed gender differences in academic performances in science subjects using 252 students (54% males and 46% females). In assessing performances of the 252 science students at the SHS level using students' grades earned in the WASSCE, a significant chi-square test ($p = 0.603$, $\chi^2 = 15.162$) found that, in Physics, the percentage of students who obtained grades between A1 and B3 for male respondents was about 78.4%, while that of female students was about 59.8%. This implies that, males' performances significantly dominated that of females.

It can be concluded that, the gender gap exists in Physics across various educational levels and in diverse countries. This performance gap mostly turns in favour of males than females. Some of the possible explanations for this according to Amunga et al. (2011) are that, the way students engage in the classroom gives males more opportunity than females in learning Physics, and performance levels may be a reflection of the higher expectations for males. Thus, Wrigley-Asante et al. (2023) highlighted that how Physics works in relation to performance levels are impacted by learning preferences of both male and

female students, especially in high school. Fundamental concepts and formulas exist in Physics, which must be thoroughly understood before they can be applied. However, males seem to push themselves to learn these ideas by memorising them, while many females would prefer to have a deeper grasp of these principles and occasionally the justification before putting them into practice.

Again, it is reported that competition among students heavily impact high school students' academic performances in the science classroom. Wrigley-Asante et al. (2023) explained that students that do well in class would want to keep things the same and would work harder to keep up their performance levels. These students frequently do not want either of their classmates to outperform them, whether they are male or female, therefore they will do everything it takes to keep up their performance in order to consistently rank high.

Also, researchers such as Appiah-Twumasi et al. (2022) and Bottomley et al. (2023) have suggested that Physics students tend to have unbalanced Physics self-efficacy, with female students being lower than that of males. Physics self-efficacy according to Appiah-Twumasi et al. (2022) is the capacity of a Physics student to plan and carry out the activity necessary to achieve a particular sort of performance. Therefore, low self-efficacy among Physics students will prevent them from making the necessary plans and exerting the necessary effort to do better in Physics.

2.3.5.1.2 Reducing the Gender Gap in Academic Performance in Physics

The performance discrepancies between the male and female sexes are alarming since it is likely that they are a factor in the poor participation of females in Science, Technology, Engineering and Mathematics (STEM) fields at both the secondary and tertiary levels as well as in STEM-related occupations. Wilson and Low (2017) suggest that, although cultural influences undoubtedly play a part, if female students score worse on assessment tasks than their male colleagues, this is likely to have an impact on their choice of studies and, ultimately, jobs. Therefore, according to Wilson and Low (2017), corroborated by Assem et al. (2023), altering the manner in which courses are delivered to foster communication among students and between students and teaching staff offers opportunity to communicate various ways of knowing and fosters this dialogue.

Lorenzo et al. (2006) suggested the following strategies to help reduce the gender gap in academic performance;

1. Incorporating interests and daily experiences that are pertinent to both genders into the instruction.
2. Employing activities that decrease competitiveness must be employed by the teacher.
3. Creation of new knowledge by drawing on students' prior knowledge.
4. Establishing interactive learning environments that improve student participation and communication with the teacher.
5. Alternation between group discussion and structured teaching.

2.3.6 The Concept of Thermal Physics

Thermal Physics deals with various concepts related to heat and temperature. It involves thermal energy, methods of heat transfer, phase changes, microscopic behaviour of particles, and laws of thermodynamics (Georgiou & Sharma, 2012).

According to Georgiou and Sharma (2012), thermal energy and temperature are the two terms that are used in Thermal Physics the most frequently. Thermal energy refers to the total kinetic energy of the particles present in a system (Saito, 2002), therefore, the higher the total kinetic energy, the higher the system's thermal energy. Thermal energy also includes rotational, vibrational, and translational kinetic energies. Temperature, however, is proportional to the average kinetic energy of particles in a system. It quantifies the coldness or hotness of an object relative to a reference point and can be measured using thermometers (Young, 2012).

Factors affecting thermal energy include temperature, mass or the number of atoms or molecules in a system, and its physical state (Young, 2012). This means that even if two systems have the same temperature, they may still differ in thermal energy. For example, a large glass of water has higher thermal energy than a small glass of water, even if they are at equal temperatures. Since the large glass contains more water molecules, its total kinetic energy is significantly larger than that of the small glass.

Another essential concept in Thermal Physics is heat. In most cases, heat and temperature are interchanged, but they actually refer to two different quantities. Temperature is related

to the average kinetic energy of molecules or atoms in a system. Heat, on the other hand, is energy transfer caused by temperature differences. It is also called "energy in transit." Heat spontaneously flows from hotter to colder objects through conduction, convection, or radiation (Young, 2012).

In Ghana, the study of thermal Physics includes concepts such as heat and temperature, temperature measurement and the effect of temperature changes. There is also the study of the amount of heat emitted or absorbed and the physical changes brought on by the transfer of heat, as well as natural modes of heat transfer (Ministry of Education, 2010).

2.3.6.1 Students' Difficulties in Thermal Physics

International and local studies have shown that students usually encounter challenges in Thermal Physics. These challenges range from misconceptions to general poor academic performance in Thermal Physics. For example, Kruatong et al. (2006) in Thailand found that, in a test consisting of heat energy, temperature, heat transfer, thermal properties, insulators, conductors and thermal equilibrium concepts, 167 students (80%) out of 214 obtained 0-5 marks and 47 students (20%) obtained 6-9 marks. Also, no student could obtain a score above 50% of the full score, which was 20.

Alwan (2011) also found that, among 53 science students in Faculty of Education, studying at Al. Fateh University in Tripoli, Libya, between 40.0% and 100% of the respondents had inaccurate ideas in all 19 items. In Indonesia, Fenditasari et al. (2020) also reported that out of 39 Physics students, 40.3% had misconceptions applications of convection and

radiation, while 61.5% students had misconceptions on thermal equilibrium. In addition, 20.5% demonstrated misconceptions on heat flow.

Similarly, the Ghanaian Physics teaching context has also witnessed SHS students' difficulties and challenges in the area of Thermal Physics. Appiah-Twumasi et al. (2021) conducted a diagnosed students' misconceptions about heat and temperature using two-tier test instrument. The results indicated that 56 SHS students used for the study held misconceptions, lack of understanding, and demonstrated difficulties explaining heat and temperature concepts. Furthermore, Awudi and Danso (2023) conducted a study which sought to improve SHS students' performance and conceptual understanding of heat transfer using demonstration method. Their pretest results showed that, 86% of the sample (N=30) performed poorly in the test which was scored out of 20, taking 5 as the pass mark. These students' misconceptions are inevitably affecting students' academic performances in the area of Thermal Physics. For example, the West African Examinations Council (WAEC) chief examiners' reports were examined, and it was discovered that "many candidates had difficulty solving problems on resistance and gas thermometers" (WAEC, 2017). Candidates also struggled to solve heat problems and showed a lack of understanding of the idea of heat transfer (WAEC, 2018). Similar concerns cropped up in 2019 and 2020, where candidates had trouble solving them and seemed to know less about some heat-related problems (WAEC, 2019, 2020). In 2021, the chief examiner reported concerning problems under Thermal Physics that, "most of the candidates could not explain what a calorimeter is, and also only few candidates, among the very few that opted, could solve heat problems (WAEC, 2021)".

2.4 Empirical Review of the Study

2.4.1 Empirical Review of 5E Instructional Model on Students' Academic Performances in Physics

Various studies have investigated the effectiveness of using 5E Instructional Model to enhance the academic performance of students in the teaching and learning of Physics, and have found the 5E Instructional Model to be effective in enhancing students' academic performance. For instance, Bunkure (2019) employed the quasi-experimental design to assess the effect of 5E learning strategy on the academic performance of Physics students in Rano Education zone, Kano State-Nigeria using two intact classes of senior secondary school II physics students. The experimental group was exposed to 5E Instructional Model while the control group was instructed using the lecture method (conventional method of teaching). A significant z-test ($z\text{-cal}=3.145$, $df=132$, $p=0.00<0.05$) revealed that the experimental group performed better (mean=17.69, SD=4.2681) than the control group (mean=16.08, SD=3.8953). Therefore, according to Bunkure, the use of 5E Instructional Model in teaching Physics enhances the academic performances of the students.

Also, a meta-analysis on the effect of 5E Learning Model conducted by Cakır (2017) reported that the effect sizes of 5E Instructional Model on academic performance, attitude and science process skills were 1.27, 0.58 and 1.67 respectively. In the same vein, Bahadir and Melih (2022) conducted a meta-analytic study on the effect of 5E Instructional Model on students' academic performance in Physics. Bahadir and Melih (2022) found that, the overall effect size value at the 95% confidence interval in Physics was 0.733, representing

a large effect. This means that 5E Instructional Model had a significant positive impact on Physics students' academic performances.

Karthikyeyan and Densia (2021) moreover found in a randomised control group study that, secondary school Physics students who were instructed through the 5E Instructional Model performed better (mean=21.65; $t=3.26$; $p=0.00<0.05$) than the control group who were instructed through the conventional method (mean=19.650). Karthikyeyan and Densia added that the experimental group exhibited better retention of concepts after permanence test scores revealed significant difference in scores between experimental and control group in the permanence test in favor of the experimental group ($t_{(43)}=7.656$ and $p=0.000<0.05$).

In another study conducted by Appiah-Twumasi et al. (2021) in Ghana to determine the effect of the 5E Instructional Model on students' academic performances in Physics, a pretest, posttest and delayed posttest were conducted. After controlling for the effect of pretest on the posttest, an Analysis of Covariance (ANCOVA) results revealed there was a significant effect of teaching method on the posttest scores ($F=201.614$, $p<0.05$), implying that Physics students instructed using the 5E Instructional Model and the conventional teaching methods performed significantly different in the posttest, with the experimental group (taught using 5E Instructional Model) having pretest and posttest mean scores of 6.425(SD=1.259) and 12.075(SD=1.095), respectively. Also, the control group (taught using the conventional teaching method) had pretest mean score of 6.450(SD=1.413) and posttest mean score of and 7.500(SD=1.987). The normalised gain of the experimental

group was 0.659, indicating a medium gain, whereas the normalised gain for the control group was 0.122, indicating a low gain.

2.4.2 Empirical Review of 5E Instructional Model on Gender in Physics

With respect to the effect of 5E Instructional Model on gender, it appears paucity of research have been reported in literature both internationally and locally. Reviewing the few available studies conducted, it was found that there was conflicting evidence on the use of 5E Instructional Model to improve both male and female students' performance in Physics. For instance, Ellah and Achor (2018) examined the effect of 5E Instructional Model on Students' academic performance and attitude towards Physics in Senior Secondary Schools, and an ANCOVA results revealed that there was a significant effect of gender ($F=18.87$; $p=0.00<0.05$) on students' academic performance favouring males (with mean gain score =12.76) than females (with mean gain score =9.14). The finding of Ellah and Achor (2018) thus showed that the use of 5E Instructional Model was not effective in bridging the gender gap in academic performance in Physics.

Ellah and Achor's finding was in contrast to Appiah-Twumasi et al. (2021) whose findings revealed no significant difference in the pretest ($t_{(78)}= 0.084$, $p>0.05$) and the posttest ($t_{(78)}= 0.0357$, $p>0.05$) of male and female students taught using 5E Instructional Model. However, Appiah-Twumasi et al. (2021) found that there was a significant difference in delayed posttest mean scores of male (mean=10.975, SD= 2.749) and female students (mean=9.975, SD=1.493; $t_{(78)}=2.995$, $p=0.004<0.05$) taught using 5E Instructional Model,

indicating that male Physics students retained concepts better than their female counterparts after the use of 5E Instructional Model.

2.4.3 Empirical Review of Differentiated Instruction on Students' Academic Performance

The effect of Differentiated Instruction on students' academic performances in Physics have scarcely been investigated by researchers. Literature search revealed a study conducted by Ducey (2011) who sought to determine if Differentiated Instruction is an effective classroom methodology for high school Physics students in California. A test of Multiple Analysis of Variance (MANOVA) on the posttest scores of students in three different tests under heat and temperature, waves and light, electricity and magnetism between students taught using conventional teaching method and Differentiated Instruction was not statistically significant at the 0.05 level (Wilks $\Lambda = 0.987$; $F_{(3, 198)} = 0.867$; $p = 0.459 > 0.05$), indicating there was no significant difference in performance based on the instructional strategies used. Ducey (2011) therefore concluded that Differentiated Instruction did not show significant effect on students' performance in Physics.

However, in other fields of study, Differentiated Instruction has been found to be more effective than the conventional teaching method. For example, Awofala and Lawani (2020) ascertained the use of Differentiated Instruction in increasing Mathematics Performance of Senior Secondary School Students. Awofala and Lawani employed a quasi-experimental pretest/posttest nonequivalent control group design, using 220 second year Senior Secondary School Mathematics students. Six intact classes were selected and divided into

two groups, where three classes were experimental (taught using Differentiated Instruction) and three classes were control groups (taught using conventional teaching method). Using an analysis of covariance (ANCOVA), it was found that there was a significant difference in performance between students taught using Differentiated Instruction (Mean=32.81, SD=3.83) and conventional teaching method (Mean=21.48, SD=4.32; $F_{(1,219)}=213.37$, $p=0.000$, $\eta^2=0.498$). Therefore, Differentiated Instruction, according to Awofala and Lawani, enhanced Mathematics students' academic performances.

Alsahhi et al. (2021) in like manner investigated the impact of using Differentiated Instruction on students' performance in an intermediate school science course, by employing quasi-experimental design using 483 students. Their results revealed that students who were instructed using Differentiated Instruction performed significantly better (mean=16.86, SD=1.70) than those taught using the conventional teaching method (mean= 11.50, SD=1.64; $t=35.291$, $p=0.000$).

Similarly, Obafemi (2022) studied the impact of Differentiated Instruction on Mathematics students' academic performance in Kwara State, Nigeria. A quasi-experimental pretest/posttest control group research design was adopted. The findings of the study revealed that students taught using Differentiated Instruction significantly performed better (mean=34.54, SD=2.21) than those taught using conventional teaching method (mean=22.28, SD=2.32; $F_{(1,78)}= 64.888$, $P=0.000<0.05$) in Mathematics.

Tambaya et al. (2023) also employed a pretest/posttest quasi-experimental factorial design with 60 second year high school Biology students to assess the effectiveness of Differentiated Instruction on the academic performance of Biology students. An ANCOVA results of their study revealed no significant difference in students' academic performance in Biology between students instructed using Differentiated Instruction and those instructed using conventional teaching method (mean difference=4.97, $F_{(1,59)}=20.84$; $p=0.00<0.05$), with the difference favouring students taught using Differentiated Instruction. In effect, Differentiated Instruction significantly improved students' performance in Biology.

2.4.4 Empirical Review of Differentiated Instruction on Gender

With respect to gender performance of students taught using Differentiated Instruction, it appears literature is silent in the field of Physics. However, in other fields of study, the study of Awofala and Lawani (2020), an ANCOVA results showed no significant influence of gender ($F=0.061$, $p=0.805>0.05$, $\eta^2=0.00$) on Senior Secondary School students' performance in Mathematics. This means that male and female students instructed in Mathematics using Differentiated Instruction performed significantly equivalent.

Similarly, the study of Obafemi (2022) revealed no significant difference in students' academic performance in Mathematics between males and females who were taught using Differentiated Instruction ($F_{(1,78)}=0.437$; $p>0.05$). In a another study, Tambaya et al. (2023) revealed that there was neither main significant effect of gender ($F_{(1,59)}=0.22$; $p>0.05$) nor

significant interaction effect of gender and treatment ($F_{(1,59)}=0.00$; $p>0.05$) on students' performance in Biology.

2.4.5 Empirical Review of Comparative Effect of 5E Instructional Model and Differentiated Instruction on Students' Academic Performance

From literature, much attention has not been turned to the comparative study of 5E Instructional Model and Differentiated Instruction on students' academic performance. It appears there is scarcity of research available in literature. Salar and Turgut (2021) employed quasi-experimental pre-test/post-test control group design using a sample size of 162 10th grade Physics students from three purposively selected high schools. In each school Salar and Turgut randomly selected one experimental group (taught using Differentiated Instruction) and one control group (instructed using 5E Instructional Model). The results from an Analysis of Covariance (ANCOVA) revealed that there was no significant difference ($F_{(1,55)}=0.131$, $p=0.719>0.05$, $\eta^2=0.002$) between experimental group (adjusted mean=12.25) and control group (adjusted mean=11.98) in the first school, where science was taught predominantly.

On the other hand, in the second school, where science and social lessons were taught equally, there was a significant difference ($F_{(1,50)}=24.369$, $p=0.000<0.05$, $\eta^2=0.328$) between the experimental group (adjusted mean=8.94) and control group (adjusted mean=5.98). The results from students' scores in the third school, where social lessons were taken predominantly, similarly revealed a significant difference ($F_{(1,47)}=4.585$, $p=0.037<0.05$, $\eta^2=0.089$) between the experimental group (adjusted mean=8.05) and

control group (adjusted mean=6.92). Therefore, Salar and Turgut concluded that Differentiated Instruction improved the academic performances of Physics students in electricity better than the 5E Instructional Model in schools where science and social lessons were taken equally, as well as schools where social lessons were taken predominantly, but in schools where science lessons were taught predominantly, there was no significant difference in academic performance of Differentiated Instruction and 5E Instructional Model.

2.6 Summary of Literature Review

The literature reviewed revealed that, 5E Instructional Model is grounded in the constructivism theory while Differentiated Instruction has its root in both constructivism and the theory of multiple intelligence. Both theories operate on the basic tenet that learners should be the focal point of the learning process, through series of engaging activities with minimum help from the teacher, thereby rendering the teacher as a facilitator of the learning process. These theories are therefore applied when teachers employ teaching methods that allow tailoring instructions to fit the students' abilities and developmental levels. Accordingly, students will see the content learned as concrete rather than abstract, helping them apply concepts learned in other situations, thereby improving their academic performances.

After reviewing the literature, two significant limitations and conclusions were identified from previous studies. First of all, it appears no comparative study has been conducted in the Ghanaian context regarding the effect of 5E Instructional Model, Differentiated

Instruction and Conventional teaching method on SHS Physics students' academic performances. Secondly, from the literature reviewed, it appears paucity of research exist globally regarding the comparative effect of 5E Instructional Model and Differentiated Instruction. The only accessible study however, did not compare both 5E Instructional Model and Differentiated Instruction with the conventional teaching method since it is argued (Abah, 2020; Altun, 2023) that classroom instruction cannot completely do away with the conventional teaching method.

Also, the literature search revealed lack of consensus on the efficacy of 5E Instructional Model in reducing the gender gap in academic performance of students, with apparently little or no attention turned to the use of Differentiated Instruction to reduce the gender gap in academic performance in Physics. This makes it difficult for researchers to get a comprehensive understanding of how the 5E Instructional Model and Differentiated Instruction affect the academic performance of male and female students in Physics. Therefore, it is important to investigate the comparative efficacy of 5E Instructional Model, Differentiated Instruction and Conventional teaching method in Ghana, as well as how gender influences students' academic performance using the 5E Instructional Model, Differentiated Instruction and conventional teaching method, with SHS Physics students in Mampong Municipality and Sekyere South District. This in part helps fill the gap in identified in literature.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter discusses the method employed in this study. It begins by describing the study area and the methodological paradigm adopted for this study. The population, sample, and sampling procedure that were employed to determine the study's sample size are further described in this chapter. A thorough explanation of the research instrument utilised to collect the data for analyses, followed by the determination and results regarding the validity and reliability of the study's instrument are also provided in this chapter. This chapter similarly discusses the procedure for collecting data and how the data collected were analysed. Finally, the ethical considerations of this study are addressed in this chapter.

3.1 Study Areas

The study was conducted in the Mampong Municipality and the Sekyere South District. Located in the Ashanti Region of Ghana (see Figure 3.1), Mampong Municipality forms part of the 43 Metropolitan, Municipal and District Assemblies (MMDAs) in the Ashanti Region, Ghana, with Mampong-Ashanti as its capital. It spans an approximate area of 23.9 km² and is situated between longitudes 0.05° and 1.30° West and latitudes 6.55° and 7.30° North. Upon the division and improvement of the erstwhile Sekyere West District into Mampong Municipal and Sekyere Central District through Legislative Instrument (L.I.) 1908, Mampong Municipality was brought into existence. Sekyere South District borders to the south of the Municipality, Sekyere Central District lies to the east, and Ejura

Sekyedumase Municipal lies to the north. As of the 2021 Population and Housing Census, the Municipality has 116,632 residents, 56,965 of whom are men and 59,667 of whom are women. About 75% of the economically active labor force is employed in agriculture, which is the primary economic activity. Thus, the Municipality has vast arable land which inhabitants cultivate for various kinds of food and cash crops (Ghana Statistical Service, 2021).

The Municipal has 96 Primary Schools, 62 Junior Secondary Schools, five public Senior Secondary Schools and one private Senior High School, as well as a vocational training school. There are also two Colleges of Education, one Nursing and Midwifery Training College and one University. Among the SHSs in the municipality is one single-sexed (female) school (Ghana Statistical Service, 2021).

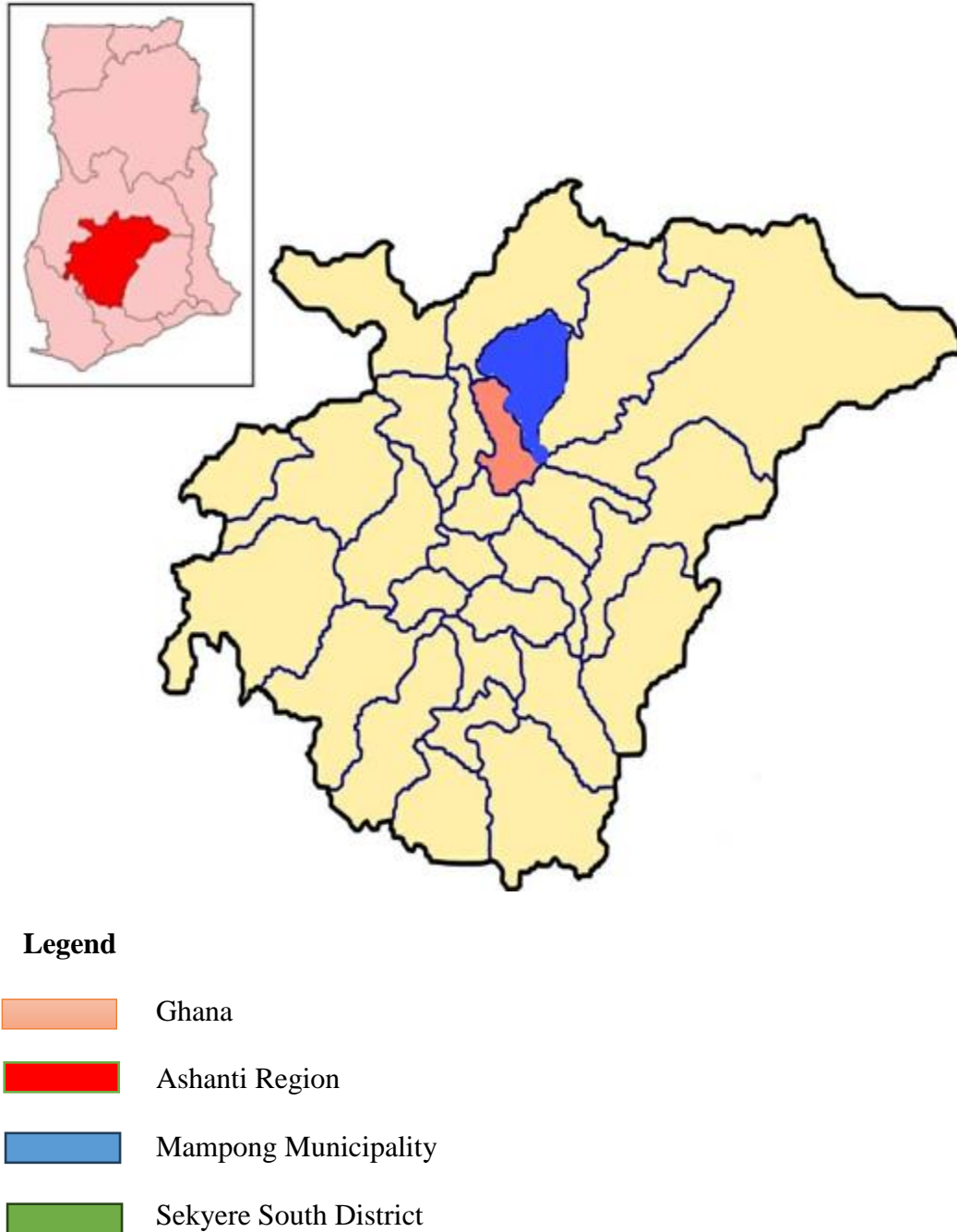


Figure 3.1 Geographical Map of Study Areas

With its administrative capital at Agona-Ashanti, Sekyere South District (see Figure 3.1) is one of the 43 MMDAs of Ashanti Region, Ghana. Along the Kumasi-Mampong trunk route, the Sekyere South District is 37 kilometers from Kumasi, situated in the northeastern

region of the Ashanti Region. With a total land area of 416.8 square kilometers, the district makes up roughly 1.7% of the 24,389 square kilometers that make up the Region. The district lies between latitude 6.50° and 7.10° North and Longitude 1.40° and 1.25° West. The following municipalities share borders with the Sekyere South District: Offinso Municipality to the west, Kwabre East Municipal to the south, Mampong Municipal to the east, and Ejura Sekyedumase Municipal to the north. According to the 2021 Population and Housing Census, the district has a population of 120,076 people, with 58,065 males and 62,011 females. Major towns in the district include; Agona, Bepoase, Jamasi, Agona-Bipoa, Boanim, Tano-Odumasi, Kona, Ashanti-Asamang, and Wiamoase (Ghana Statistical Service, 2021).

The Sekyere South district has 91 kindergartens, 92 primary schools, 65 Junior High Schools (JHS), five public Senior High Schools (SHS), one private SHS, one vocational school, one College of Education, one special school of education, one nursing and midwifery institution and one private university college within the district (Ghana Statistical Service, 2021).

3.2 Research Paradigm

As Kivunja and Kuyini (2017) stated, the term paradigm is used to describe a researcher's 'worldview'. That is, the viewpoint or a way of thinking that guide how research data are interpreted. This means that, a research paradigm is a method, model, or pattern for conducting research (Creswell, 2009; Kelle & Reith, 2023).

This study operated in the realm of positivist paradigm. Positivism hinges on the philosophy that reality or truth is absolute which can be found deductively through the scientific method (Creswell, 2014). Positivists contend that the world is an objective reality that exists independently of the observer's thoughts and is, thus, completely knowable (Khaldi, 2017). This reality we observe are caused by other factors. The researcher's job then, is to explain and evaluate this reality. Positivists share the premise that, in the natural and social sciences, the researcher can be disassociated from the subject of their inquiry and, as a result, examine it objectively and without influencing it. This means that the positivist paradigm places emphasis on the fact that knowledge is measurable (quantitative) and can be broken into variables, that comprise hypotheses and research questions, collection of data through observation and experience, that either supports or refutes the hypotheses, making analyses, making conclusions and drawing extrapolations (Cohen et al., 2018; Creswell, 2009; Kivunja & Kuyini, 2017). Therefore, as quantitative method was used in explaining the effect of the independent variables on the dependent variable, through the scientific process to test hypotheses and make inferences, this study aligns with the positivist paradigm.

3.3 Research Design

In general, a research design can be said to be the framework of a research or an inquiry. Kothari (2004) explains that the research design serves as the guide for data collection, measurement, and analysis. Thus, Cohen et al. (2018), summarise a research design as a strategy or plan created to organise the study, make it workable, and allow for the proper use of evidence and justifications in the answers to the research questions.

Working from the positivism paradigm, data were analysed quantitatively, thus rendering this study quantitative research. Several research designs can be named operating from this approach. Amongst them are “true” experimental designs (controlled experiments in laboratory conditions), quasi-experimental designs, correlational designs amongst others (Kivunja & Kuyini, 2017). However, the design employed for this study was the quasi-experimental pretest/posttest non-equivalent control group. The choice for the employment of this design was the fact that, this study aimed to make some causal inferences by making comparisons of pretest and posttest scores to determine the effect of 5E Instructional Model, Differentiated Instruction, and conventional teaching method on the academic performances of SHS Physics students (Cohen et al., 2018).

Also, this study was carried out in more naturalistic settings, using intact classes, which led to the decision to employ the quasi-experimental pretest/posttest non-equivalent control group design. As a result, students were assessed on previous knowledge concerning Thermal Physics, in order to determine whether participants had equivalent entry behaviours, hence the use of pretest. The posttest was then used to ascertain the efficacy of 5E Instructional Model, Differentiated Instruction and the Conventional teaching method on the academic performances of SHS Physics students. Thus, the major independent variables in this study were 5E Instructional Model, Differentiated Instruction and the Conventional teaching method, while the dependent variable was students’ academic performances in Thermal Physics.

3.3.1 Overall Study Design

A flow chart representation of this study's design is shown in Figure 3.2. Phase 1 involved identification of the population for the study to whom the findings of this study were extrapolated. This was done through initial field survey by the researcher in the study areas. Phase 2 involved selection of sampled students (n=291) from the total population through various sampling techniques. Since it was a quasi-experimental study, six intact classes from three different SHSs were used.

After selecting sampled students who participated in this study, the research instrument which was used to collect data was validated at Phase 3, and subsequently piloted with a sample (n=49) to assess the reliability of the scores at Phase 4. Following the determination of validity and reliability was the random assignment of sampled intact classes into experimental and comparison groups, which occurred at Phase 5. The collection of data through the administration of the final version of the research instrument before and after the treatments also occurred at Phase 6 with a sample size of 291 students. The data collected at Phase 6 were subjected to data analyses, using descriptive statistics to describe the data and inferential statistics to test hypotheses at Phase 7. At Phase 8, the results were interpreted and inferences were drawn based on the results obtained.

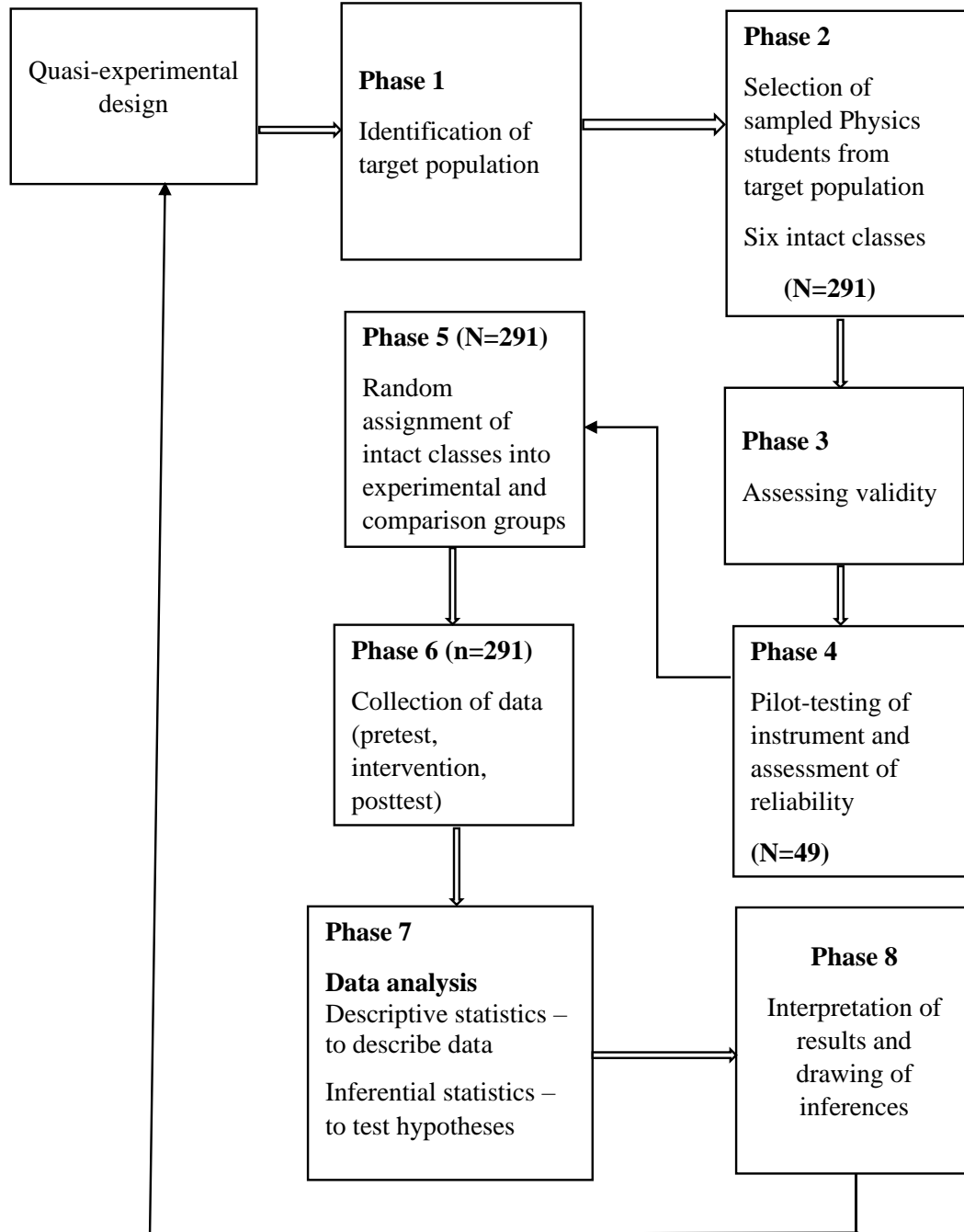


Figure 3.2: A Flowchart of the Study Design

3.4 Population

The target population for this study included all SHS Physics students within Mampong Municipality and Sekyere South District, in the Ashanti Region, Ghana. The accessible population however, included all SHS 2 Physics students within Mampong Municipality and Sekyere South District. SHS 2 Physics students were selected because Thermal Physics, according to the Physics syllabus, is studied in SHS 2 (Ministry of Education, 2010).

3.5 Sample

The sample size for this study comprised 291 SHS 2 Physics students from six intact classes selected randomly from the three participating schools. That is, two intact classes from each school were sampled. In effect, there were a total of 181 males, while 110 were females. The three sampled schools were classified A, B, and C for quick identification and handling while maintaining anonymity. The distribution of participants according to school and gender is tabulated in Table 3.1.

Table 3.1: Participants' Distribution According to School and Gender

School	Number of Male Physics Participants	Number of Female Physics Participants	Total Number of Participants
A	62	39	101
B	62	36	98
C	57	35	92
Total	181	110	291

3.6 Sampling Technique

Multi-stage sampling was employed to select the sample for this study, which according to Cohen et al., (2018), means that it contains two or more stages in selecting a sample for a study. Therefore, at each stage of the sampling procedure, the sample population changes. The various stages for this study are presented in Table 3.2 below.

Table 3.2: Stages of Multi-Stage Sampling Technique Used in this Study

Stage	Sampling procedure	Activity	Sample size (N)
Stage 1	Purposive sampling	Selection of public SHS offering Physics as elective.	8
Stage 2	Purposive sampling	Selection of co-categorical schools.	4
Stage 3	Simple random sampling	Selection of participating schools from the study areas.	3
Stage 4	Simple random sampling	Selection of intact classes.	6
Stage 5	Simple random sampling	Assignment of intact classes into experimental and comparison groups.	6

Stage 1 – Purposive sampling was employed to select public Senior High Schools offering Physics as an elective subject. This is due to the fact that two SHSs in the study areas did not offer Physics as an elective subject, and no private SHS granted permission for the research to be undertaken. In effect, eight public SHSs were selected at this stage from Mampong Municipality and Sekyere South District.

Stage 2 – From the eight public SHSs remaining, purposive sampling was employed to select four schools of the same category (category C) since this was a comparative study (Cohen et al., 2018). In selecting schools of the same category, the categorisation based on the Ghana Education Service (2022) was used. From the four selected schools, two schools

were located in Mampong Municipality while two schools were located in Sekyere South District.

Stage 3 – Simple random sampling was employed to select the three participating schools from the four schools within Mampong Municipality and Sekyere South District. Each participating school was assigned to a treatment (teaching method) since there were three different treatments to be introduced to participants in their intact classes without randomisation (Creswell, 2014).

Stage 4 – Simple random sampling was employed to select two intact classes from each selected participating school. This is because, there were more than two intact Physics classes in each participating school. Two intact classes were selected in order to increase the sample size for this study.

Stage 5 – Random assignment was also done to assign selected intact classes into experimental and comparison groups. Each group was named according to the instructional method assigned to them, thus, resulting in 5E Instructional Model group (taught using 5E Instructional Model), Differentiated Instruction group (taught using Differentiated Instruction), and conventional group (taught using conventional teaching method).

Each participating school selected from different towns, therefore, had two participating intact classes exposed to the same treatment. This was done to control for interaction effect which would affect the validity of the study (Cohen et al., 2018).

3.7 Data Collection Instrument

The research instrument used in collecting data was an achievement test named Thermal Physics Concept Test (TPCT). The choice for an achievement test is that, achievement tests

evaluate attained performance in a particular subject area according to Cohen et al. (2018), which was the objective of this study. This instrument which was prepared by the researcher, and was used as pretest and posttest, comprised of two sections A and B (see Appendix A). “Section A” of the TPCT comprised of 20 multiple-choice items with four answer options, lettered A-D to each item, and “Section B” consisted of two essay-type questions.

The use of both multiple-choice and essay formats was based on the assertion of Hift (2014) and Aalaei et al. (2016) who argue that a multiple-choice format, which contains fixed-response allows for a wider sampling of the content because more questions could be given in the testing period, which could not be achieved with essay test items. However, the fixed responses in a multiple-choice format tends to emphasise recall and encourage guessing (Oduro-Okyireh & Annor, 2018). In addition, Oduro-Okyireh and Annor (2018) argue that, essay test items reflect student knowledge of a subject much better than multiple choices, and therefore are the best format for testing higher-order behaviours and mental processes such as analysis and evaluation. Therefore, to reduce the inadequacies in both test formats, multiple-choice items and essay test items were used.

In scoring the test items, “Section A” of the instrument was scored dichotomously, while “Section B” employed polytomous scoring. The items for the instrument consisted of Thermal Physics Concepts considered in this study, and which were selected from the Ghanaian Physics Syllabus. The selection of Thermal Physics contents for this study was based on that reported in literature (Appiah-Twumasi et al., 2021; Awudi & Danso, 2023;

Fenditasari et al. (2020), as well as WAEC’s chief examiners’ reports (WAEC 2017, 2018, 2019, 2020). Table 3.3 shows the content representation of the items on the TPCT.

Table 3.3: Content Selection of Thermal Physics Concept Test

Concept	Questions
Heat	Q6, Q18
Temperature and its measurement	Q1, Q3, Q5, Q10, Q14,
Thermometers	Q13,
Thermometric substances	Q11,
Thermal expansion	Q7, Q8, Q9, Q12,
Heat transfer	Q2, Q4, Q15, Q16, Q17, Q19, Q20, Q21, Q22

As can be seen from Table 3.3, out of the 22 items, heat concept consisted of two items, five items from the concept of temperature and its measurement, one item each from the concepts of thermometers and thermometric substances, four items from thermal expansion, and nine items from the concept of heat transfer.

3.8 Validity of the Instrument

The validity of an instrument determines how accurately it measures what it is intended to measure (Cohen et al., 2018). In this study, the content validity was employed to determine the validity of the TPCT. Thus, the content validity was used to ensure that the instrument included adequate set of items that represent the concepts (Bhattacharjee, 2012), which in this study, is Thermal Physics. The content validity of an instrument can be determined qualitatively and quantitatively (Mohajan, 2017). According to Mohajan (2017), the content validity of an instrument can be determined qualitatively using expert judgement.

Therefore, the TPCT was given to a panel of six Physics educators (experts), as recommended by Lynn (1986), who were asked to evaluate the items in the TPCT to assess their accuracy, and ability to measure the dependent variable (academic performance of SHS Physics students) being considered in the study. The six Physics experts comprised of two experienced Physics education lecturers from Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), and four experienced SHS Physics teachers, who were examiners from SHSs within the study areas, with the rank of Assistant Director 1 (AD1). The six experts scrutinized each item on the instrument and when needed, offered insightful critiques. This was to determine face validity of the instrument (Mohajan, 2017).

The information gathered from the Physics educators (experts) helped to revise, delete, or substitute inappropriate items. However, according to Baghestani et al. (2019), face validity is a type of content validity. Therefore, after the evaluation of the TPCT by the Physics experts, the content validity of the TPCT was evaluated quantitatively using the Content Validity Ratio (CVR), an item statistic proposed by Lawshe (1975). The CVR is determined by first finding the Content Validity Index (CVI). According to Rutherford-Hemming (2015) for each item, the CVI is computed as the number of experts rating the item as relevant divided by the total number of experts who evaluated the item. In this study, the experts rated relevant items as 1 and irrelevant items as 0, as shown in Table 3.4. Once a CVI was determined for each item, an overall CVI for the entire items was calculated, which Rutherford-Hemming (2015) explains that it is determined by the mean

of all individual CVIs. The CVR was then determined by dividing the overall CVI by the total number of items, as presented in Table 3.4.

Table 3.4: Calculated Content Validity Index and Content Validity Ratio for TPCT

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	0	1	1	1	5	0.833
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	1	1	1	1	1	1	6	1.000
7	1	1	1	1	1	1	6	1.000
8	1	1	1	1	0	1	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	0	1	1	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
16	1	1	1	1	1	1	6	1.000
17	1	1	1	1	1	1	6	1.000
18	1	1	0	1	1	1	5	0.833
19	1	1	1	1	1	1	6	1.000
20	1	1	1	1	1	1	6	1.000
21	1	1	0	1	1	1	6	0.833
22	1	1	1	1	0	1	6	0.833
CVR								0.954

Where,

$$\text{CVI} = \text{Content Validity Index} = \frac{N_E}{N}$$

N_E = Number of experts indicating items as essential

N = total number of experts

$$\text{CVR} = \text{Content Validity Ratio} = \frac{\text{total CVI}}{\text{Total number of items}} = \frac{20.998}{22} = 0.954$$

According to Obilor and Miwari (2022), CVR yields values which ranges from -1.000 to 1.000. The closer the CVR is to 1, the higher the overall content validity of a test instrument. Also, positive values indicate that at least half the expert judges rated the item as essential. Therefore, as presented in Table 3.4, in this study, the content validity ratio of TPCT was 0.954, which according to Obilor and Miwari, indicate a valid instrument.

3.9 Pilot testing of the Instrument

After determining the validity of the instrument, the TPCT was pilot-tested. The participants used for the pilot testing was part of the target population but they did not take part in the main study. Therefore, they shared similar characteristics of the research participants. According to Hertzog (2008), a sample size ranging from 10 to 40 per group is endorsed for evaluating the adequacy of the research instrument. Similarly, Johanson and Brooks (2010) advocated that 30 representative samples from the target population of interest are practically appropriate for a pilot study. In view of this, 49 SHS 2 Physics students (one intact class) were used for the pilot testing of the instrument. Thus, the sample size for the pilot test exceeded the recommendations by Hertzog (2008), as well as Johanson and Brooks (2010), therefore the sample size for the pilot test was deemed appropriate.

3.10 Reliability of Research Instrument

The results of the pilot study were used to determine the reliability of the research instruments. The reliability analyses, specifically internal consistency of the scores from the pilot study was statistically assessed using the Cronbach alpha coefficient, for the multiple-choice section, and inter-rater reliability using Cohen's kappa, for the essay section. The results are presented in Tables 3.5 and 3.6.

Table 3.5: Internal Consistency for “Section A” of TPCT

Reliability Statistics	
Cronbach's Alpha	N of Items
.808	20

As represented in Table 3.5, the Cronbach Alpha value, which measured the internal consistency of the multiple test items of the TPCT scores was 0.808. This value, according to Pallant (2011) indicates a preferable internal consistency of the scores. This means that the internal consistency of TPCT was reliable, and that the Cronbach Alpha value of TPCT was high for the items to be used in the main study.

Also, with the essay section of the research instrument (TPCT), the solved items by the students in the pilot study were given to two raters to score them independently. The consistency of scores from the raters was therefore computed using Kappa's measure of agreement for which according to Kottner et al. (2011), as a rule of thumb, values ≤ 0 as indicate no agreement and 0.01–0.20 as none to slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate agreement, 0.61–0.80 as good or substantial agreement,

and 0.81–1.00 as perfect agreement. In this study, the value of Kappa’s measure of agreement as seen from Table 3.6 was 0.780, which is a substantial agreement, according to Kottner et al. (2011).

Table 3.6: Results for Inter-Rater Reliability of “Section B” of TPCT

		Value	p
Measure of Agreement	Kappa	.780	.000
N of Valid Cases		49	

Therefore, it can be concluded that the reliability of the scores of the instrument was deemed sufficient for the instrument to be used in the main study.

3.11 Data Collection Procedure

In this study, only quantitative data were collected for analyses and generalisations. The data collection process, which was done in person by the researcher, lasted for 13 weeks. The data was collected in person by the researcher to ensure a high degree of confidence in the data (Bhasin, 2021). The data collection procedure was done in three stages, thus, pre-intervention phase, intervention phase, and post-intervention phase. The various phases and their related activities are explained below.

3.11.1 Pre-Intervention phase

This is the first phase in the data collection process. During this phase, an introductory letter was sought from the Department of Integrated Science Education of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (see Appendix U). Using the introductory letter, official permission was sought from the

Municipal and District Education Directorates of the Mampong Municipality and the Sekyere Central District for the study to be conducted in the study areas. Afterwards, headmasters of various schools that were selected for the study were notified and their permissions were sought using the introductory letter from the Department of Integrated Science Education, as well as the acceptance letter from the Municipal and District Education Directorates. The various heads of departments of science and Physics teachers in the participating schools were also informed. During the interaction with the respective academic headmasters, heads of departments for science, and Physics teachers, the benefits and importance of this study were highlighted to the authorities. As a result, copies of the research instrument were presented to them for their examination, and they were assured of the confidentiality of any information provided by students. These activities took place from 28th November to 15th December, 2022.

The second step in this phase was the conduction of the pilot test. The pilot study was conducted using participants who did not take part in the main study; however, they shared similar characteristics with participants of the main study. The pilot test was conducted on 20th January, 2023. Data collected from the pilot study helped in establishing the reliability of the instrument.

Following the pilot study and the subsequent determination of the validity and reliability of the scores of the instrument, the intact classes selected for the main study through simple random sampling were visited for familiarisation with students, and ensuring their maximum cooperation where the importance of this study were highlighted to the students,

and the ensuing benefits it will add to their academic growth and science education in general. This activity took place from 22nd to 24th February, 2023. Afterwards, the pre-intervention test (pretest) was conducted in all sampled intact classes with the assistance of Physics teachers in the various schools. The administration of the pretest test took place on 13th to 17th March, 2023. Students' scripts in addition to the question papers were collected after they had completed the pretest. This was because, same items were used for the post-intervention test (posttest). Also, students were not informed of the intention to use the same instrument for the posttest in order to minimise the influence of the pretest on the posttest performance.

3.11.2 Intervention Phase

This is the second phase in the data collection process. During this phase, the interventions were introduced, where students were exposed to the teaching methods according to their groups. The various groups (experimental and comparison groups) were instructed in the Thermal Physics content for four weeks each, using the same content but different treatments (teaching methods). The intervention phase lasted for eight weeks, thus, beginning from 20th March to 12th May, 2023. The treatment of each teaching method to respective groups was done by one instructor (the researcher) in order to control for teacher differences, which would affect the validity of the results of the study (Cohen et al., 2018). The Thermal Physics contents that were covered during the period of interventions are presented in Table 3.7.

Table 3.7: Thermal Physics Content Taught to All Groups

Period	Content Taught
1 st and 2 nd week 3 rd and 4 th week	Heat, Temperature and its Measurement Thermometers and Thermometric Substances
5 th and 6 th week 7 th and 8 th week	Thermal Expansion Heat Transfer

Since the various groups were exposed to different treatments (teaching methods), treatment activities therefore differed across the three groups, thus 5E Instructional Model group, Differentiated Instruction group, and Conventional group. Tables 3.8, 3.9 and 3.10 highlight the treatment activities for all groups.

Table 3.8: Intervention Activities for 5E Instructional Model Group

Stage	Teacher's Activity	Learners' Activity	Objective
Phase 1 Engagement	Presented a conflicting real-life problem to pique students' interests	Articulated ideas, shared observations and developed mental models.	Identification of the learners' prior knowledge. Increase students' motivation.
Phase 2 Exploration	Provided the needed TMLs to learners. Assisted learners to design scientific investigation.	Carried out investigations by gathering, describing and documenting data. Compared findings, concepts and conclusions with other students.	Learners' development of conceptual understandings.
Phase 3 Explanation	Provided opportunities for classroom discussion	Reported and discussed new findings with whole class	Development of learners' scientific communication skills.
Phase 4 Elaboration	Assisted students make connections between their prior knowledge and the new scientific ideas and experiences by using scientific terminology	Applied definitions, fresh knowledge, and conclusions to related scientific situations.	Broader understanding scientific concepts.
Phase 5 Evaluation	Used formative and summative assessments tools to test learners' understanding	Used scientific ideas and concepts to provide answers to questions.	Identification of learning gaps.

Adapted from (Bybee, 2018)

In the Differentiated Instruction group, prior to the implementation of the teaching method, first steps were taken to administer students' interest inventory (see Appendix R) adopted from Shumow and Schmidt (2013) as well as learning style questionnaire which was also adopted from Bright (2006) (see Appendix S). This was done to determine students' characteristics based on which the differentiation was done. Also, pre-instruction test was

conducted before every lesson which provided information on students' prior knowledge on the content to be taught. After identifying students' characteristics and prior knowledge, the lessons were then differentiated using the activities as illustrated in Table 3.9.

Table 3.9: Intervention Activities for Differentiated Instruction Group

Element of Differentiation	Students' Characteristics	Activities
Content	Readiness	Provided texts and additional resources at diverse reading levels. Reinforced lectures with videotapes. Provided important lists of vocabularies lists for reference during note-taking.
	Interest	Offered a diversity of resources pertaining to a range of student interests. Incorporated illustrations and examples according to the interests of the students.
	Learning Profile	Presented content in visual (images), auditory (lecture), and kinesthetic (hands-on experiments) formats. Applied ideas, models, and depictions from a variety of cultures and societies, as well as from both genders.
Process	Readiness	Employed tiered activities. Varied the pace at which students completed their assignments and exercises.
	Interest	Employed the Jigsaw and think-pair-share cooperative strategies to allow students to focus in aspects of a topic which they found interesting.
	Learning Profile	Gave students the choice to express what they learned. Blended independent and collaborative works
Product	Readiness	Used tiered product assignment.
	Interest	Encouraged students to communicate their knowledge, understanding, and skills in related topics of interest. Offered opportunities for students to conduct independent investigations with the guidance of the teacher.
	Learning Profile	Encouraged students to work independently or in groups on assignments and exercises.

Adapted from Tomlinson and Eidson (2003)

Teaching method introduced to the conventional group was predominantly teacher-centered, specifically, lecture, as presented in Table 3.10.

Table 3.10: Intervention Activities for Conventional Group

Stage	Activities
Stage 1 Introduction	The teacher presented the lesson to the students
Stage 2 Development	The teacher explained key points and write notes for students to copy
Stage 3 Application	The teacher gave students in-class examples and questions to solve
Stage 4 Evaluation	Using both formative and summative assessment techniques to determine the achievement of lesson objectives.

3.11.3 Post-Intervention Phase

After the exposure to the treatments, students were given one week to revise their notes and to make additional research, after which the post-intervention test was conducted on 18th and 19th May, 2023. The researcher at this stage conducted the post-intervention test in person with the assistance of the Physics teachers in the various schools. Students from all three groups were given 40 minutes to answer the test items. The researcher then marked the students' scripts, after which the scores were ready for data analyses. During this study, there was no attrition, that is no student in all the three groups withdrew from the study. As a result, the number of students who participated in the pre-intervention test was equal to the number of students who participated in the post-intervention test.

3.12 Data Analyses Procedure

This study adopted quasi-experimental with quantitative approach; therefore, data were analysed quantitatively. To process, manipulate, and analyse the scores from the pre-intervention test and post-intervention test, descriptive and inferential statistical techniques were employed via Statistical Package for Social Sciences (SPSS) version 26.

3.12.1 Descriptive Statistics

Descriptive statistics are the kind of information presented to describe the data in a study (Mishra et al., 2019). Thus, these statistical techniques were used to summarise the set of observations (pretest and posttest scores of SHS Physics students), in an effort to convey the most information in an understandable manner. The descriptive statistics specifically used in this study were mean and standard deviation.

Also, normality tests were conducted to describe the distribution of the data. Normality tests, according to Mishra et al. (2019) are numerical and graphical techniques that are used to organise and describe the characteristics of the sample. Thus, numerically, the normality tests used in this study were Kolmogorov-Smirnov test and Shapiro-Wilk test, while the graphical representations used were histograms, box-plots, and Normal Quantile-Quantile plots (Q-Q plots). By determining the normality of the data ensured that the data complied with a distribution pattern that mathematically allowed parametric tests to be conducted (Marshall & Jonker, 2010).

3.12.2 Inferential Statistics

Inferential Statistics, on the other hand make deductions from data that are subject to random variation (Mishra et al., 2019). This means that, inferential statistics make predictions and conclusions about a population by studying a smaller sample, through the testing of research hypotheses. According to Mishra et al (2019), inferential statistical methods used for data analyses in this study, which are independent samples t-test, one-way between groups analysis of variance (one-way ANOVA), one-way between groups analysis of covariance (one-way ANCOVA), and two-way analysis of covariance (two-way ANCOVA), make assumptions about normality, since they are parametric tests.

Specifically, one-way ANOVA was used to determine any significant difference in pretest scores (entry characteristics) between all the three groups prior to the intervention. However, hypotheses 1 and 2 were tested using an independent samples t-test, since the assumptions for using one-way ANCOVA were violated in testing these hypotheses. The decision to use ANCOVA was based on the premise that there was non-random assignment of participants to the different groups, therefore existing groups were used. Pallant (2011) argues that these groups might have differed on a number of different attributes, and not just the one the researcher is interested in. Therefore, the use of ANCOVA was used in an attempt to reduce some of these differences, amongst which may be any influence that the exposure to the pretest items may have on the posttest scores, since the same test was used as pretest and posttest, as argued by Kim and Willson (2010) as well as Janelli and Lipnevich (2021).

Nevertheless, as a parametric statistical technique, ANCOVA is based on a number of assumptions (Pallant, 2011; Schneider et al., 2015) of which a major one (assumption of homogeneity of regression slopes) was violated in testing hypotheses 1 and 2 (see Appendices I1, I2, K1 and K2) thus preventing one-way ANCOVA to be used since the violation of this assumption would skew the results of hypotheses 1 and 2 (Pallant, 2011). In view of this, an independent samples t-test, which assumptions were not violated, was used to test hypotheses 1 and 2.

Contrary to those for hypotheses 1 and 2, the assumption of homogeneity of regression slopes was not violated when testing hypotheses 3 and 4, hence one-way ANCOVA and two-way ANCOVA were used to test hypotheses 3 and 4 respectively. The accepted level of significance ($p < 0.05$) was used as the basis to report whether significant differences in the performances of SHS Physics students existed after exposure to 5E Instructional Model, Differentiated Instruction, and conventional teaching method, as well as any significant gender differences within all groups.

3.13 Ethical Considerations

The collection of data from human subjects for any reason without ethical approval would be regarded as unethical in educational research (Creswell, 2014). Therefore, when a researcher or a group of researchers conduct qualitative, quantitative, or mixed-method research in educational institutions, ethical issues must be taken into account. Some of the ethical issues considered in this study are discussed in the following sub-sections.

3.13.1 Confidentiality

Participating students were assured of their confidentiality of any data provided relating to this study. Consequently, confidentiality was ensured before, during, and after the study. For example, students were assured of their anonymity. The researcher initially briefed the participants on the study's objectives and provided confidentiality protection and anonymity procedures to report the research results. Hence, their names were not disclosed in any way. Additionally, participants were assured that any information they provided would not be used against them in any way.

3.13.4 Informed Consent

Informed consent generally refers to the idea that before human participants volunteer to participate in research, they should have full disclosure about their involvement in it. Participants must be aware of the purpose of the study and freely choose to participate (Cohen et al., 2018). Thus, the study's participants were fully informed of what was asked of them, how the data would be used, and more importantly, what (if any) potential effect there could be. The study followed all criteria for the privacy of the participating schools and the participants. Communications between the participants and the researcher were initially made possible through the approval of the respective authorities of the selected schools; precisely, the Assistant Headmaster in charge of Academics of the participating schools in the Mampong Municipality and the Sekyere Central District. Each student was therefore presented with a letter of informed consent before the beginning of the study (See Appendix T).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

In this chapter the demographic characteristics of the participants, as well as results and findings of the study are presented. The data collected were analysed in terms of descriptive and inferential statistics. Descriptive and inferential statistics were conducted at 0.05 level of significance for testing hypotheses, after testing for respective assumptions.

4.1 Gender Distribution of Participants

In this study, 291 SHS 2 Physics students participated. Out of the 291 students who took part in the study, 181 were males, representing 62.2% while 110 were females, representing 37.8%, as seen from Figure 4.1. Among these, the treatment groups, namely, 5E Instructional Model and Differentiated Instruction groups respectively had 101 and 98 students who participated. The Conventional group, which served as a comparison group for this study had 92 participants. In the 5E Instructional Model group, there were 62 males, representing 21.3%, and 39 females, representing 13.4%. The Differentiated Instruction group had 62 males (21.3%) and 36 females (12.4%). In the conventional group, the male participants were 57, representing 19.26%, while female participants were 35, representing 12.0%, as seen from Figure 4.1.

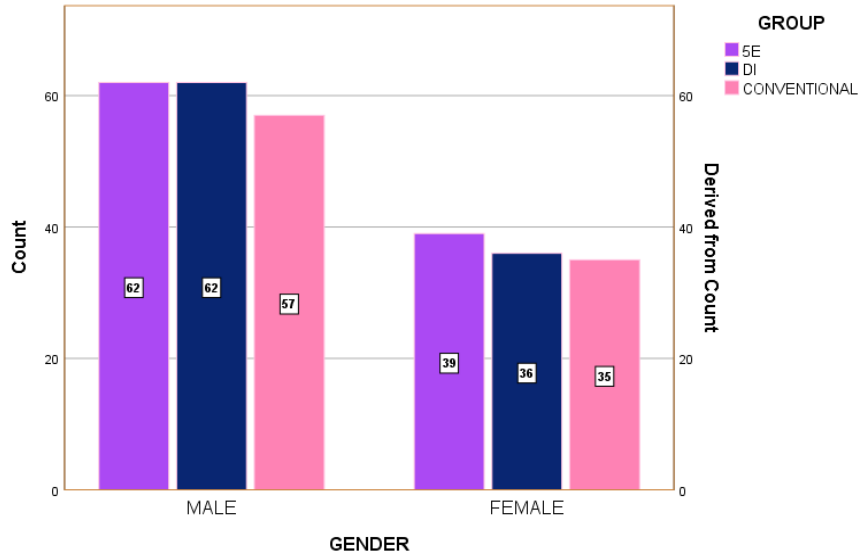


Figure 4.1: Gender Distribution of Participants

4.2 Pretest and Posttest Scores for 5E Instructional Model, Differentiated and Conventional groups

The scores of the pretest and posttest for 5E Instructional Model (5E), Differentiated Instruction (DI), as well as Conventional groups were computed and their means, standard deviations, minimum, and maximum scores are reported as indicated in Table 4.1.

Table 4.1: Descriptive Statistics of Pretest and Posttest Scores of 5E Instructional Model (5E), Differentiated Instruction (DI) and Conventional Groups

GROUP		PRETEST	POSTTEST
5E	N	101	101
	Minimum	2	7
	Maximum	12	28
	Mean	6.09	16.59
	Standard Deviation	2.761	5.168
DI	N	98	98
	Minimum	3	7
	Maximum	12	30
	Mean	5.01	19.12
	Standard Deviation	2.988	5.766
Conventional	N	92	92
	Minimum	2	3
	Maximum	11	23
	Mean	5.53	13.34
	Standard Deviation	2.679	5.010
Overall mean (Std. Dev.)		5.89 (2.815)	16.42 (5.805)
Source (field data)			

As observed from Table 4.1, 5E Instructional Model group and conventional group obtained a minimum pretest score of 2, while the Differentiated Instruction group obtained a minimum pretest score of 3. However, both 5E Instructional Model and Differentiated Instruction groups recorded the highest pretest scores of 12, while the conventional group recorded the lowest pretest score of 11. Moreover, comparing their mean scores, the 5E Instructional Model group obtained the highest mean score of 6.09(SD=2.761), while the Differentiated Instruction group obtained the least mean score of 5.01(SD=2.679), with the

Conventional group obtaining a mean score of 6.02(2.988). The overall mean pretest score in this study was therefore 5.89(SD=2.815).

Also, in the posttest, as observed from Table 4.1, both 5E Instructional Model and Differentiated Instruction groups obtained minimum scores of 7, while the Conventional group recorded the lowest minimum score of 3. However, the Differentiated Instruction group obtained the highest posttest score of 30, while conventional group recorded the least posttest score of 23. As a result, the Differentiated Instruction group obtained the highest posttest mean score of 19.12(SD=5.766), while the Conventional group obtained the lowest posttest mean score of 13.34(SD=5.010), with the 5E Instructional Model group obtaining a posttest mean score of 16.59(5.168). The overall mean score posttest score was 16.42(SD=5.805).

2.4 Pretest and Posttest Scores of Male and Female SHS Physics Students Within All Groups

The scores of the pretest and posttest for both gender groups (males and females) within all the three groups were also computed and their descriptive statistics were determined as presented in Table 4.2.

Table 4.2: Descriptive Statistics of Pretest and Posttest Scores of Male and Female SHS Physics Students Within All Groups

Group		Pretest Mean	SD	Posttest Mean	SD	Mean Gain.
5E	Male	6.39	2.905	16.77	5.190	10.40
	Female	5.62	2.477	16.31	5.187	10.69
	Mean Difference	0.77		0.46		
DI	Male	6.19	2.947	19.42	5.947	13.23
	Female	5.72	3.076	18.61	5.484	12.89
	Mean Difference	0.47		0.81		
Conventional	Male	5.02	2.608	15.86	3.819	10.84
	Female	6.37	2.613	9.23	3.889	2.86
	Mean Difference	1.35		6.63		

Source (field data)

As indicated in Table 4.2, male SHS Physics students in the 5E Instructional Model group (taught using 5E Instructional Model) obtained a mean gain of 10.40 between the pretest (mean=6.39, SD=2.905) and posttest (mean=16.77, SD=5.190), while their female counterparts obtained a mean gain of 10.69 between the pretest (mean=5.72, SD=2.477) and posttest (mean=16.31, SD=5.187). However, there was a reduction in mean differences from 0.77 in the pretest to 0.46 in the posttest, which both favoured males.

Also, in the Differentiated Instruction group (taught using Differentiated Instructional), males obtained a mean gain of 13.23 between the pretest (mean=6.19, SD=2.947) and posttest (mean=19.42, SD=5.947), while their female counterparts obtained a mean gain of 12.89 between the pretest (mean=5.72, SD=3.076) and posttest (mean=18.61, SD=5.484).

However, there was a relatively small increase in mean differences from 0.47 in the pretest, (in favour of females) to 0.81 in the posttest (in favour of males).

Again, as observed in Table 4.2, male students in the conventional group (taught using Conventional teaching method) obtained a mean gain of 10.84 between the pretest (mean=5.02, SD=2.608) and posttest (mean=15.86, SD=3.819), while their female counterparts obtained a mean gain of 2.86 between the pretest (mean=6.37, SD=2.613) and posttest (mean=9.23, SD=3.889). However, there was a relatively large increase in mean differences from 1.35 in the pretest to 6.63 in the posttest, which both favoured males.

4.4 Data Distribution of Pretest and Posttest Scores for All Groups

Normality tests of the pretest and posttest scores for all three groups, thus 5E Instructional Model group, Differentiated Instruction group, and Conventional group, were conducted using statistical analyses and graphical representations, specifically, histogram, box plots, and Q-Q plots. This was done since parametric tests (that is, independent sample t-test, one-way between groups analysis of variance, and two-way analysis of variance) were used in analysing the data collected in this study. As one of their assumptions, parametric tests assume that the data collected should not deviate from normality (Pallant, 2011). The normality tests were performed through the Kolmogorov-Smirnov and Shapiro-Wilk tests, which was guided by an assumption that the pretest and posttest scores should be normally distributed within all the three groups. The decision of the normality assessment of the data was based on the null hypothesis that “the data are normally distributed” (Mishra, Pandey,

et al., 2019; Pallant, 2011). That is, the null hypothesis is rejected if the alpha (p) value is below 0.05. The results of the normality tests are presented in Table 4.3.

Table 4.3: Test of Normality for Pretest and Posttest Scores of 5E Instructional Model (5E), Differentiated Instruction (DI) and Conventional Groups

	Group	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Pretest	5E	.085	101	.071	.980	101	.131
	DI	.087	98	.063	.976	98	.064
	Conventional	.079	92	.200*	.975	92	.070
Posttest	5E	.057	101	.200*	.980	101	.121
	DI	.071	98	.200*	.977	98	.079
	Conventional	.083	92	.147	.977	92	.104

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Df – Degrees of freedom

As indicated in Table 4.3, the normality tests produced non-significant Shapiro-Wilk and Kolmogorov values ($p > 0.05$) for the pretest and posttest scores for all groups, indicating normal distribution of the pretest and posttest scores for all the three groups.

However, according to Mishra et al. (2019), Hernandez (2021) and Kwak and Park (2019), the Shapiro-Wilk test of normality is more powerful test to assess the distribution of data. Accordingly, as observed in Table 4.3, statistical test of normality using Shapiro Wilk's tests produced non-significant normally distributed measures of 0.980($p=0.131 > 0.05$) for the pretest scores for 5E Instructional Model group; 0.976($p=0.064 > 0.05$) in the Differentiated Instruction group; and 0.975($p=0.070 > 0.05$) in the Conventional group.

Also, for the posttest scores, 5E Instructional Model group revealed a non-significant measure of 0.980($p=0.121>0.05$); 0.977($p=0.079>0.05$) for Differentiated Instruction group; and 0.977($p=0.104>0.05$) for the Conventional group. Therefore, as indicated in Table 4.3, the pretest and posttest scores of all three groups were considered approximately normal. This can be inspected graphically with histograms, box plots, and normal Quantile-Quantile plots (Q-Q plots) for pretest and posttest scores of all three groups (see Appendices B1 to H2).

4.5 Preliminary Analysis of Pretest Scores of SHS Physics Students Within All Groups

Considering that this study was carried out in classrooms, because of practical constraints, it was unable to maintain the level of random assignment possible in a true experiment. Therefore, a preliminary step was taken to ascertain whether this approach of grouping (use of intact classes) produced groups that were comparable in terms of fundamental traits (Creswell, 2014), which in this study is academic performance. Thus, the pretest, as mentioned in chapter three, was conducted to determine if there were significant differences among the three groups prior to the intervention. This was done using one-way between groups analysis of variance. However, a one-way analysis of variance maintains, as one of its assumptions that, there should be homogeneity of variances among all groups (Pallant, 2011). That is, the variance in the pretest scores should be the same for each of the three groups, which are 5E Instructional Model group, Differentiated Instruction group, and the Conventional group, in addition to normal distribution (see Table 4.3, and Appendices B1, B2, D1, D2, F1, F2 and H1). The assumption of homogeneity of variances

was tested using Levene’s test (Mishra et al., 2019) and the results are presented in Table 4.4.

Table 4.4: Results for Test of Homogeneity of Variances on Pretest Scores for All Groups

	Levene’s Statistic	df1	df2	p
Pretest	.850	2	288	0.428

df – degrees of freedom

From Table 4.4, it can be observed that the Levene’s statistic, which tests the null hypothesis that the variances among all the three groups are equal (Pallant, 2011), is 0.850. However, this value was not significant ($p=0.428>0.05$). Therefore, the null hypothesis was accepted. As a result, the variances in the pretest scores among all the three groups were considered equal. This implies that the assumption of homogeneity of variances was not violated. Subsequently, the one-way between groups analysis of variance of the pretest scores for all three groups, which are, 5E Instructional Model, Differentiated Instruction, and Conventional groups was conducted. The results of the one-way between groups analysis of variance are presented in Table 4.5.

Table 4.5: Results of One-way Between Groups Analysis of Variance on Pretest Scores for All Groups

	Sum of Squares	df	Mean Square	F	p
Between Groups	17.422	2	8.711	1.100	0.334
Within Groups	2281.059	288	7.920		
Total	2298.481	290			

$P>0.05$; df – degrees of freedom

From Table 4.5, it can be observed that there was no significant difference in mean pretest scores among the three groups ($F_{(2,288)}=1.100$, $p=0.334>0.05$). This therefore suggests that the performances of all the three groups were significantly equivalent prior to the intervention.

4.6 Difference Between the Use of 5E Instructional Model and Conventional Teaching Method in the Teaching and Learning of Thermal Physics

4.6.1 Testing of Hypothesis 1

Hypothesis 1 was stated to determine whether the difference in academic performance between 5E Instructional Model group and the conventional group was statistically significant. The null hypothesis, H_0 , stated that; *there is no significant difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and those taught using conventional teaching method*. As explained in Section 3.12.2, the assumptions of ANCOVA were violated in testing this hypothesis (see Appendices I1 and I2), where 16.6% (partial eta squared=0.166) of the variance in the pretest scores which significantly influenced the posttest performance would have been statistically controlled (see Appendix J).

Hypothesis 1 therefore was tested using an independent samples t-test on the posttest scores of Thermal Physics Concept Test (TPCT) for 5E Instructional Model group and the conventional group at an alpha level of 0.05. However, an independent sample t-test also assumes that, the variances in the posttest scores between 5E Instructional Model group and the conventional group must be equal (Pallant, 2011). The assumption of homogeneity

of variances was tested based on the null hypothesis that the variances in the posttest scores for 5E Instructional Model group and conventional group are equal (Mishra et al., 2019). Using Levene’s test, as Pallant (2011) and Mishra et al. (2019) suggest, this assumption was tested and the results are presented in Table 4.6.

Table 4.6: Results for Test of Homogeneity of Variances on Posttest Scores of 5E Instructional Model Group and Conventional Group

		Levene’s Test Statistic	
		F	p
Posttest	Equal Variances Assumed	0.001	0.973

From Table 4.6, it could be observed that, the variances in the posttest scores of 5E Instructional Model and conventional groups were equal, since Levene’s statistic, F, was not significant ($F=0.001$, $p=0.973>0.05$). Consequently, the assumption of homogeneity of equal variances was not violated, in addition to normal distribution of posttest scores of both groups (see Table 4.3 and Appendices C1, C2, G1 and G2). Accordingly, the independent samples t-test between the posttest scores of the 5E Instructional Model group and the conventional group was conducted, and the results are presented in Table 4.7.

Table 4.7: Results of Independent Sample t-test for Posttest Scores of 5E Instructional Model and Conventional Groups

Group	N	Mean	SD	t	df	p	Eta Squared
5E Instructional Model	101	16.59	5.168	4.437	191	.000*	0.093
Conventional	92	13.34	5.010				

* $p<0.05$; df – degrees of freedom

The results of the independent sample t-test, as revealed in Table 4.7, shows that there was a significant difference in posttest scores between 5E Instructional Model group ($M=16.59$, $SD=5.168$) and the conventional group was significant ($M=13.34$, $SD=5.010$; $t_{(191)}=4.437$, $p=0.000<0.05$). An effect size, which describes the magnitude of the difference in means between the two groups was also determined using eta squared statistic (see Appendix V), which produced an eta squared value of 0.093 as shown in Table 4.7, indicating a moderate effect according to Pallant (2011). Consequently, we fail to accept the null hypothesis since there was not sufficient evidence to accept the null hypothesis. Therefore, there was a significant difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and students taught using conventional teaching method.

4.7 Difference Between the Use of Differentiated Instruction and Conventional Teaching Method in the Teaching and Learning of Thermal Physics

4.7.1 Testing of Hypothesis 2

Hypothesis 2 was to determine whether any existing difference in academic performance between students who received Differentiated Instruction and students who were taught using conventional teaching method was statistically significant. The null hypothesis, H_0 , stated that, *there is no significant difference in academic performance between SHS Physics students taught Thermal Physics using Differentiated Instruction and students taught using conventional teaching method.*

As previously explained in section 3.12.2, the assumptions of ANCOVA were violated in testing hypothesis 2 (see Appendices K1 and K2), where 25.2% (partial eta squared 0.252)

of the variance in the pretest scores significantly influencing the posttest performance would have been statistically controlled (see Appendix L). As a result, hypothesis 2 was tested using an independent samples t-test on the posttest scores of Differentiated Instruction group and the conventional group at an alpha level of 0.05. However, an assumption of homogeneity of variances of posttest scores of Differentiated Instruction group and the conventional group was tested using Levene’s test, and the results are presented as shown in Table 4.8.

Table 4.8: Results for Test of Homogeneity of Variances on Posttest Scores for Differentiated Instruction Group and Conventional Group

		Levene’s Test Statistic	
		F	p
Posttest	Equal Variances Assumed	1.697	0.194

From Table 4.8 it could be observed that, the variances in the posttest scores of Differentiated Instruction group and conventional group were equal, since Levene’s statistic, F, was not significant ($F=1.697$, $p=0.194>0.05$). Therefore, the assumption of homogeneity of equal variances was not violated, in addition to normal distribution of posttest scores of both groups (see Table 4.3, and Appendices E1, E2, G1 and G2). Hence, the independent sample t-test for Posttest Scores of Differentiated Instruction and conventional groups was conducted and the results are presented in Table 4.9.

Table 4.9: Results of Independent Sample t-test on Posttest Scores of Differentiated Instruction and Conventional Groups

Group	N	Mean	SD	t	df	p	Eta Squared
Differentiated Instruction	98	19.12	5.766	7.362	188	0.000*	0.22
Conventional	92	13.34	5.010				

*p<0.05; df – degrees of freedom

As revealed in Table 4.9, the results of the independent sample t-test, shows that there was a significant difference in posttest scores between Differentiated Instruction group (M=19.12, SD=5.766) and the conventional group was significant (M= 13.34, SD=5.010; $t_{(188)}=7.362$, $p=0.000<0.05$). The magnitude of the difference in means between the two groups was also determined using eta squared statistic (see Appendix V), which produced an eta squared value of 0.224 as shown in Table 4.9, indicating a large effect according to Pallant (2011). As a result, we fail to accept the null hypothesis since there was not sufficient evidence to accept the null hypothesis. This means that there was a significant difference in performance between SHS Physics students taught Thermal Physics using Differentiated Instruction and students taught using conventional teaching method.

4.8 Difference Between the Use of 5E Instructional Model and Differentiated Instruction in the Teaching and Learning of Thermal Physics

4.8.1 Testing of Hypothesis 3

Hypothesis 3 sought to determine whether any existing difference in academic performance between 5E Instructional Model group and Differentiated Instruction group was statistically significant. The null hypothesis H_{03} , states that, *there is no significant*

difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and students taught using Differentiated Instruction.

This hypothesis was tested using a one-way analysis of covariance (one-way ANCOVA) on the posttest scores of Thermal Physics Concept Test (TPCT) for 5E Instructional Model group and Differentiated Instruction group at an alpha level of 0.05, using their pretest scores as covariate, in order to statistically control for the influence of the pretest on the posttest scores as explained in section 3.12.2. However, prior tests of an assumptions of linearity, homogeneity of regression slopes, and homogeneity of variances were conducted to determine non-violation of these assumptions, which, Pallant (2011) argues that, would reduce the power of the ANCOVA test. According to Pallant (2011), the assumption of linearity requires that the relationship between the dependent variable (posttest scores) and the covariate (pretest scores) of each group is linear or straight-line (see Appendix M1).

Also, the assumption of homogeneity of regression slopes requires that the relationship between the covariate (pretest scores) and dependent variable (posttest scores) for each of group is the same. This is indicated by similar slopes on the regression line for each group (see Appendix M1). Unequal slopes would indicate that there is a significant interaction between the covariate (pretest scores) and the treatment (Pallant, 2011), which in this case, was not significant (see Appendix M2). On the other hand, the assumption of homogeneity of variances requires that the variances in posttest scores within each group should be the equal (Mishra et al., 2019). This assumption was tested using Levene's test (see Appendix N), which operates on the null hypothesis that the variances in scores within each group are equal (Mishra et al., 2019; Pallant, 2011).

Having not violated these assumptions (Appendices M1, M2 and N), the one-way analysis of covariance was conducted on the posttest scores for 5E Instructional Model group and Differentiated Instruction group, and the results are presented in Table 4.10.

Table 4.10: Results of One-Way Analysis of Covariance on Posttest Scores for 5E Instructional Model Group and Conventional Groups

Source	df	F	p	Partial Eta Squared
Pretest	1	398.473	0.000	0.670
Teaching Method	1	34.833	0.000	0.151
Error	196			

It can be seen from Table 4.10 that, after adjusting for the influence of pretest on the posttest scores, there was a significant effect of teaching method on the posttest scores of SHS Physics students in the 5E Instructional Model group and Differentiated Instruction group ($F_{(1,196)}=34.833$, $p=0.000$) with an effect size of 0.151, indicating that, the use of 5E Instructional Model and Differentiated Instruction contributed to 15.1% of the variances in the posttest scores. Moreover, Table 4.10 reveals that, the effect of the pretest on the posttest was also significant ($F_{(1,196)}= 398.473$, $p=0.00$) with an effect size (partial eta squared) of 0.670, indicating that the pretest scores contributed to 67.0% of the variances in the posttest scores. As a result, the influence of the pretest scores was statistically controlled in the ANCOVA model, thereby adjusting the posttest mean scores of SHS Physics students in both groups. This therefore produced an adjusted posttest mean scores of SHS Physics students in the 5E Instructional Model group and Differentiated Instruction group. The results of the adjusted means are presented in Table 4.11.

Table 4.11: Descriptive Statistics of Adjusted Posttest Mean Scores of 5E Instructional Model Group and Differentiated Instruction Group

Group	Adjusted Mean	Std. Error
5E	16.54	0.313
DI	19.17	0.318

It can be observed from Table 4.11 that, after controlling for the effect of the pretest scores on the posttest, the 5E Instructional Model group obtained the lower adjusted mean score of 16.54(std. error=0.313), while the Differentiated Instructional group obtained an adjusted mean score of 19.17(std. error=0.318). Thus, the results as presented in Tables 4.10 and 4.11 suggest that there was not sufficient evidence to accept the null hypothesis, therefore we fail to accept the null hypothesis. This means that, there was a significant difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and students taught using Differentiated Instruction.

4.9 Difference Between the Use of 5E Instructional Model, Differentiated Instruction and Conventional Teaching Method on Male and Female SHS Physics Students in the Teaching and Learning of Thermal Physics

4.9.1 Testing of Hypothesis 4

Hypothesis 4 aimed to determine any significant difference in academic performance between male and female SHS Physics students within 5E Instructional Model group, Differentiated Instruction group, and the Conventional group. The null hypothesis H_{04} , stated that “*there is no significant difference in academic performances between male and*

female SHS Physics students taught Thermal Physics using at least one of 5E Instructional Model, Differentiated Instruction, and conventional teaching method”.

A 2 by 2 between-groups analysis of covariance (two-way ANCOVA) was conducted at an alpha level of 0.05, to assess the effectiveness of 5E Instructional Model, Differentiated Instruction, and Conventional teaching method on male and female SHS Physics students. The independent variables were the teaching methods (5E Instructional Model, Differentiated Instruction, and Conventional teaching method) and gender (male and female). The dependent variable was posttest scores of Thermal Physics Concepts Test (TPCT), administered following completion of the intervention. The pretest scores on the Thermal Physics Concepts Test (TPCT) prior to the commencement of the intervention were used as a covariate to control for prior significant differences in pretest scores of male and female SHS Physics students (Pallant, 2011) (see Appendix O) as well any influence of the pretest on the posttest scores of male and female SHS Physics students within each group (Janelli & Lipnevich, 2021; Kim & Willson, 2010).

However, preliminary checks were conducted to ensure that there was no violation of the assumptions of linearity, homogeneity of regression slopes and homogeneity of variances (see Appendices P1, P2 and Q). The results of the 2 by 2 between groups analysis of covariance on the posttest scores of male and female SHS Physics students in each of the groups are presented in Table 4.12.

Table 4.12: Results of 2 by 2 Between Groups Analysis of Covariance of Male and Female SHS Physics Students Within All Groups

Source	df	F	p	Partial Eta Squared
Pretest	1	241.395	0.000	0.459
Teaching Method	2	61.669	0.000	0.303
Gender	1	35.771	0.000	0.112
Teaching Method * Gender	2	37.444	0.000	0.209
Error	284			

Table 4.12 reveals that, after adjusting for pretest scores, there was a significant interaction ($F_{(2,284)}=37.444$, $p=0.000<0.05$), with a small effect size (partial eta squared=0.209), meaning that the interaction between teaching methods and gender explained 20.9% of the variances in the dependent variable (posttest scores). This indicates that there was a significant difference in the effect of teaching method on the posttest scores for males and females in at least one of the three groups. Therefore, it can be said that, there was not enough evidence to accept the null hypothesis, hence we fail to accept the null hypothesis. Thus, there was a significant difference in academic performances between male and female SHS Physics students taught Thermal Physics in at least one of 5E Instructional Model, Differentiated Instruction, and conventional teaching method groups.

The interaction between teaching method and gender can further be inspected graphically by a plot of estimated marginal means for the posttest scores of TPCT, split for males and females and for the three interventions as shown in Figure 4.2. The estimated marginal means provides the adjusted means (effect of the covariate has been statistically removed) on the dependent variable for each of the three groups, split according to each of the

independent variables (teaching method and gender) separately and then jointly (Pallant, 2011).

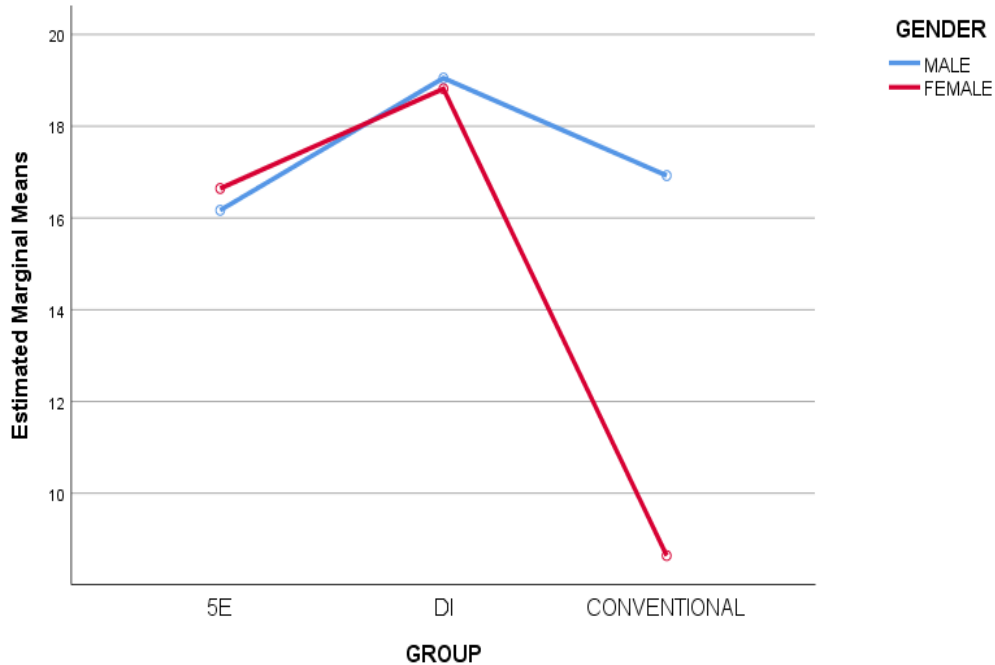


Figure 4.2: Estimated marginal means plot of posttest scores of TPCT for male and female SHS Physics students for 5E Instructional Model, Differentiated Instruction, and Conventional groups

It can be seen from Figure 4.2 that there was an interaction between the two independent variables (teaching methods and gender) after controlling for the effect of the pretest scores on the posttest. This clearly suggests that males and females appeared to respond differently to the teaching methods, as indicated in Table 4.13 which shows the adjusted means for male and female SHS Physics students within all groups.

Table 4.13: Descriptive Statistics of Male and Female SHS Physics Students' Adjusted Posttest Scores Within All Groups

Group	Gender	Adjusted Mean	Std. Error
5E	Male	16.167	0.472
	Female	16.643	0.593
DI	Male	19.049	0.471
	Female	18.816	0.617
Conventional	Male	16.925	0.495
	Female	8.641	0.627

Table 4.13 reveals that, after controlling for the effect of the pretest scores on the posttest, SHS male Physics students within the 5E Instructional Model group obtained an adjusted posttest mean score of 16.167(std. error=0.472), while their female counterparts obtained an adjusted posttest mean score of 16.643(std. error=0.593). Also, within the Differentiated Instruction group, SHS male Physics students obtained an adjusted posttest mean score of 19.09(std. error=0.471), whereas their female counterparts obtained an adjusted posttest mean score of 18.816(std. error=0.617). Additionally, within the Conventional group SHS male Physics students obtained an adjusted posttest mean score of 16.925(std. error=0.495), while their female counterparts obtained an adjusted posttest mean score of 8.641(std. error=0.627).

Moreover, simple effect analysis was conducted to determine specifically within which group(s) did the significant gender difference(s) exist. To avoid increasing the risk of committing a Type I error, that is rejecting the null hypothesis when it is actually true (Creswell, 2012), the simple effect analysis was conducted simultaneously within all three groups, instead of conducting individual tests for both gender groups within all three

groups. In view of this, Bonferroni adjustment for multiple comparisons was made. The Bonferroni correction was made by dividing the p-value, α (0.05), by the number of comparisons made, that is, three pairs of comparisons across all three groups. This yielded a new α -value of 0.0167. As a result, the mean differences of male and female SHS Physics students' academic performances within each group is significant if the sig. values obtained in Table 4.14 are less than 0.0167. The results of the simple effect analysis are presented in Table 4.14.

Table 4.14: Simple Effect Analysis of Posttest Scores of Male and Female SHS Students Within All Groups

Group	(I) Gender	(J) Gender	Mean Difference		
			(I-J)	Std. Error	Sig. ^b
5E	Male	Female	-.475	.759	.532
DI	Male	Female	.233	.777	.765
Conventional	Male	Female	8.284*	.802	.000

Based on estimated marginal means.

* $p < 0.0167$

b. Adjustment for multiple comparisons: Bonferroni.

As revealed in Table 4.14, after adjusting for the influence of pretest on the posttest scores, there was no significant difference in the posttest scores of male and female SHS Physics students within the 5E Instructional Model group (mean difference=0.75, $p=0.532$) and Differentiated Instruction group (mean difference=0.233, $p=0.765$). However, it can be observed from Table 4.14 that, the difference between male and female SHS Physics students in the conventional group was significant (mean difference=8.284, $p=0.000$).

4.10 Discussion of Findings

The purpose of this study was to determine comparatively the efficacy of 5E Instructional Model and Differentiated Instruction to help SHS Physics students to improve upon their performances in Thermal Physics. In this study, the sampled students were divided into two treatment groups (5E Instructional Model and Differentiated Instruction groups) and one control group (taught using the conventional teaching method). The results of this study are discussed below.

4.10.1 Discussion of Results for Hypothesis 1

H₀₁: There is no significant difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and those taught using conventional teaching method.

This hypothesis sought to determine the effects of 5E Instructional Model and the conventional teaching method on the academic performances of SHS Physics students in Thermal Physics. An independent sample t-test analysis was conducted on the posttest scores of SHS Physics students taught using 5E Instructional Model and those taught using conventional teaching method. It was found that, after exposure to the treatments, there was a significant difference in posttest scores between 5E Instructional Model group (M=16.59, SD=5.168) and the conventional group was significant (M=13.34, SD=5.010; $t_{(191)}=4.437$, $p=0.000<0.05$). This indicates that the use of 5E Instructional Model enhanced SHS Physics students' performance in Thermal Physics.

The higher level of performance observed in the 5E Instructional Model group agrees with findings of Bunkure (2019), Karthikyeyan and Densia (2021), and Appiah-Twumasi et al. (2021) that by employing the 5E Instructional Model, students perform better compared to the conventional teaching method. This is because, compared to the conventional classroom, where content was fully explained by the teacher, students in the 5E Instructional Model class were always engaged with the learning material, where they could feel and experience the content through hands-on activities. By so doing, students were able to raise questions and strive to seek clarification in areas where they seem not to understand the concept better. Consequently, students tend to think creatively and have better understanding of concepts (Martín & Bybee, 2022). Additionally, students were encouraged to work in groups in the 5E Instructional Model classrooms, where peer assistance were always allowed. Thus, in the absence of the teacher, group members who understood some areas of the content better aided students who struggled to understand. The importance of this is that students participate actively in the teaching and learning processes (Appiah-Twumasi et al., 2021), which has advantages as shown by the findings of the current study.

4.10.2 Discussion of Results for Hypothesis 2

H₀₂: There is no significant difference in academic performance between SHS Physics students taught Thermal Physics using Differentiated Instruction and students taught using conventional teaching method.

The purpose of this hypothesis was also to compare effectiveness of Differentiated Instruction and the conventional teaching method on the academic performances of SHS

Physics students taught Thermal Physics. In light of this, an independent sample t-test analysis was conducted on the posttest scores of SHS Physics students taught Thermal Physics using Differentiated Instruction and Conventional teaching method. The results revealed there was a significant difference in posttest scores between Differentiated Instruction group (M=19.12, SD=5.766) and the conventional group (M= 13.34, SD=5.010; $t_{(188)}=7.362$, $p=0.000<0.05$). That is, students in the Differentiated Instruction group significantly outperformed students in the conventional group after being exposed to the treatments. This rendered the use of Differentiated Instruction more effective in enhancing SHS Physics students' academic performances in Thermal Physics than the conventional teaching method.

This finding corroborated with prior findings (Alsalmi et al., 2021; Awofala & Lawani, 2020; Obafemi, 2022; Tambaya et al., 2023). The fact that the Differentiated Instruction not only gave students the chance to work together in flexible grouping, but also that students' individual differences were considered in the instruction, was the reason why the group which received Differentiated Instruction performed better than the group receiving conventional instruction, as revealed by Lyndon and Luard (2018) in their qualitative study, as well as Awofala and Lawani (2020). The purpose of Differentiated Instruction was to account for differences in readiness levels, interests, and learning profiles. Therefore, the teacher provided the students with the chance to gain knowledge and abilities through in Thermal Physics, which they were interested in learning. This was done by taking into account their individual needs. The instructor accounted for the academic needs of their students by looking into their degree of readiness, and took into consideration

the students' preferences for visual, kinesthetic, and auditory learning by looking into their learning styles.

The use of Differentiated Instruction in the Differentiated Instruction group allowed the teacher to modify the content and instruction in Thermal Physics by selecting and organising the Thermal Physics content in accordance with learning objectives, selecting instructional strategies for its efficient delivery, and developing learning activities and assessments that took into account the interests, learning preferences, and readiness levels of the students. Students were consequently exposed to unique situations that, according to Awofala and Lawani (2020), required them to actively establish conceptual connections where new knowledge was effectively incorporated into prior knowledge.

However, in the conventional group, lessons were delivered by the teacher in a whole-class lecture format where students were only passive in the instructional process, depriving them of the actual interaction with learning materials through hands-on activities, and not taking their individual differences into account. This might have resulted in shallow understanding of concepts since students might have learned Thermal Physics concepts by rote due to little or no active involvement of students, hence their underperformance, as Lak et al. (2017) suggest.

4.10.3 Discussion of Results for Hypothesis 3

H₀₃: There is no significant difference in academic performance between SHS Physics students taught Thermal Physics using 5E Instructional Model and students taught using Differentiated Instruction.

This hypothesis sought to determine the comparative effects of 5E Instructional Model and Differentiated Instruction on the academic performances of SHS Physics students in Thermal Physics. After adjusting for the influence of pretest on the posttest scores, there was a significant difference in posttest scores between SHS Physics students taught using 5E Instructional Model group and those taught Differentiated Instruction group ($F_{(1,196)}=34.833$, $p=0.000$). Adjusted mean posttest scores revealed that Differentiated Instruction group obtained the higher adjusted mean score of 19.17(std. error=0.318), while the 5E Instructional Model group obtained the lower adjusted mean score of 16.54(std. error=0.313). This means that the employment of Differentiated Instruction enables SHS Physics students to perform better in Thermal Physics than the 5E Instructional Model. This finding supported the finding of Salar and Turgut (2021) who also found Differentiated Instruction more effective than 5E Instructional Model in teaching Electricity concepts. This was probably due to the tailoring of instruction to every student in terms of content, process and product in the Differentiated Instruction group, which allowed students to learn at different pace with the support of the teacher, as pointed by Lyndon and Luard (2018), which was not possible in the 5E Instructional Model group, although students worked collaboratively through hands-on experiences.

4.10.4 Discussion of Results for Hypothesis 4

H₀₄: There is no significant difference in academic performances between male and female SHS Physics students taught Thermal Physics in at least one of 5E Instructional Model, Differentiated Instruction, and conventional teaching method.

For this hypothesis, the purpose was to determine any significant gender differences of SHS Physics students in terms of their academic performances in Thermal Physics after exposure to 5E Instructional Model, Differentiated Instruction and Conventional teaching method. This difference was determined within each group. In view of this, two-way ANCOVA was conducted at an alpha level of 0.05, to assess the effectiveness of 5E Instructional Model, Differentiated Instruction, and Conventional teaching method on male and female SHS Physics students. It was found that after adjusting for pretest scores, there was a significant interaction ($F_{(2, 284)} = 37.444, p=0.000 < 0.05$) between teaching method and gender, indicating that males and females appeared to respond differently to the teaching methods.

After adjusting for the influence of pretest on the posttest scores, and also using Bonferroni adjustment for multiple comparisons, a simple effect analysis revealed that there was no significant difference in the posttest scores of male SHS Physics students (adjusted mean=16.167, std. error=0.472) and female SHS Physics students (adjusted mean=16.643, std. error=0.593; $p=0.532 > 0.0167$) within the 5E Instructional Model group. There was also no significant difference in the posttest scores of male SHS Physics students (adjusted mean=19.09, std. error=0.471) and female SHS Physics students (adjusted mean=18.816, std. error=0.617; $p=0.765 > 0.0167$) in the Differentiated Instruction group. However, there

was a significant difference in the posttest scores of male SHS Physics students (adjusted mean=16.925, std. error =0.495) and female SHS Physics students (adjusted mean=8.64, std. error=0.627; $p=0.000<0.0167$).

This means that gender did not have any significant effect on the use of both 5E Instructional Model and Differentiated Instruction, while gender had significant effect on the use of the conventional teaching method. Similar to previous findings, Appiah-Twumasi et al. (2021) found that 5E Instructional Model significantly reduces the gender gap in Physics classroom compared to the conventional teaching method. However, contrary to the finding of this study, Ellah and Achor (2018) found significant difference in performance between male and female Senior Secondary School Physics students in a Physics classroom taught using 5E Instructional Model, even after controlling for the effect of pretest on the posttest scores. Nevertheless, in agreement with the finding of this study, Awofala and Lawani (2020), Obafemi (2022), Tambaya et al. (2023) found no significant difference between male and female SHS students using Differentiated Instruction.

Researchers such as Lorenzo et al. (2006), Deborah (2015) as well as Wilson and Low (2017) acquiesce that when instructional methods which ensure that both gender groups in the classroom have equal access to the learning material, there is a great possibility that males and females will perform at equivalent levels. For instance, Lorenzo et al. (2006) revealed that by using interactive engagement, the gender gap in a Physics classroom is reduced. Also, Deborah (2015) found that the use of demonstration stands out as efficient teaching method in bridging the gender gap in the Physics classroom. Likewise, the use of

5E Instructional Model can foster active participation and academic success for both male and female students in Physics classes by encouraging active engagement, practical exploration, thorough explanations, application-based learning, and inclusive evaluation techniques (Bybee, 2019). Also, with Differentiated Instruction, teachers can adapt their teaching strategies and course materials to each student's unique learning requirements and interests. This method, according to Thakur (2014) can enable both male and female students in grasping complex Physics concepts at their own pace by enabling the creation of a more inclusive learning environment that fits varied learning styles and skills.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

The focus of this chapter is to present the summaries of the findings of this study. Four key findings were identified in this study. Subsequently, conclusions, recommendations, and suggestions for further research have been made, based on the findings.

5.1 Summary of Findings

In this study, 291 SHS Physics students from six non-equivalent intact classes within Mampong Municipality and Sekyere South District in Ashanti Region, Ghana, were employed. The classes were randomly divided into three groups, where each group was treated with a particular teaching method. One group was treated with 5E Instructional Model which comprised of 101 Physics students, another group was treated with Differentiated Instruction, which was made up of 98 Physics students, while the last group served as a control group, also made up of 92 Physics students, where the conventional teaching method was used. The same instrument (TPCT) was used to collect data, specifically, the pretest and posttest scores.

The study revealed that 5E Instructional Model had a significantly enhanced SHS Physics students' academic performances in Thermal Physics more than the conventional teaching method. The results from the 5E Instructional Model group and the conventional group showed that there was a significant difference (mean difference=3.257, $t=4.47$,

$p=0.00<0.05$) between the mean posttest scores of the 5E Instructional Model group (mean=16.59, SD=5.168) and the conventional group (mean=13.34, SD=5.010).

Secondly, Differentiated Instruction was also found to significantly enhance SHS Physics students' academic performances in Thermal Physics more than the conventional teaching method. This is because, it was found by comparing the posttest scores of the Differentiated Instruction group to the conventional group that, there was a significant difference (mean difference=5.786, $t=7.362$, $p=0.00<0.05$) between the mean posttest scores of the 5E Instructional Model group (mean=19.12, SD=5.766) and the conventional group (mean=13.34, SD=5.010).

However, the comparative analysis of the posttest scores of 5E Instructional Model and Differentiated Instruction groups revealed that, Differentiated Instruction was found to be significantly more effective than 5E Instructional Model. Thus, after statistically controlling for the influence of the pretest on the posttest scores, there was a significant difference ($F_{(1,196)}=34.833$, $p=0.000$) between the mean posttest scores of the 5E Instructional Model group 16.54(std. error=0.313) and Differentiated Instruction group 19.17(std. error=0.318).

Lastly, it was found that treatment conditions did not differ between male and female SHS Physics students who were taught using 5E Instructional Model and Differentiated Instruction, but differed between male and female SHS Physics students who were taught using the conventional teaching method. This is because, a two-way between groups analysis of variance revealed that, there was significant interaction between gender and

teaching method ($F_{(2, 285)} = 10.563$, $p = 0.000 < 0.05$) on SHS Physics students' academic performances in Thermal Physics. Subsequently, simple effect analysis showed that there was no significant difference between the academic performances of male and female students who were taught using both 5E Instructional Model (mean difference = 0.467, $p = 0.650$) and Differentiated Instruction (mean difference = 0.808, $p = 0.444$). However, there was a significant difference in academic performances between male and female SHS Physics students taught thermal Physics using the conventional teaching method (mean difference = 6.631, $p = 0.000$).

5.2 Conclusions

Per the findings of this study, 5E Instructional Model and Differentiated Instruction both proved to be effective over the conventional teaching method in the teaching and learning of Thermal Physics to SHS Physics students in the Mampong Municipality and the Sekyere South District. However, this study revealed that the employment of Differentiated Instruction helped SHS Physics students in the Mampong Municipality and the Sekyere South District to understand Thermal Physics concepts better than the employment of 5E Instructional Model, though they are both student-centered teaching methods. This is because, the employment of Differentiated Instruction tailored the lessons to individual students and catered for the needs of the students more than the 5E Instructional Model. Also, the employment of both 5E Instructional Model and Differentiated Instruction in this study contributed to the bridging of the gender gap in students' academic performance in Thermal Physics. That is, gender did not have influence on the use of both instructional

methods, but the conventional teaching method in this study, was found not to help bridge the gender gap in Thermal Physics among SHS students.

5.3 Recommendations

As a result of this study, educational stakeholders in the Mampong Municipal and Sekyere South District are being presented with several recommendations concerning SHS Physics teaching and learning to increase students' academic performance in Thermal Physics.

1. SHS Physics teachers in Mampong Municipality and Sekyere South District are encouraged to differentiate their Thermal Physics lessons, where lessons will be tailored to the needs of the students, instead of using conventional teaching method.
2. As the findings of this study revealed, SHS Physics teachers in Mampong Municipality and Sekyere South District are encouraged to consider the use of 5E Instructional Model more than the Conventional teaching method, where Physics students will be engaged in activities which will maximize their learning.
3. Again, the findings of this study have led to a recommendation that SHS Physics teachers in Mampong Municipality and Sekyere South District are encouraged to however, consider the use of Differentiated Instruction more than 5E Instructional Model in Thermal Physics lessons.
4. SHS Physics teachers in Mampong Municipality and Sekyere South District are encouraged to Differentiate their Thermal Physics lessons, in addition to employing 5E Instructional Model, in an attempt to help both male and female Physics students perform at equivalent levels.

5.4 Suggestions for Further Research

The following recommendations for further research were offered in light of the study's findings:

1. It is suggested that this study should be replicated using 5E Instructional Model and Differentiated Instruction on other Physics concepts, as well as in other science subjects at the SHS level. This would furnish a foundation for a more extensive generalisation of the deductions made from the results of this study.
2. Also, more comparative studies should be conducted with other student-centered instructional methods, in order to better inform Physics teachers and educators the appropriate student-centered teaching method to employ in their lessons.
3. Since learning embraces the cognitive, affective, and psychomotor domains, the effect of 5E Instructional Model and Differentiated Instruction on the affective domain, which amongst others, encompasses the attitudes, motivations, perceptions, anxiety, of SHS Physics students should be investigated to assess their holistic impact on SHS Physics students' learning.

REFERENCES

- Aalaei, S., Azizi, M., Ahmadi, T., & Aalaei, A. (2016). A Comparison of Multiple-Choice and Essay Questions in The Evaluation of Dental Students. *International Journal of Advanced Biotechnology and Research (IJBR)*, 7(5), 1674–1680. <http://www.bipublication.com>
- Abah, J. A. (2020). An Appeal in the Case involving Conventional Teaching: Emphasizing the Transformation to Enhanced Conventional Teaching in Mathematics Education. *VillageMath Educational Review*, 1(1), 1–10. <https://doi.org/10.5281/zenodo.3860320>
- Abdi, A., Laee, S., & Ahmadyan, H. (2013). The Effect of Teaching Strategy Based on *Universal Journal of Educational Research*, 1(4), 281–284. <https://doi.org/10.13189/ujer.2013.010401>
- Abdulraheem, Y., Bello, M. B., & Odutayo, A. O. (2018). In Search of a More Effective Strategy: Using the 5E Instructional Strategy to Teach Civic Education in Senior Secondary Schools in Ilorin, Nigeria. *Journal of International Social Studies*, 8(1), 62–85. <http://www.iajiss.org/index.php/iajiss/article/view/322>
- Ablaza, G. G. C. (2021). Interventions in Addressing Gender Issues in the Classroom. *Turkish Journal of Computer and Mathematics Education*, 12(4), 1503–1510. <https://doi.org/10.17762/turcomat.v12i4.1400>

- Abuh, Y. P. (2021). Gender and Assessment of Physics Students' Academic Performance in Senior Secondary School SSIII (SS3) Olamaboro Local Government Area of Kogi State, Nigeria Abstract. *African Journal of Science, Technology and Mathematics Education*, 6(2), 1–9.
- Achor, E. E., Danjuma, I. M., & Orji, A. B. C. (2019). Classroom Interaction Practices and Students' Learning Outcomes in Physics: Implication for Teaching-Skill Development for Physics Teachers. *Journal of Education and E-Learning Research*, 6(3), 96–106. <https://doi.org/10.20448/journal.509.2019.63.96.106>
- Ahmad, N., Shaheen, N., & Gohar, S. (2018). 5E Instructional Model: Enhancing Students Academic Achievement in the Subject of General Science at Primary Level. *Journal of Education & Social Research*, 1(1), 91–100.
- Aina, J. K., & Akintunde, Z. T. (2013). Analysis of Gender Performance in Physics in Colleges of. *Journal of Education and Practice*, 4(6), 1–6.
- Alsahhi, N. R., Abdelrahman, R., Abdelkader, A. F. I., Ahmad Al-Yatim, S. S., Habboush, M., & Qawasmi, A. Al. (2021). Impact of Using the Differentiated Instruction (DI) Strategy on Student Achievement in an Intermediate Stage Science Course. *International Journal of Emerging Technologies in Learning*, 16(11), 25–45. <https://doi.org/10.3991/ijet.v16i11.22303>
- Altun, M. (2023). The Ongoing Debate over Teacher Centered Education and Student Centered Education. *International Journal of Social Sciences & Educational Studies*, 10(1). <https://doi.org/10.23918/ijsses.v10i1p106>

- Alwan, A. A. (2011). Misconception of heat and temperature Among physics students. *Procedia Social and Behavioral Sciences*, 12, 600–614. <https://doi.org/10.1016/j.sbspro.2011.02.074>
- Amankona, D., Kweitsu, G., & Korankye, B. (2018). A critical assessment of public funding of education in Ghana. *British Journal of Interdisciplinary Research*, 8(1), 19–28.
- Amineh, J. R., & Asl, D. H. (2015). Review of Constructivism and Social Constructivism. *Journal of Social Sciences, Literature and Languages*, 1(1), 9–16.
- Ampofo, E. T., & Osei-Owusu, B. (2015). Academic Ambition and Effort in the Public Senior High Schools. *International Journal of Academic Research and Reflection*, 3(5), 19–35.
- Amunga, J. K., Amadalo, M., & Musera, G. (2011). *Disparity in the Physics Academic Achievement and Enrolment in Secondary Schools in Western Province: Implication for Strategy Renewal*. 31(18), 1–15. <http://www.scientiasocialis.pdf>
- Andam, A. B., Amponsah, P. E., Nsiah-Akoto, I., Hood, C. O., & Nyarko, S. (2019). Women in physics in Ghana: Our story. *AIP Conference Proceedings*, 2109(June), 10–12. <https://doi.org/10.1063/1.5110092>
- Apata, F. (2013). Influence of Gender and Class Size on Students' Practical skills in Physics. *Journal of Educational Studies and Management*, 1(1), 33–43.
- Appiah-Twumasi, E. (2020). An Investigation into the Selection of Teaching Methods and Factors Influencing the Selection: A Case of Science Teachers of Berekum Municipality, Ghana. *International Journal of Innovative Research and Development*, 9(12), 67–74. <https://doi.org/10.24940/ijird/2020/v9/i12/dec20050>

- Appiah-Twumasi, E., Ameyaw, Y., & Kwasi Anderson, I. (2022). Development and Validation of Questionnaire for Physics Learning Self-Efficacy among Ghanaian Senior High Schools. *East African Journal of Management and Business Studies*, 2(1), 8–18. <https://doi.org/10.46606/eajess2022v03i01.0141>
- Appiah-Twumasi, E., Nti, D., Acheampong, R., & Ameyaw, F. (2021). Diagnostic Assessment of Students' Misconceptions about Heat and Temperature Through the Use of Two-Tier Test Instrument. *British Journal of Education, Learning and Development Psychology*, 4(1), 90–104. <https://doi.org/10.52589/bjeldp-o22b5epk>
- Appiah-Twumasi, E., Nti, D., Acheampong, R., & Eminah, C. (2021). Effect of the 5E Instructional Model on Physics Academic Achievement Based on Gender and Students' Ability: A Case of Berekum Senior High Schools in Ghana. *East African Journal of Education and Social Sciences*, 2(1), 1–10. <https://doi.org/10.46606/eajess2021v02i01.0060>
- Appiah-Twumasi, E., & Osei, J. K. (2018). Cooperative Learning Strategy: Effective Student-Centered Intervention To Enhance Performance And Knowledge Retention. *International Journal of Innovative Research and Advanced Studies*, 5(5), 151–156. https://www.researchgate.net/publication/348522861_Cooperative_Learning_Strategy_Effective
- Applefield, J. M., Huber, R., & Moallem, M. (2001). Constructivism in Practice and Theory: Toward a Better Understanding. *The High School Journal*, 84(2), 35–53.

- Assem, H. D., Nartey, L., Appiah, E., & Aidoo, J. K. (2023). A Review of Students' Academic Performance in Physics : Attitude, Instructional Methods, Misconceptions and Teachers Qualification. *European Journal of Education and Pedagogy*, 4(1), 84–92. <https://doi.org/10.24018/ejedu.2023.4.1.551>
- Awofala, A. O. A., & Lawani, A. O. (2020). Increasing Mathematics Achievement of Senior Secondary School Students through Differentiated Instruction. *Journal of Educational Sciences*, 4(1), 1. <https://doi.org/10.31258/jes.4.1.p.1-19>
- Awudi, B., & Danso, S. (2023). Improving Students' Performance And Conceptual Understanding Of Heat Transfer Using Demonstration Method. *Journal of Mathematics and Science Teacher*, 3(2), 1–10. <https://doi.org/10.29333/mathsciteacher/13164>
- Azigwe, J. B., Kyriakides, L., Panayiotou, A., & Creemers, B. P. M. (2016). The Impact Of Effective Teaching Characteristics in Promoting Student Achievement in Ghana. *International Journal of Educational Development*, 51, 51–61. <https://doi.org/10.1016/j.ijedudev.2016.07.004>
- Babajide, & Folasade, T. V. (2013). Enhancing Female Participation in Practical Physics: Effects of Instructional Strategies. *African Journal of Pedagogy*, 5(1821–8474).
- Baghestani, A. R., Ahmadi, F., Tanha, A., & Meshkat, M. (2019). Bayesian Critical Values for Lawshe's Content Validity Ratio. *Measurement and Evaluation in Counseling and Development*, 52(1), 69–73. <https://doi.org/10.1080/07481756.2017.1308227>

- Bahadir, F., & Melih, D. (2022). The Effect of 5E Instructional Model on Students' Academic Achievement: A meta-Analytic Study. *Istanbul Aydın Üniversitesi Sosyal Bilimler Dergisi*, 14(4), 532–552. <https://doi.org/10.17932/IAU.IAUSBD.2021.021/iausbd>
- Balgan, A., Renchin, T., & Ojgoosh, K. (2022). An Experiment in Applying Differentiated Instruction in STEAM Disciplines. *Eurasian Journal of Educational Research*, 98(1), 21–37. <https://doi.org/10.14689/ejer.2022.98.02>
- Balogun, S. O., Olaleye, A. S., & Ibidoja, J. O. (2020). University Students' Academic Performance: An Approach of Tau Statistic. *Proceedings of the 36th International Business Information Management Association, November*, 4–5. <https://digitalcommons.unl.edu/libphilprac>
- Bara, G., & Xhomara, N. (2020). The Effect of Student-Centered Teaching and Problem-Based Learning on Academic Achievement in Science. *Journal of Turkish Science Education*, 17(2), 182–199. <https://doi.org/10.36681/tused.2020.20>
- Bekteshi, E., Avdiu, E., & Xhaferi, B. (2022). Enhancing the 5E Learning Model (Engage-Explore-Explain-Elaborate-Evaluate) Among University Students in Kosovo. *Journal of Language and Literary Studies*, 13(40), 335–350. <https://doi.org/10.31902/fl.40.2022.17>
- Bertrand, M. (2020). Gender in the Twenty-First Century. *American Economic Association Papers and Proceeding*, 101(3), 1–24. <https://doi.org/10.1257/pandp.20201126>
- Bhasin, H. (2021, January 4). *Data Collection-Definition, Importance, Steps, Methods and Uses*. Retrieved from <https://www.marketing91.com/data-collection/>

- Bhattacharjee, J. (2015). Constructivist Approach to Learning– An Effective Approach of Teaching Learning. *Research Journal of Interdisciplinary & Multidisciplinary Studies (IRJIMS) A Peer-Reviewed Monthly Research Journal*, 65, 2394–7969. <http://www.irjims.com>
- Bhattacharjee, A. (2012). *Social Science Research: Principles, Methods, and Practices* (2nd ed.). Open Access Textbooks.
- Bloom, B., Krathwohl, D., & Masia, B. (1973). *Taxonomy of Educational Objectives. The Classification of Educational Goals: Handbook 2: Affective Domain* (pp. 1–196). Longmans Green and Co. Ltd.
- Blundell, S. J., & Blundell, K. M. (2010). *Concepts in Thermal Physics* (2nd edition). Oxford University Press Inc.
- Boakye, S., & Nabie, M. J. (2022). *The Effect of Using the 5E Instructional Model on Students ' Performance in and Motivation to Learn Sine Rule and its Applications*. *I(1)*, 14–35.
- Bonney, E. A., Amoah, D. F., Micah, S. A., Ahiameny, C., & Lemaire, M. B. (2015). The Relationship between the Quality of Teachers and Pupils Academic Performance in the STMA Junior High Schools of the Western Region of Ghana. *Journal of Education and Practice*, 6(24), 13.
- Borah, R. (2020). Enhancing Performance Of 8th Grade Learners Using Constructivist '5E' Model in Social Science at Elementary. *International Journal of Management*, 11(7), 1475–1481. <https://doi.org/10.34218/IJM.11.7.2020.131>

- Bottomley, E., Kohnle, A., Mavor, K. I., Miles, P. J., & Wild, V. (2023). The relationship between gender and academic performance in undergraduate physics students: the role of physics identity, perceived recognition, and self-efficacy. *European Journal of Physics*, 44(2). <https://doi.org/10.1088/1361-6404/aca29e>
- Bright, C. E. (2006). *Learning Style Questionnaire*. <https://learning.ucmerced.edu/sites/learning.ucmerced.edu/files/page/documents/learningstylequestionnaire.pdf>
- Brunello, A., & Brunello, F. E. (2022). The Relationship Between Differentiated Instruction and Student Motivation in Mixed Ability Classrooms. *International Journal of Communication Research*, 12(4), 279–284.
- Buabeng, I., Aquinas Ossei-Anto, T., & Ampiah, J. G. (2014). An Investigation into Physics Teaching in Senior High Schools. *World Journal of Education*, 4(5), 40–50. <https://doi.org/10.5430/wje.v4n5p40>
- Buchmann, C., Buchmann, C., & Mcdaniel, A. (2007). *Gender Inequalities in Education* (No. 34; 07-15).
- Budiarti, I. S., Suparmi, Sarwanto, & Harjana. (2017). Students' Conceptual Understanding Consistency of Heat and Temperature. *Journal of Physics: Conference Series*, 795, 1–5. <https://doi.org/10.1088/1742-6596/755/1/011001>
- Bunkure, Y. I. (2019). Efficacy of 5E Learning Strategy in enhancing Academic Achievement in Physics among Students in Rano Education Zone , Kano State , Nigeria. *Journal Of Science Technology And Education*, 7(3), 296–304. <http://www.atbuftejoste.com/index.php/joste/article/view/848>

- Bybee, R. W. (2018). BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications. *Science and Children*, 51(8), 15–18.
- Bybee, R. W. (2019). Using The BSCS 5E Instructional Model to Introduce STEM Disciplines. *Science and Children*, 51(2), 8–12.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van, P., Powell, J. C., Westbrook, A., Landes, N., Spiegel, S., Stuhlsatz, M. M., Ellis, A., Thomas, H., Bloom, M., Moran, R., Getty, S., & Knapp, N. (2006). The BSCS 5E Instructional Model: Origins and Effectiveness by 5415 Mark Dabling Boulevard. *Science*, June.
- Cakır, N. K. (2017). Effect of 5E Learning Model on Academic Achievement, Attitude and Science Process Skills: Meta-Analysis Study. *Journal of Education and Training Studies*, 5(11), 157. <https://doi.org/10.11114/jets.v5i11.2649>
- Chibwana, B., & Rajamehala, M. (2022). Factors Affecting Performance of Learners in Physics and Biology Subjects in Community Day Secondary Schools. *IJNRD2209197 International Journal of Novel Research and Development*, 7(9), 1665–1674.
- Choirunnisa, N. L., Prabowo, P., & Suryanti, S. (2018). Improving Science Process Skills for Primary School Students Through 5E Instructional Model-Based Learning. *Journal of Physics: Conference Series*, 947(1), 1–5. <https://doi.org/10.1088/1742-6596/947/1/012021>
- Coffie, I. S., Frempong, B. B., & Appiah, E. (2020). Teaching and Learning Physics in Senior High Schools in Ghana: The Challenges and the Way Forward. *Advances in Research*, 21(3), 35–42. <https://doi.org/10.9734/air/2020/v21i330192>

- Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed).
Routledge.
- Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods
Approaches*. (3rd ed.). SAGE Publications. Inc.
- Creswell, J. W. (2012). *Educational Research: Planning, Conducting, and Evaluating
Quantitative and Qualitative Research* (4th ed.). Pearson Education, Inc.
- Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods
Approaches* (4th ed.). SAGE Publications, Inc.
- Danso, S. (2018). Fulfilling Diverse Learner Needs: Preparing Learners for High School
Science Success Through Differentiated Instructions. *XVIII IOSTE Symposium:
Future Educational Challenges from a Science and Technology Perspectives*, 84–93.
<https://doi.org/10.24834/978-91-7104-971-1>
- Deborah, T. A. (2015). Bridging Gender Gap in the Physics Classroom : The Instructional
Method Perspective. *Journal of Education and Practice*, 6(20), 14–24.
- Djajalaksana, Y. M., Dedrick, R. F., & Eison, J. A. (2013). Factors that Associate with the
Selection of Instructional Strategies in Information Systems Discipline. *Proceedings
of the Information Systems International Conference*, 196–201.
- Djami, C. B. N., & Kuswando, P. (2020). Teachers' Strategies to Implement Higher-
Order Thinking Skills in English Instruction. *Metathesis: Journal of English
Language, Literature, and Teaching*, 4(1), 25–40. [https://doi.org/10.31002/metathe
sis.v4i1.2048](https://doi.org/10.31002/metathe
sis.v4i1.2048)

- Dodge, M. M. (2017). The Effect of the 5E Instructional Model on Student Engagement and Transfer of Knowledge in a 9th Grade Environmental Science Differentiated Classroom. In *Journal of Education and Practice*. Montana State University.
- Donkoh, S., Osei, J., & Annan, M. K. (2021). Demystifying the “Dense” Problem of Density Using 5E Learning Cycle. *Journal of Science, Technology, Engineering, Mathematics and Art Education*, 4(1), 31–42.
- Ducey, M. N. (2011). *Improving Secondary Science Education Through the Implementation of Differentiated Instruction*. The University of Memphis.
- Ellah, B. O., & Achor, E. E. (2018). Effect of 5E Constructivist Instructional Approach on Students’ Achievement and Attitude to Physics in Senior Secondary Schools. *Journal of Research in Curriculum and Teaching*, 10(3), 120–132.
- Ergin, İ. (2012). Constructivist Approach Based 5E Model and Usability Instructional Physics. *Latin American Journal of Physics Education*, 6(1), 20. <http://www.lajpe.org>
- Fayazi-Nasab, E., & Ghafournia, N. (2016). The Relationship between Multiple Intelligences and Motivational Strategies. *English Linguistics Research*, 5(2), 20–27. <https://doi.org/10.5430/elr.v5n2p20>
- Felder, R., & Brent, R. (2017). Learner-Centered Teaching : How and Why *. *Learning Abstracts*, 20(5).
- Fenditasari, K., Jumadi, Istiyono, E., & Hendra. (2020). Identification of misconceptions on heat and temperature among physics education students using four-tier diagnostic test. *Journal of Physics: Conference Series*, 1470(1). <https://doi.org/10.1088/1742-6596/1470/1/012055>

- Fernando, S. Y., & Marikar, F. M. (2017). Constructivist Teaching/Learning Theory and Participatory Teaching Methods. *Journal of Curriculum and Teaching*, 6(1), 110. <https://doi.org/10.5430/jct.v6n1p110>
- Ferrier, A. M. (2007). The effects of Differentiated Instruction on academic achievement in a second-grade science classroom [Walden University]. In *Dissertation Abstracts International Section A: Humanities and Social Sciences*. https://protect-eu.mimecast.com/s/A-6_Cj2gwhA3j8fy5YUxO?domain=ovidsp.ovid.com
- Gardner, H. (1999). Theory of Multiple Intelligences from: Frames of Mind: The Theory of Multiple Intelligences. *PSIA - Rocky Mountain Division – AASI*.
- Garg, S. G., Bansal, R. M., & Ghosh, C. K. (2012). *Thermal Physics: Kinetic Theory, Thermodynamics and Statistical Mechanics* (2nd edition). Tata McGraw Hill Education Private Limited.
- Garzón-Agudelo, P. A., Palacios-Alvarado, W., & Medina-Delgado, B. (2020). Contributing factors in academic performance and troubles associated with teaching in areas of physics in engineering students. *Journal of Physics: Conference Series*, 1674(1). <https://doi.org/10.1088/1742-6596/1674/1/012011>
- Georgiou, H., & Sharma, M. D. (2012). University students' understanding of thermal physics in everyday contexts. *International Journal of Science and Mathematics Education*, 1119–1142.
- Ghana Education Service. (2022). *Senior High and Technical Vocational Schools*. 1–38. https://ges.gov.gh/wp-content/uploads/2020/08/SHSTVET_SCHOOLS.pdf
- Ghana Statistical Service. (2021). *District Analytical Report: Mampong Municipal*.

- Heinich, R., Molenda, M., Russel, J. D., & Smaldino, S. E. (2002). *Instructional Media and Technologies for Learning* (7th ed.). Prentice Hall.
- Hernandez, H. (2021). Testing for Normality: What is the Best Method? *ForsChem Research*, 6(5), 1–38. <https://doi.org/10.13140/RG.2.2.13926.14406>
- Hertzog, M. A. (2008). Considerations in Determining Sample Size for Pilot Studies. *Research in Nursing & Health*, 31, 180–189. <https://doi.org/10.1002/nur.20247>
- Hift, R. J. (2014). Should Essays and Other Open-Ended-Type Questions Retain a Place in Written Summative Assessment in Clinical Medicine? *BMC Medical Education*, 14(1), 1–18. <https://doi.org/10.1186/s12909-014-0249-2>
- Hodgson, C. (2017). Educational Psychology: Theory and Practice. In *Canadian Journal of Education / Revue canadienne de l'éducation* (Vol. 9, Issue 3). Library Press. <https://doi.org/10.2307/1494305>
- Hoque, M. E. (2016). Three Domains of Learning: Cognitive, Affective and Psychomotor. *The Journal of EFL Education and Research*, 2(2), 45–52. www.edrc-jeffler.org
- Huang, Y.-C. (2021). Comparison and Contrast of Piaget and Vygotsky's Theories. *Proceedings of the 7th International Conference on Humanities and Social Science Research*, 554, 28–32. <https://doi.org/10.2991/assehr.k.21.0519.007>
- Ismajli, H., & Imami-Morina, I. (2018). Differentiated Instruction: Understanding and Applying Interactive Strategies to Meet the Needs of all the Students. *International Journal of Instruction*, 11(3), 207–218. <https://doi.org/10.12973/iji.2018.11315a>
- Janelli, M., & Lipnevich, A. A. (2021). Effects of Pre-tests and Feedback on Performance Outcomes and Persistence in Massive Open Online Courses. *Computers & Education*, 16(1), 1–13. <https://doi.org/10.1016/j.compedu.2020.104076>

- Johanson, G. A., & Brooks, G. P. (2010). Initial scale development: Sample size for pilot studies. *Educational and Psychological Measurement, 70*(3), 394–400. <https://doi.org/10.1177/0013164409355692>
- Jugović, I. (2017). Students' Gender-Related Choices and Achievement in Physics. *Center for Educational Policy Studies Journal, 7*(2), 71–95. <https://doi.org/10.26529/cepsj.170>
- Kalender, Z. Y., Marshman, E., Schunn, C. D., Nokes-Malach, T. J., & Singh, C. (2019). Why Female Science, Technology, Engineering, And Mathematics Majors Do Not Identify With Physics: They Do Not Think Others See Them That Way. *Physical Review Physics Education Research, 15*(2), 20148. <https://doi.org/10.1103/PhysRevPhysEducRes.15.020148>
- Kamran, M., Munir, N., & Wattoo, R. M. (2019). A Comparative Exploration of the Effect of Differentiated Teaching Method vs. Traditional Teaching Method on Students' Learning at 'A' level. *Global Social Sciences Review, IV*(I), 61–66. [https://doi.org/10.31703/gssr.2019\(iv-i\).08](https://doi.org/10.31703/gssr.2019(iv-i).08)
- Karthikyeyan, S., & Densia, S. P. (2021). The effect of 5E learning cycle model in teaching Physics on students' academic achievement and the permanence of their knowledge. *Elementary Education Online, 20*(5), 6324–6330. <https://doi.org/10.17051/ilkonline.2021.05.713>
- Kelle, U., & Reith, F. (2023). Strangers in Paradigms!? Alternatives to Paradigm-Bound Methodology and Methodological Confessionalism. *Forum Qualitative Sozialforschung, 24*(1). <https://doi.org/10.17169/fqs-24.1.4015>

- Khadija, K. (2020). Constructivist Theories of Piaget and Vygotsky : Implications for Pedagogical Practices. *Psychological & Educational Studies*, 13(3), 359–372.
- Khaldi, K. (2017). Quantitative, Qualitative or Mixed Research: Which Research Paradigm to Use? *Journal of Educational and Social Research*, 7(2), 15–24. <https://doi.org/10.5901/jesr.2017.v7n2p15>
- Kim, E. S., & Willson, V. L. (2010). Evaluating Pretest Effects in Pre – Post Studies. *Educational and Psychological Measurement*, 70(5), 744–759. <https://doi.org/10.1177/0013164410366687>
- Kivunja, C., & Kuyini, A. B. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education*, 6(5), 26. <https://doi.org/10.5430/ijhe.v6n5p26>
- Kola, A. J. (2017). Developing a Constructivist Model for Effective Physics Learning. *International Journal of Trend in Scientific Research and Development*, 1(4), 59–67. <https://doi.org/10.31142/ijtsrd85>
- Kótay-Nagy, A. (2023). Differentiated Instruction in The EFL Classroom: An Interview Study on Hungarian Primary and Secondary School EFL Teachers’ Views and Self-Reported Practices. *Journal of Adult Learning, Knowledge and Innovation*, 6(1), 33–46. <https://doi.org/10.1556/2059.2023.00076>
- Kothari, C. R. (2004). *Research Methodology Methods & Techniques* (2nd Editio). New Age International (P) Ltd.
- Kotob, M. M., & Abadi, A. M. (2019). The Influence of Differentiated Instruction on Academic Achievement of Students in Mixed Ability Classrooms. *International Linguistics Research*, 2(2), p8. <https://doi.org/10.30560/ilr.v2n2p8>

- Kottner, J., Audig, L., Brorson, S., Donner, A., & Gajewski, B. J. (2011). Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. *Journal of Clinical Epidemiology*, *64*, 96–106. <https://doi.org/10.1016/j.jclinepi.2010.03.002>
- Kruatong, T., Sung-Ong, S., Singh, P., & Jones, A. (2006). Thai high school students' understanding of heat and thermodynamics. *Kasetsart Journal - Social Sciences*, *27*(2), 321–330.
- Kumalasari, L., Yusuf H. A., & Priyandoko, D. (2017). The Application of Multiple Intelligence Approach to the Learning of Human Circulatory System. *Journal of Physics: Conference Series*, *909*(1), 1–8. <https://doi.org/10.1088/1742-6596/909/1/012066>
- Kwaah, C. Y., & Palojoki, P. (2018). Entry characteristics, academic achievement and teaching practices: A comparative study of two categories of newly qualified teachers in basic schools in Ghana. *Cogent Education*, *5*(1), 1–19. <https://doi.org/10.1080/2331186X.2018.1561144>
- Kwak, S. G., & Park, S. H. (2019). Normality Test in Clinical Research. *Journal of Rheumatic Diseases*, *26*(1), 5–11. <https://doi.org/10.4078/jrd.2019.26.1.5>
- Lak, M., Soleimani, H., & Parvaneh, F. (2017). The Effect of Teacher-Centeredness Method vs. Learner-Centeredness Method on Reading Comprehension among Iranian EFL Learners. *Journal of Advances in English Language Teaching*, *5*(1), 1–10. www.european-science.com/http://www.european-science.com/jaelt
- Lare, A. I., & Abegunrin, O. A. (2014). Gender Difference, Self-Efficacy, Active Learning Strategies and Academic Achievement of Undergraduate Students. *International Journal of Teaching and Case Studies*, *4*(3), 1–26.

- Lawshe, C. H. (1975). A Quantitative Approach To Content Validity. *Personnel Psychology*, 28(4), 563–575. <https://doi.org/10.1111/j.1744-6570.1975.tb01393.x>
- Leavy, P. (2017). *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches*. The Guilford Press.
- Lee, J. L. C., Nader, K., & Schiller, D. (2017). An Update on Memory Reconsolidation Updating. *Trends in Cognitive Sciences*, 21(7), 531–545. <https://doi.org/10.1016/j.tics.2017.04.006>
- Leinonen, R., Asikainen, M. A., & Hirvonen, P. E. (2013). Overcoming Students' Misconceptions Concerning Thermal Physics with the Aid of Hints and Peer Interaction During a Lecture Course. *Physical Education Research*, 9(2), 1–22. <https://doi.org/10.1103/PhysRevSTPER.9.020112>
- Lindqvist, A., Sendén, M. G., & Renström, E. A. (2021). What is gender, anyway: a review of the options for operationalising gender. *Psychology and Sexuality*, 12(4), 332–344. <https://doi.org/10.1080/19419899.2020.1729844>
- Lorenzo, M., Crouch, C. H., & Mazur, E. (2006a). Reducing the gender gap in the physics classroom. *American Journal of Physics*, 74(2), 118–122. <https://doi.org/10.1119/1.2162549>
- Lunenburg, F. C., & Lunenburg, M. R. (2014). Applying Multiple Intelligences in the Classroom: A Fresh Look at Teaching Writing. *International Journal of Scholarly Academic Intellectual Diversity*, 16(1), 1–15.
- Lyndon, F. C. S., & Luard, M. L. (2018). Middle School Teachers' Perception of Differentiated Instruction on Lower Third Student Achievement. *Teacher Education and Curriculum Studies*, 3(3), 20–33. <https://doi.org/10.11648/j.tecs.20180303.11>

- Lynn, M. R. (1986). Determination and Quantification of Content Validity. *Nursing Research*, 35(6), 382-385
- Marcourt, S. R., Aboagye, E., Ossei-anto, T. A., Armoh, E. K., & Vinette, V. (2022). Teaching Method as a Critical Issue in Science Education in Ghana. *Social Education Research*, 4(1), 82–90. [https://doi.org/http s://doi.org/10.37256/ser.4120 232058](https://doi.org/http%3A%2F%2Fdoi.org%2F10.37256%2Fser.4120232058)
- Marghitan, A., Tulbure, C., & Gavrilă, C. (2016). Students' Perspective Regarding the Necessity and Opportunity of Using the Differentiated Instruction in Higher Education. *Bulletin of the Transilvania University of Braşov*, 9(2), 179–186.
- Marshall, G., & Jonker, L. (2010). An introduction to descriptive statistics: A review and practical guide. *Radiography*, 16(4), 1–7. <https://doi.org/10.1016/j.radi.2010.01.001>
- Martín, H. R., & Bybee, R. W. (2022). The cognitive principles of learning underlying the 5E Model of Instruction. *International Journal of STEM Education*. <https://doi.org/10.1186/s40594-022-00337-z>
- Ministry of Education. (2010). *SHS Teaching Syllabus for Elective Physics*. Curriculum Research and Development Division. 1-46.
- Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia*, 22(1), 67–72. https://doi.org/10.4103/aca.ACA_157_18
- Mishra, P., Singh, U., Pandey, C. M., Mishra, P., & Pandey, G. (2019). Application of Student's T-Test, Analysis of Variance, and Covariance. *Annals of Cardiac Anaesthesia*, 22(4), 407–411. <https://doi.org/10.4103/aca.ACA-94-19>

- Mohajan, H. K. (2017). Two Criteria for Good Measurements in Research: Validity and Reliability. *Munich Personal RePEc Archive*, 17(3), 58–82. <http://www.jstor.org/stable/2393203>
- Mohammed, H. S., & Kinyo, L. (2020). The role of constructivism in the enhancement of social studies education. *Journal of Critical Reviews*, 7(7), 249–256. <https://doi.org/10.31838/jcr.07.07.41>
- Moran, S., Kornhaber, M., & Gardner, H. (2006). Orchestrating Multiple Intelligences Profile Students, Don't Score Them. *Educational Leadership*, 64(1), 22–27.
- Morgan, M. A., & Aboagye, G. K. (2022). Students' interest in physics by gender, school type and programme of study. *International Journal of Research and Innovation in Social Science*, 06(08), 591–601. <https://doi.org/10.47772/ijriss.2022.6830>
- Muhammad, B. A., Omwirhiren, E. M., & Abubakar, S. (2019). Influence of 5E-Teaching Cycle on Attitude, Retention and Academic Performance of Students with Varied Ability in Selected Secondary Schools in Zaria Education Zone, Kaduna State, Nigeria. *International Journal of Research in Commerce and Management Studies*, 1(1), 60–71.
- Murphy, L., Eduljee, N. B., & Croteau, K. (2021). Teacher-Centered versus Student-Centered Teaching. *Journal of Effective Teaching in Higher Education*, 4(1), 18–39. <https://doi.org/10.36021/jethe.v4i1.156k>
- Namazi, M., & Namazi, N. (2016). Conceptual Analysis of Moderator and Mediator Variables in Business Research. *Procedia Economics and Finance*, 36(16), 540–554. [https://doi.org/10.1016/S2212-5671\(16\)30064-8](https://doi.org/10.1016/S2212-5671(16)30064-8)

- Ngari, E. W., Kimani, M., & Kinga, T. N. (2018). Influence Of Students Characteristics On Performance Of Physics, In Kenya Certificate Of Secondary Education In Selected Public Secondary Schools, Laikipia County, Kenya. *International Journal of Innovative Research and Advanced Studies*, 4(8), 268–277.
- Njiru, S. M., & Karuku, S. (2015). An Exploration of Factors that Contribute to Low Performance in Physics: A Case of a Secondary School in Kenya. *International Journal of Innovation and Scientific Research*, 17(2), 381–390.
- Noemy, M. S., Inés G., R., Cristina, I. G., & Patricia, A. P. (2017). Exploring Academic Performance: Looking beyond Numerical Grades. *Universal Journal of Educational Research*, 5(7), 1105–1112. <https://doi.org/10.13189/ujer.2017.050703>
- Nurasiah, L., Priatna, B. A., & Priatna, N. (2020). The effect of Differentiated Instruction on student mathematical communication ability. *Journal of Physics: Conference Series*, 1469(1). <https://doi.org/10.1088/1742-6596/1469/1/012160>
- Obafemi, D. T. A., & Aderonmu, T. S. B. (2022). Identification and Sources of Misconceptions Held By Secondary School Physics Students in Heat Energy In Rivers State, Nigeria. *European Journal of Education Studies*, 9(4), 120–133. <https://doi.org/10.46827/ejes.v9i4.4241>
- Obafemi, K. E. (2022). Effect of Differentiated Instruction on The Academic Achievement Of Pupils In Mathematics In Ilorin West Local Government Area, Kwara State. *Kwasu International Journal of Education*, 4(1), 51–59. <https://www.kije.com.ng>
- Obilor, E. I., & Miwari, G. U. (2022). Content Validity in Educational Assessment. *International Journal of Innovative Education Research*, 10(2), 57–69. www.seahipaj.org

- Oduro-Okyireh, G. & Annor S.Y., (2018). Introduction to Educational Assessment and Evaluation. Abundance of Grace Publications. pp 55-64
- OECD. (2018). *Creating Effective Teaching and Learning Environments: First Results from TALIS*. OECD publications Service.
- Ogundeji, O. M. (2022). Vygotsky and Tomlinson's Perspective on Differentiation Instruction: Implication for Science Education Classroom. *Psychology in Theory and Practice, 1*(4), 99–112. <https://doi.org/10.5281/zenodo.8184892>
- Ogunleye, B. O., & Babajide, V. F. T. (2016). Commitment to Science and Gender as Determinants of Students Achievement and Practical Skills in Physics. *Journal of the Science Teachers Association of Nigeria, 46*(1), 125–135.
- Olifer, O. (2020). The learner-centred paradigm of education: its features and philosophical basis. *International Conference on History, Theory and Methodology of Learning, 75*, 1–9. <https://doi.org/10.1051/shsconf/20207503002>
- Olusola, O. O., Popoola, O. E., & Omonijo, A. R. (2020). Comparative Analysis and Gender Effects of Students Academic Performance in Senior Secondary School Certificate Examination (SSCE) in Physics Between Year 2013 and 2017 in Ekiti State, Nigeria. *European Journal of Educational and Development Psychology, 8*(1), 11–19.
- Omotayo, S. A., & Adeleke, J. O. (2017). The 5E Instructional Model: A Constructivist Approach for Enhancing Students' Learning Outcomes in Mathematics. *Journal of the International Society for Teacher Education, 21*(2), 15–26.

- Opore, S. A., Manu, F. O., Ackah, J. K., & Akrosumah, S. M. (2018). An Investigation into Teaching and Learning Materials (TLMs) Science Tutors Use to Assess Physics Lessons in the Colleges of Education in Ghana. *American Journal of Modern Physics and Application*, 5(4), 91–96.
- Pallant, J. (2011). *SPSS Survival Manual: A Step by step guide to data analysis using SPSS* (4th ed.). Allen & Unwin.
- Pham, H. L. (2012). Differentiated Instruction And The Need To Integrate Teaching And Practice. *Journal of College Teaching & Learning*, 9 (1), 13–20. [https://doi.org/10.1016/S0720-048X\(99\)00076-5](https://doi.org/10.1016/S0720-048X(99)00076-5)
- Piaget, J. (1976). Piaget and His School: A Reader in Developmental Psychology. *Physical Therapy*, 58(3), 375–375. <https://doi.org/10.1093/ptj/58.3.375a>
- Poonam, S. (2017). Constructivism: A new paradigm in teaching and learning. *International Journal of Academic Research and Development*, 2 (4), 183–186.
- Pozas, M., Letzel, V., & Schneider, C. (2020). Teachers And Differentiated Instruction: Exploring Differentiation Practices to Address Student Diversity. *Journal of Research in Special Educational Needs*, 20 (3), 217–230. <https://doi.org/10.1111/1471-3802.12481>
- Quansah, F., Hagan, J. E., Sambah, F., Frimpong, J. B., Ankomah, F., Srem-Sai, M., Seibu, M., Abieraba, R. S. K., & Schack, T. (2022). Perceived Safety of Learning Environment and Associated Anxiety Factors during COVID-19 in Ghana: Evidence from Physical Education Practical-Oriented Program. *European Journal of Investigation in Health, Psychology and Education*, 12(1), 28–41. <https://doi.org/10.3390/ejihpe12010003>

- Radzali, U. S., Mohd-yusof, K., & Phang, F. A. (2018). Changing the Conception of Teaching from Teacher-Centred to Student- Centred Learning among Engineering Lecturers. *Global Journal of Engineering Education*, 20(8), 119–126.
- Rodriguez, S., Allen, K., Harron, J., & Qadri, S. A. (2019). Making and the 5E Learning Cycle. *The Science Teacher*, 86(05), 44–55. https://doi.org/10.2505/4/tst18_086_05_48
- Rutherford-Hemming, T. (2015). Determining Content Validity and Reporting a Content Validity Index for Simulation Scenarios. *Nursing Education Perspectives*, 36(6), 389–393. <https://doi.org/10.5480/15-1640>
- Sadeeqe, N., Shah, N. H., & Munawar, U. (2021). Effectiveness of 5E and Lecture Model for the Teaching of Physics at Secondary Level. *International Review of Basic and Applied Sciences*, 9 (1), 1–8.
- Saito, A. (2002). Recent Advances in Research on Cold Thermal Energy Storage. *International Journal of Refrigeration*, 25(2), 177–189. [https://doi.org/10.1016/S0140-7007\(01\)00078-0](https://doi.org/10.1016/S0140-7007(01)00078-0)
- Salar, R., & Turgut, U. (2021). Effect of Differentiated Instruction and 5E Learning Cycle on Academic Achievement and Self-efficacy of Students in Physics Lesson. *Science Education International*, 32(1), 4–13. <https://doi.org/10.33828/sei.v32.i1.1>
- Saleem, A., Huma, K., & Deeba, F. (2021). Social Constructivism: A New Paradigm in Teaching and Learning Environment. *Perennial Journal of History*, 2(2), 403–421. <https://doi.org/10.52700/pjh.v2i2.86>

- Sam, C. K., Acheaw Owusu, K., & Anthony-Krueger, C. (2018). Effectiveness of 3E, 5E and Conventional Approaches of Teaching on Students' Achievement in High School Biology. *American Journal of Educational Research*, 6(1), 76–82. <https://doi.org/10.12691/education-6-1-12>
- Sanchez, J. M. P., & Ponce, M. A. (2020). Physics-Mathematics Associations: Evidence from TIMSS Student Achievements. *Science Education International*, 31(3), 229–236. <https://doi.org/10.33828/sei.v31.i3.1>
- Saricayir, H., Ay, S., Comek, A., Cansiz, G., & Uce, M. (2016). Determining Students' Conceptual Understanding Level of Thermodynamics. *Journal of Education and Training Studies*, 4(6), 69–79. <https://doi.org/10.11114/jets.v4i6.1421>
- Sawant, S. P., & Rizvi, S. (2015). Study of Passive Didactic Teacher Centered Approach and an Active Student Centered Approach in Teaching Anatomy. *International Journal of Anatomy and Research*, 3(3), 1192–1197. <https://doi.org/10.16965/ijar.2015.147>
- Schneider, B. A., Avivi-reich, M., & Mozuraitis, M. (2015). A Cautionary Note on The Use of The Analysis of Covariance (ANCOVA) in Classification Designs With and Without Within-Subject Factors. *Frontiers in Psychology*, 6(3), 1–12. <https://doi.org/10.3389/fpsyg.2015.00474>
- Şener, S., & Çokçalışkan, A. (2018). An Investigation between Multiple Intelligences and Learning Styles. *Journal of Education and Training Studies*, 6(2), 125. <https://doi.org/10.11114/jets.v6i2.2643>

- Serin, H. (2018). A Comparison of Teacher-Centered and Student-Centered Approaches in Educational Settings. *International Journal of Social Sciences & Educational Studies*, 5(1), 164–167. <https://doi.org/10.23918/ijsses.v5i1p164>
- Shabani, K., Khatib, M., & Ebadi, S. (2010). Vygotsky's Zone of Proximal Development: Instructional Implications and Teachers' Professional Development. *English Language Teaching*, 3(4), 237–248.
- Shearer, B. (2018). Multiple Intelligences in Teaching and Education: Lessons Learned from Neuroscience. *Journal of Intelligence*, 6(3), 1–8. <https://doi.org/10.3390/jintelligence6030038>
- Shumow, L., & Schmidt, J. A. (2013). *Enhancing Adolescents' Motivation for Science*. <http://www.niu.edu/eteams>
- Siddiqui, U., & Khaton, T. (2013). Teaching Physical Science: Should We Implement Teacher-Centered CAI or Student-Centered CAI at Secondary School Level in India? *European Scientific Journal*, 9(10), 136–149.
- Siwawetkul, W., & Koraneekij, P. (2020). Effect of 5E Instructional Model on Mobile Technology to Enhance Reasoning Ability of Lower Primary School Students. *Kasetsart Journal of Social Sciences*, 41(1), 40–45. <https://doi.org/10.1016/j.kjss.2018.02.005>
- Sönmez, V. (2017). Association of Cognitive, Affective, Psychomotor and Intuitive Domains in Education, Sönmez Model. *Universal Journal of Educational Research*, 5(3), 347–356. <https://doi.org/10.13189/ujer.2017.050307>

- Sotáková, I., & Ganajová, M. (2023). The Effect of the 5E Instructional Model on Students' Cognitive Processes and their Attitudes Towards Chemistry as a Subject. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(9), 1–22. <https://doi.org/10.29333/EJMSTE/13469>
- Spinath, B. (2012). Academic Achievement. In *Encyclopedia of Human Behavior: Second Edition* (2nd ed.). Elsevier Inc. <https://doi.org/10.1016/B978-0-12-375000-6.00001-X>
- Takwe, M.-A. A. (2019). Gender Disparity, Implications to Students' Academic Performance in Science Subjects in Secondary Schools in Buea Sub Division, Cameroon. *International Journal of Trend in Scientific Research and Development*, 3(5), 1541–1567. <https://doi.org/https://doi.org/10.31142/ijtsrd26763>
- Tambaya, I. S., Isah, S. A., & Onize, G. (2023). Effects of Differentiated Instruction on Academic Achievement in Biology among the Public Senior Secondary School Students in Dutsin-Ma, Katsina Afropolitan Journals Effects of Differentiated Instruction on Academic Achievement in Biology among the Publi. *African Journal of Humanities & Contemporary Education Research*, 10(1), 212–221.
- Taylor, B. K. (2015). Content, Process, and Product: Modeling Differentiated Instruction. *Kappa Delta Pi Record*, 51(1), 13–17. <https://doi.org/10.1080/00228958.2015.988559>
- Tebabal, A., & Kahssay, G. (2015). The Effects of Student-Centered Approach in Improving Students Graphical Interpretation Skills and Conceptual Understanding of Kinematical Motion. *International Journal for Physics Education*, 5(2), 374–381.

- Tetteh, H. N. K., Wilmot, E. M., & Ashong, D. (2018). Gender Differences in Performance in Mathematics among Pre-service Teachers in the Brong-Ahafo Region of Ghana. *International Journal of Education, Learning and Development*, 6(5), 38–45.
- Thakur, K. (2014). Differentiated Instruction in the Inclusive Classroom. *Research Journal of Educational Sciences*, 2(7), 10–14. www.isca.me
- Timmins, A. C. B. (2019). Multiple Intelligences: Gardner's Theory. *Practical, Assessment, Research, and Evaluation*, 5(10), 1–5. <https://doi.org/10.7275/7251-ea02>
- Tomlinson, C. A., Brighton, C., Hertberg, H., Callahan, C. M., Moon, T. R., Brimijoin, K., Conover, L. A., & Reynolds, T. (2003). Differentiating instruction in response to student readiness, interest, and learning profile in academically diverse classrooms: A review of literature. *Journal for the Education of the Gifted*, 27(2–3), 119–145. <https://doi.org/10.1177/016235320302700203>
- Tomlinson, C. A., & Eidson, C. C. (2003). *Differentiation in practice: A Source guide for differentiating curriculum grades 5-9*. Association for Supervision and Curriculum Development.
- Tularam, G. A. (2018). Traditional vs Non-traditional Teaching and Learning Strategies - the case of E-learning! *International Journal for Mathematics Teaching and Learning*, 19(1), 129–158. <https://doi.org/10.4256/ijmtl.v19i1.21>
- Umida, K., Dilor, A., & Umar, E. (2020). Constructivism in Teaching and Learning Process. *European Journal of Research and Reflection in Educational Sciences*, 8(3), 134–137. www.idpublications.org
- UNESCO. (2020). *Gender Terminology, Concepts and Definitions*. UNESCO. 36-39

- Ünlü, K. Z., & Dökme, İ. (2022). A Systematic Review of 5E Model in Science Education: Proposing a Skill-Based STEM Instructional Model Within the 21-St Century Skills. *International Journal of Science Education*, 44(13), 2110–2130.
<https://doi.org/10.1080/09500693.2022.2114031>
- Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes* (1st ed.). Harvard University Press.
- WAEC. (2017). *Chief Examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>
- WAEC. (2018). *Chief examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>
- WAEC. (2019). *Chief Examiners' Reports. Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>
- WAEC. (2020). *Chief examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>.
- WAEC. (2021). *Chief Examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>.
- Wenning, C. J., & Vieyra, R. E. (2020). Teaching High School Physics. *American Association of Physics Teachers*. <https://doi.org/10.1063/9780735422018>
- Wilson, K., & Low, D. (2017). Reducing The Gender Gap In First-Year Physics Performance. *Proceedings of the Australian Conference on Science and Mathematics Education, The University of Queensland*, 246–253.

- Wilson, K., Low, D., Verdon, M., & Verdon, A. (2016). Differences in gender performance on competitive physics selection tests. *Physical Review Physics Education Research*, *12*(2), 1–16. <https://doi.org/10.1103/PhysRevPhysEducRes.12.020111>
- Winarti, A., Nor Ichsan, A., & Istiyadi, M. (2018). Multiple Intelligences in the Classroom: The Development of Chemistry Learning Devices Using Collaborative Strategy based on Multiple Intelligences. *Advances in Social Science, Education and Humanities Research*, *14*(7), 50–53. <https://doi.org/10.2991/icsse-17.2018.13>
- Winarti, A., Yuanita, L., & Nur, M. (2019). The Effectiveness of Multiple Intelligences-Based Teaching Strategy in Enhancing the Multiple Intelligences and Science Process Skills of Junior High School Students. *Journal of Technology and Science Education*, *9*(2), 122–135. <https://doi.org/10.3926/jotse.404>
- Winarti, Cari, Suparmi, Sunarno, W., & Istiyono, E. (2017). Development of two tier test to assess conceptual understanding in heat and temperature. *Journal of Physics Conference Series*, 1–5. <https://doi.org/10.1088/1742-6596/795/1/012052>
- Wrigley-Asante, C., Ackah, C. G., & Frimpong, L. K. (2023). Gender Differences in Academic Performance of Students Studying Science Technology Engineering and Mathematics (STEM) Subjects at the University of Ghana. *Springer Nature Social Sciences Journal*, *3*(1), 1–22. <https://doi.org/10.1007/s43545-023-00608-8>
- Wurah-Norgbey, E. (2019). *Women In Science and Technology In Higher Education In Ghana: Policy Environments and Experiences*. University of Ottawa, Canada.
- Yaghoob, R. A., & Hossein, Z. P. (2016). The Correlation of Multiple Intelligences for the Achievements of Secondary Students. *Educational Research and Reviews*, *11*(4), 141–145. <https://doi.org/10.5897/err2015.2532>

- Yanti, Y. R., Amin, S. M., & Sulaiman, R. (2018). Representation of Students in Solving Simultaneous Linear Equation Problems Based on Multiple Intelligence. *Journal of Physics: Conference Series*, 947(1), 1–6. <https://doi.org/10.1088/1742-6596/947/1/012038>
- Yavich, R., & Rotnitsky, I. (2020). Multiple intelligences and success in school studies. *International Journal of Higher Education*, 9(6), 107–117. <https://doi.org/10.5430/ijhe.v9n6p107>
- Young, H. D. (2012). *College Physics* (9th ed.). Pearson Education, Inc.
- Yurt, E., & Polat, S. (2015). The Effectiveness of Multiple Intelligence Applications on Academic Achievement: A Meta-Analysis. *Journal of Social Studies Education Research*, 6(1), 84–122. <https://doi.org/10.17499/jsser.75161>
- Zheng, Z., & Mustapha, S. M. (2022). A Literature Review on the Academic Achievement of College Students. *Journal of Education and Social Sciences*, 20(1), 11–18. https://www.jesoc.com/wp-content/uploads/2022/06/JESOC20_12.pdf

APPENDICES

Appendix A

Thermal Physics Concept Test (TPCT)

**AKENTEN APPIAH – MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT (AAMUSTED)**

DEPARTMENT OF INTEGRATED SCIENCE EDUCATION

SCHOOL:

CLASS:

GENDER: Male Female

INSTRUCTION

This test consists of two sections, A and B. Please answer all questions in both sections.

DURATION: 45 MINUTES

SECTION A

(20 MARKS)

INSTRUCTION: The following questions contain four options lettered A to D. Select the correct option by circling the letter.

1. The fact that a thermometer "takes its own temperature" illustrates ...
 - A. energy conservation.
 - B. the difference between heat and thermal energy.
 - C. the fact that molecules are constantly moving.
 - D. thermal equilibrium.

2. When you touch a cold piece of ice with your finger...
- A. energy flows from the ice to your finger.
 - B. energy flows from your finger to the ice.
 - C. energy flows in both ways.
 - D. there will be no flow of energy.
3. The lowest temperature possible in nature is...
- A. -273.15°C .
 - B. 0°C .
 - C. 37K.
 - D. 273.15K.
4. How will you know when the transfer of heat has ended?
- A. Both objects reach the same temperature.
 - B. It never ends.
 - C. When you can measure the amount of heat.
 - D. When the substance that is receiving the heat reaches its boiling or melting point.
5. At what temperature are the readings on the Celsius and Fahrenheit scales be the same?
- A. -40°C and -40°F .
 - B. -60°C and -60°F .
 - C. 40°C and -40°F .
 - D. 60°C and -60°F .

6. When 100 J of heat is added to a system that performs 60 J of work, the thermal energy change of the system is...

- A. 0J.
- B. 40J.
- C. 60J.
- D. 100J.

7. When a volume of air expands against the environment and no heat enters or leaves, the air temperature will...

- A. decrease.
- B. increase.
- C. increase and later decrease.
- D. remain unchanged.

8. Suppose you put a closed, sealed can of air on a hot stove burner. The contained air will undergo an increase in...

- I. pressure.
 - II. temperature.
 - III. thermal energy.
- A. I and II only
 - B. I and II only
 - C. II and III only
 - D. I, II and III

9. As a piece of metal with a hole in it cools, the diameter of the hole...
- A. decreases.
 - B. divides by two.
 - C. increases.
 - D. remains the same.
10. You put a thermometer in a pot of hot water and record the reading. What temperature have you recorded?
- A. An equal average of the temperatures of the water and thermometer.
 - B. A weighted average of the temperatures of the water and thermometer.
 - C. The temperature of the thermometer.
 - D. The temperature of the water.
11. The following are all thermometric properties **except**...
- A. density of a metal.
 - B. electrical resistance of a metal.
 - C. length of a liquid column.
 - D. pressure of a gas.
12. Consider a metal ring with a gap cut in it. When the ring is heated, the gap...
- A. becomes narrower.
 - B. becomes wider.
 - C. closes.
 - D. retains its size.

13. In a clinical thermometer, the liquid does not rise or fall when taken out of the mouth because...
- A. it is smaller than a laboratory thermometer.
 - B. it has a thin stem.
 - C. it has a kink just above the bulb of the thermometer.
 - D. nothing happens.
14. Asamoah and Adomako measured their body temperature. Asamoah's temperature was 98.6°F and Adomako recorded 37°C. Which of the following statement is true?
- A. Both are suffering from fever.
 - B. Both have normal body temperature.
 - C. Asamoah has a higher body temperature than Adomako.
 - D. Asamoah has a lower body temperature than Adomako.
15. Handles of cooking utensils should be made of a material that...
- A. conducts heat well.
 - B. does not conduct heat well.
 - C. does not radiate heat well.
 - D. radiates heat well.
16. A substance can absorb heat energy by...
- I. conduction
 - II. convection
 - III. radiation
- A. I and II
 - B. I and III

- C. II and III
 - D. I, II and III
17. The planet earth loses heat mainly by...
- I. conduction.
 - II. convection.
 - III. radiation.
- A. I only
 - B. II only
 - C. I and II only
 - D. II and III
18. When heat is added to boiling water, the water temperature...
- A. decreases.
 - B. increases.
 - C. multiplies.
 - D. stays the same.
19. A beggar wrapped himself with a few layers of newspaper on a cold winter night. This helped him to keep himself warm because ...
- A. air trapped between the layers of newspaper is a bad conductor of heat.
 - B. friction between the layers of newspaper produces heat.
 - C. newspaper is a conductor of heat.
 - D. newspaper is at a higher temperature than the temperature of the surrounding.

20. In which method(s) of heat transfer do molecules travel from the hot to the cold portion?

- I. conduction.
 - II. convection.
 - III. radiation.
- A. I only
 - B. II only
 - C. I and II only
 - D. II and III only

SECTION B

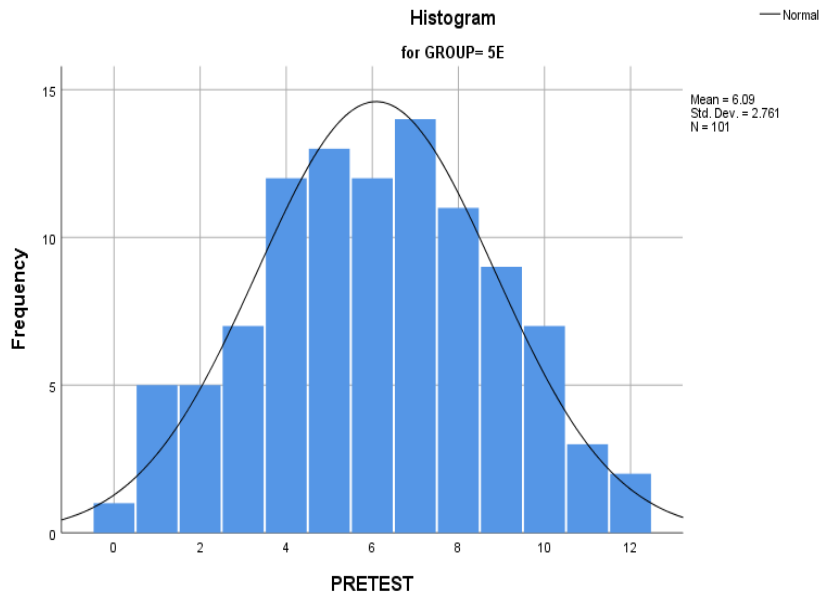
(10 MARKS)

Answer all questions in this section

1. Two objects, one bigger than the other, and at the same temperature are placed in contact.
 - (a) Will heat be transferred from one object to another? **(1 mark)**
 - (b) Explain your answer in (a). **(4 marks)**
2. Explain why heat travels up much faster in water than it travels down. **(5 marks)**

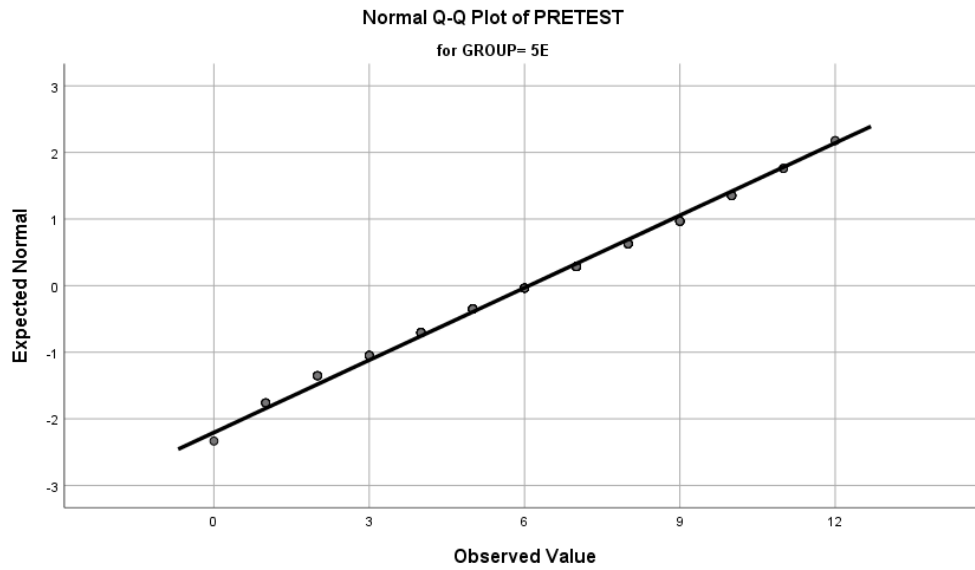
Appendix B1

Histogram Distribution of Pretest Scores of 5E Instructional Model Group



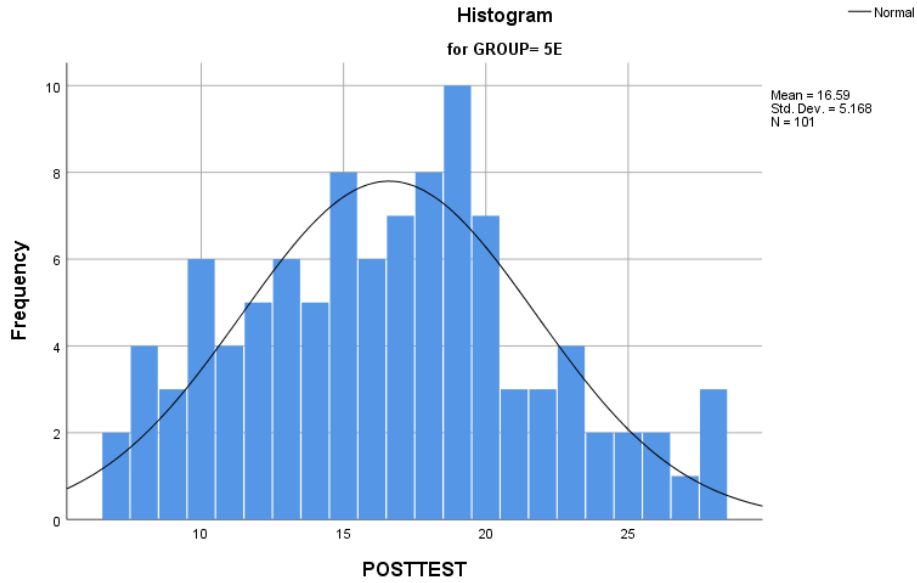
Appendix B2

Normal Q-Q Plot for Pretest Scores of 5E Instructional Model Group



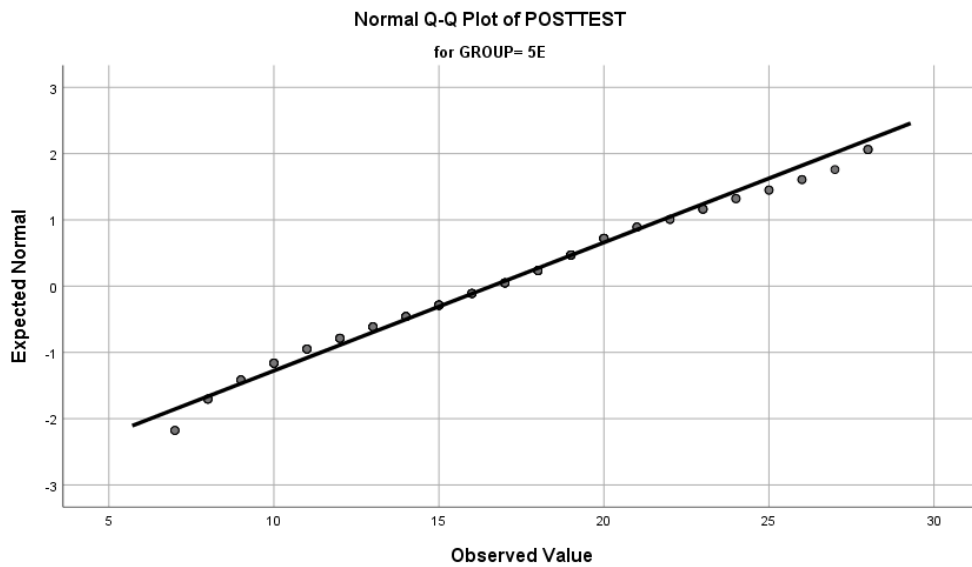
Appendix C1

Histogram Distribution for Posttest Scores of 5E Instructional Model Group



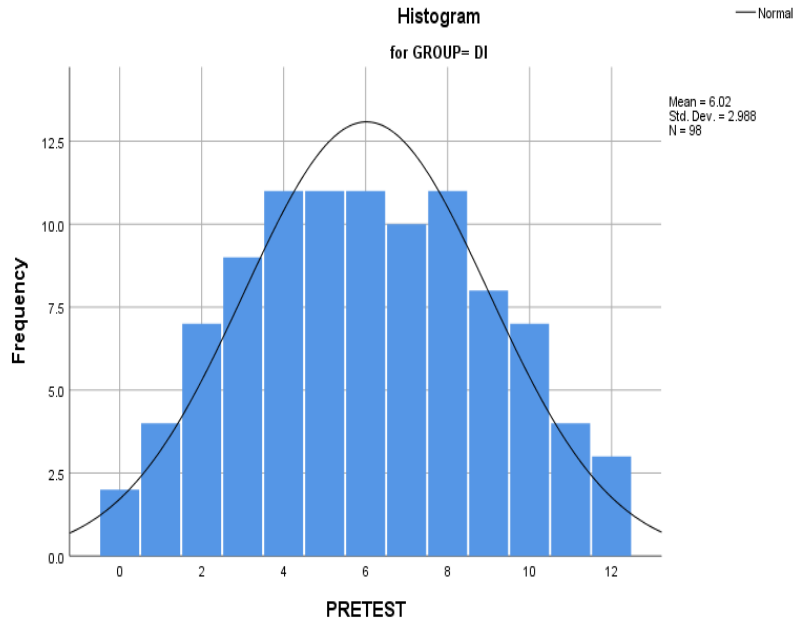
Appendix C2

Normal Q-Q Plot for Posttest Scores of 5E Instructional Model Group



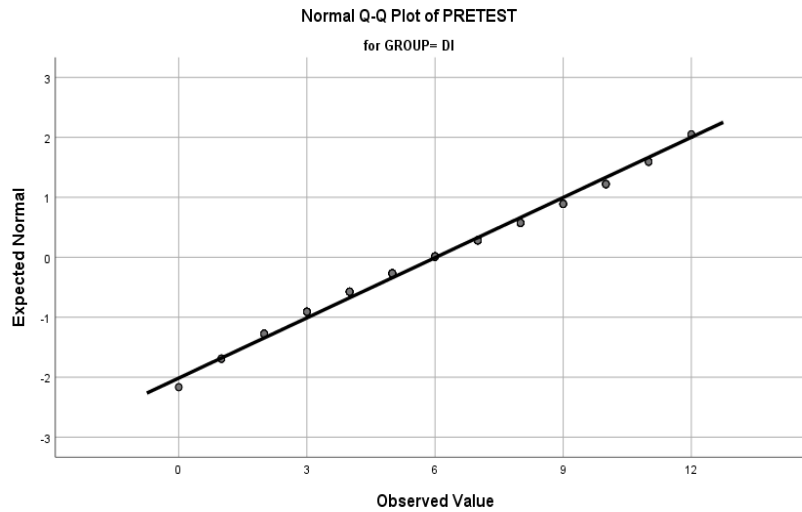
Appendix D1

Histogram Distribution for Pretest Scores of Differentiated Instruction Group



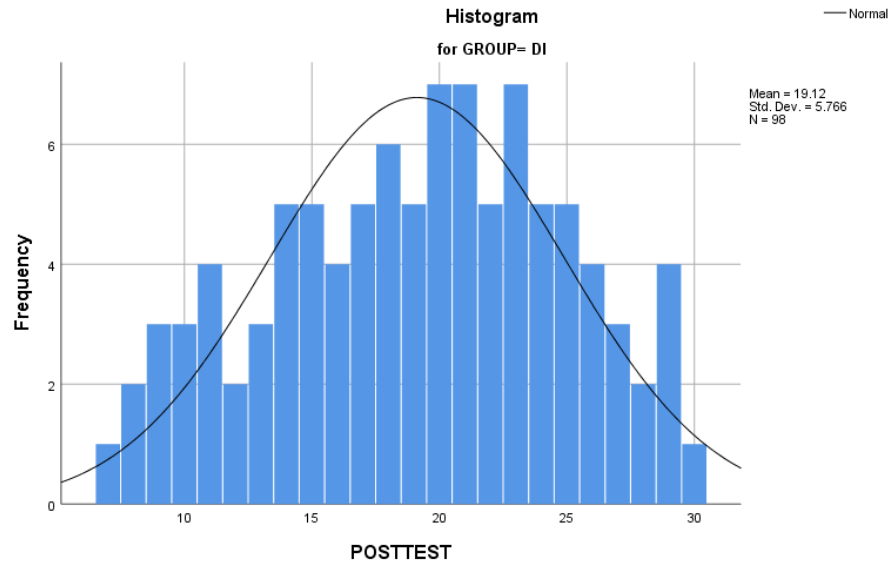
Appendix D2

Normal Q-Q Plot for Pretest Scores of Differentiated Instruction Group



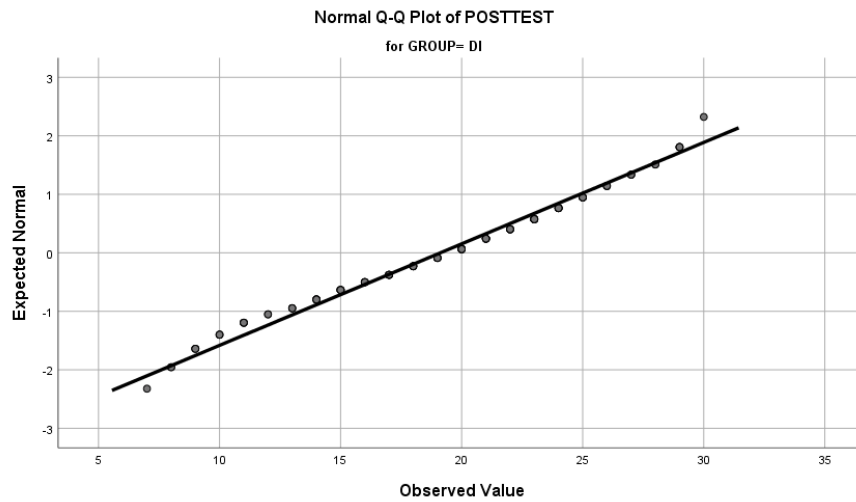
Appendix E1

Histogram Distribution for Posttest Scores of Differentiated Instruction Group



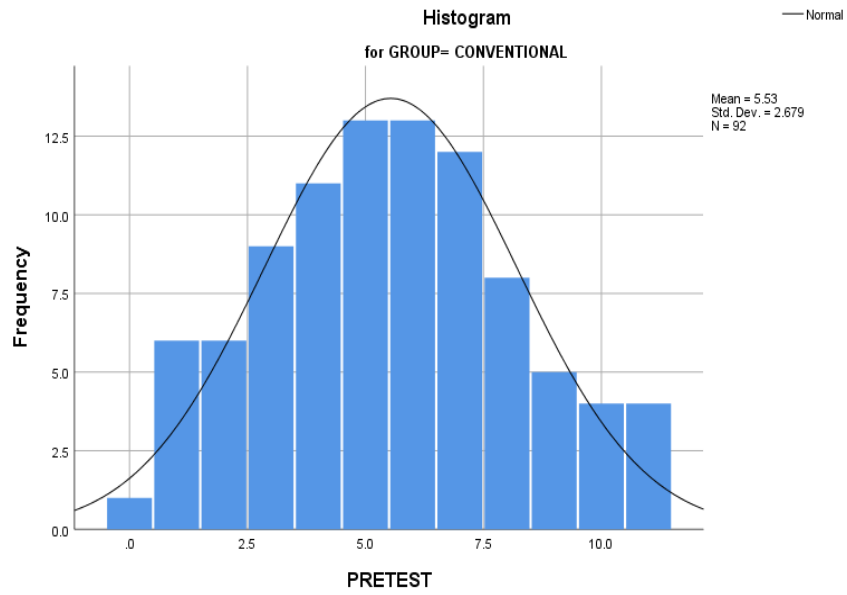
Appendix E2

Normal Q-Q Plot for Posttest Scores of Differentiated Instruction Group



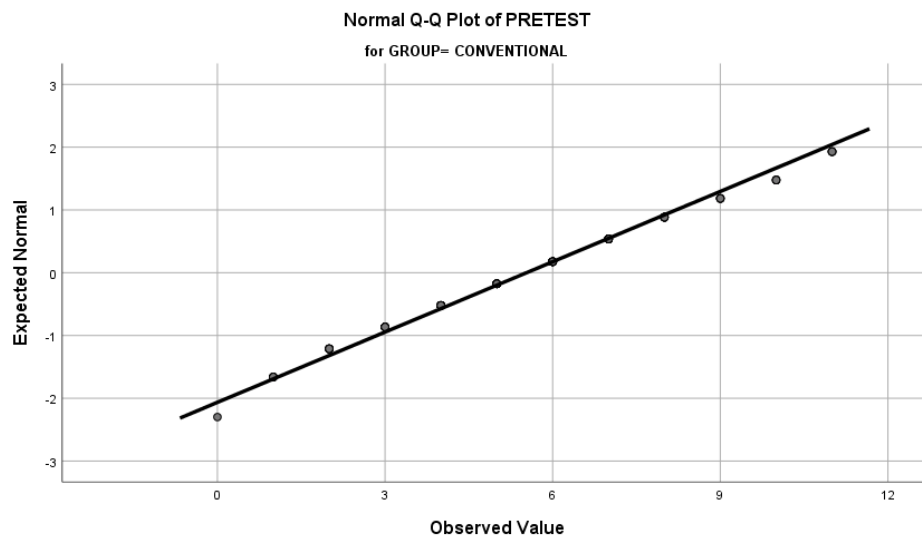
Appendix F1

Histogram Distribution for Pretest Scores of Conventional Group



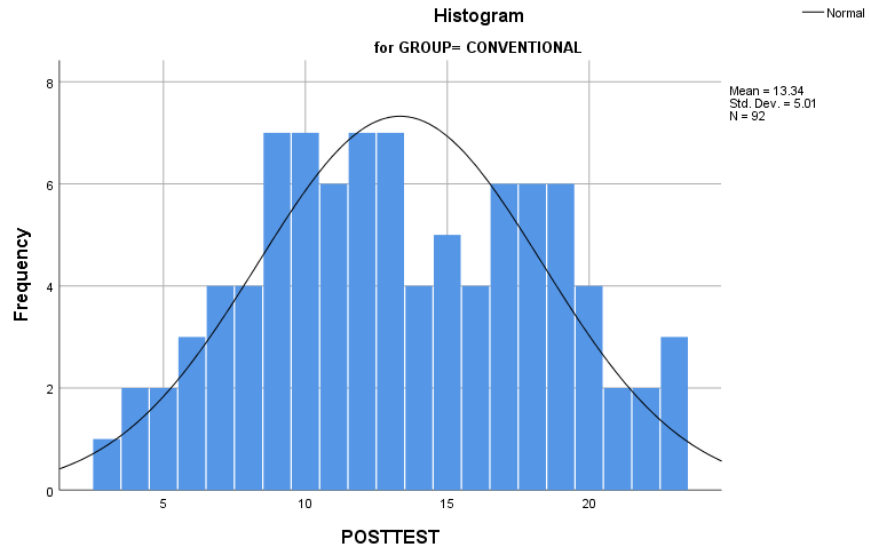
Appendix F2

Normal Q-Q Plot for Pretest Scores of Conventional Group



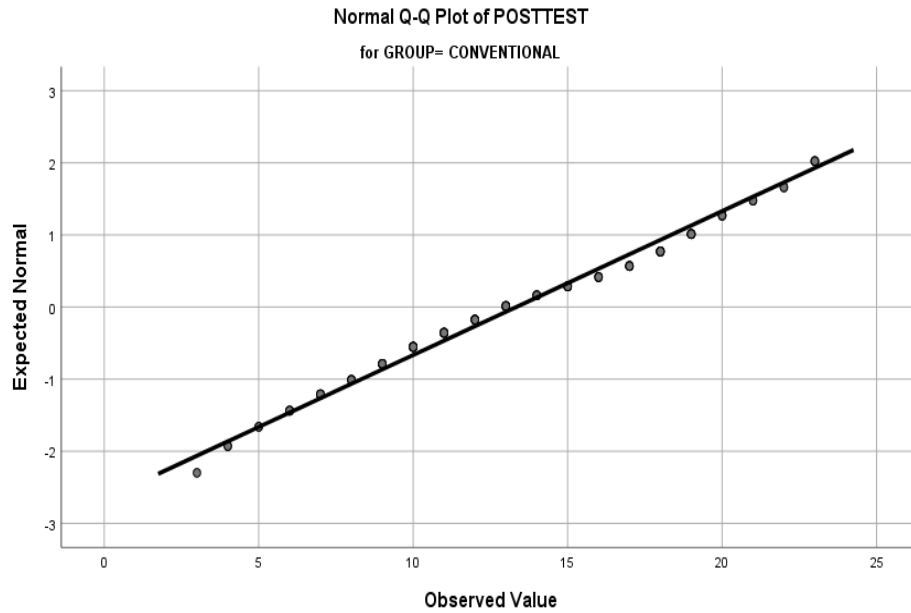
Appendix G1

Histogram Distribution for Posttest Scores of Conventional Group



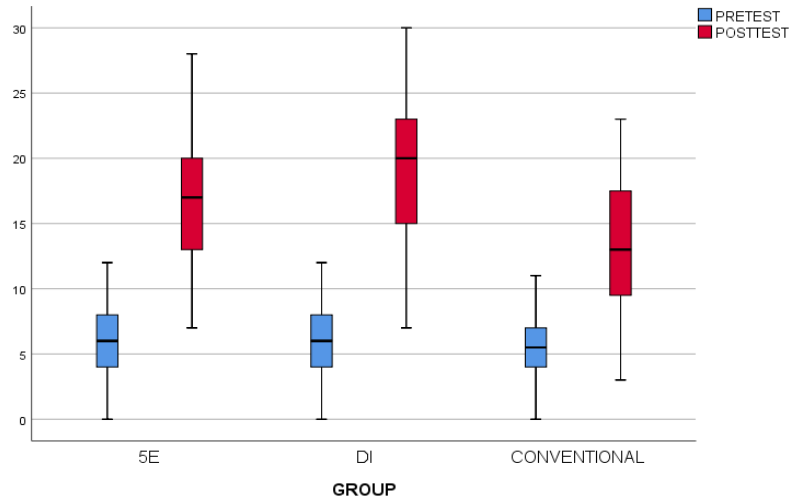
Appendix G2

Normal Q-Q Plot for Posttest Scores of Conventional Group



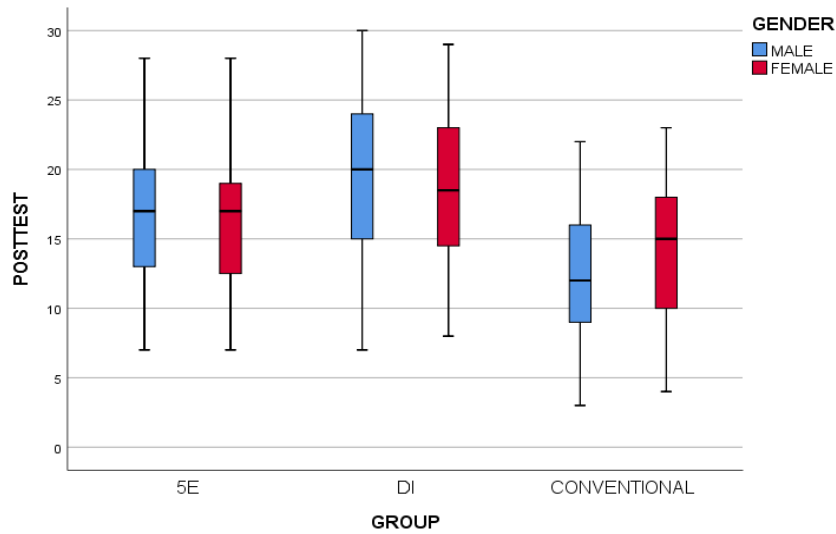
Appendix H1

Box Plots for Pretest and Posttest Scores for 5E Instructional Model, Differentiated Instruction, and Conventional Groups



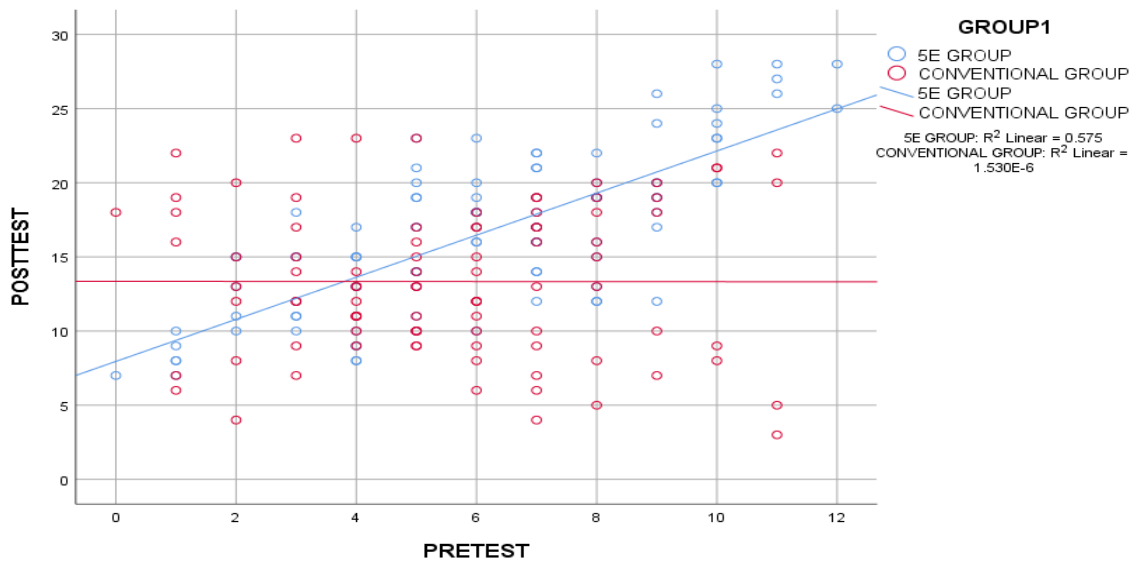
Appendix H2

Box Plots for Pretest and Posttest Scores for Male and Female Students in 5E Instructional Model, Differentiated Instruction, and Conventional Groups



Appendix I1

Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Conventional Group



Appendix I2

Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Conventional Group

Type III Sum					
Source	of Squares	df	Mean Square	F	p
Teaching Method	250.447	1	250.447	13.841	.000
Pretest	705.914	1	705.914	39.012	.000
Group * Pretest	710.534	1	710.534	39.267	.000
Error	3419.907	189	18.095		

Appendix J

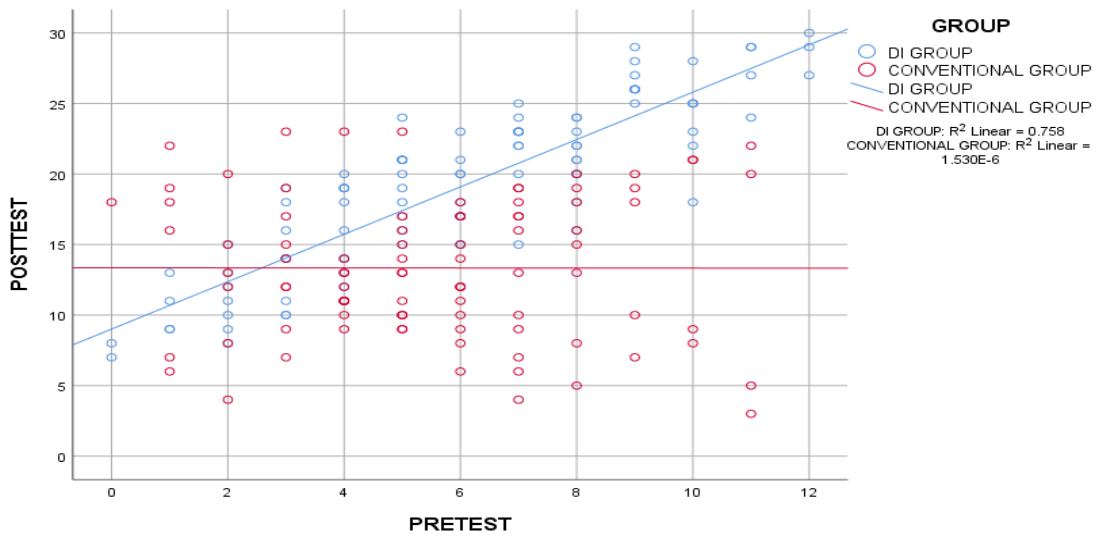
Results of One-Way ANCOVA on Posttest Scores of 5E Instructional Model Group and Conventional Group

	Type III					
	Sum of		Mean			Partial Eta
Source	Squares	df	Square	F	p	Squared
Intercept	3816.453	1	3816.453	175.557	.000	.480
Pretest	824.470	1	824.470	37.926	.000	.166
Group	382.197	1	382.197	17.581	.000	.085
Error	4130.441	190	21.739			

Appendix K1

Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Differentiated Instruction Group and

Conventional Group



Appendix K2

Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Differentiated

Instruction Group and Conventional Group

Source	Type III Sum of Squares	df	Mean Square	F	p
Teaching Method	171.621	1	171.621	10.414	.001
Pretest	1047.647	1	1047.647	63.573	.000
Teaching Method *	1053.436	1	1053.436	63.924	.000
Pretest					
Error	3065.188	186	16.480		

Appendix L

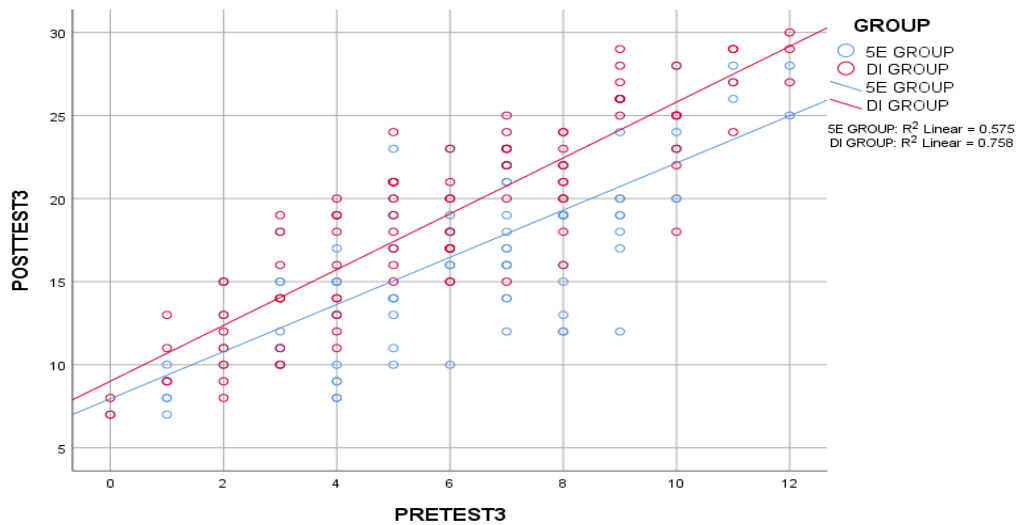
Results of One-Way ANCOVA on Posttest Scores of Differentiated Instruction

Group and Conventional Group

	Type III					
	Sum of		Mean			Partial Eta
Source	Squares	df	Square	F	Sig.	Squared
Intercept	4205.550	1	4205.550	190.947	.000	.505
Pretest	1390.462	1	1390.462	63.132	.000	.252
Group	1332.495	1	1332.495	60.500	.000	.244
Error	4118.623	187	22.025			

Appendix M1

Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Differentiated Instruction Group



Appendix M2

Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for 5E Instructional Model Group and Differentiated Instruction Group

Type III Sum					
Source	of Squares	df	Mean Square	F	p
Group	10.076	1	10.076	1.026	.312
Pretest	3893.396	1	3893.396	396.250	.000
Group * Pretest	27.575	1	27.575	2.806	.095
Error	1915.993	195	9.826		

Appendix N

Results of Levene's Test of Equality of Error Variances of Posttest Scores Between 5E Instructional Model Group and Differentiated Instruction Group

F	df1	df2	p
1.036	1	197	.310

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

Design: Intercept + Pretest + Group

Appendix O

Results for Two-Way Between Groups Analysis of Variance of Male and Female

Pretest Scores Within All Groups

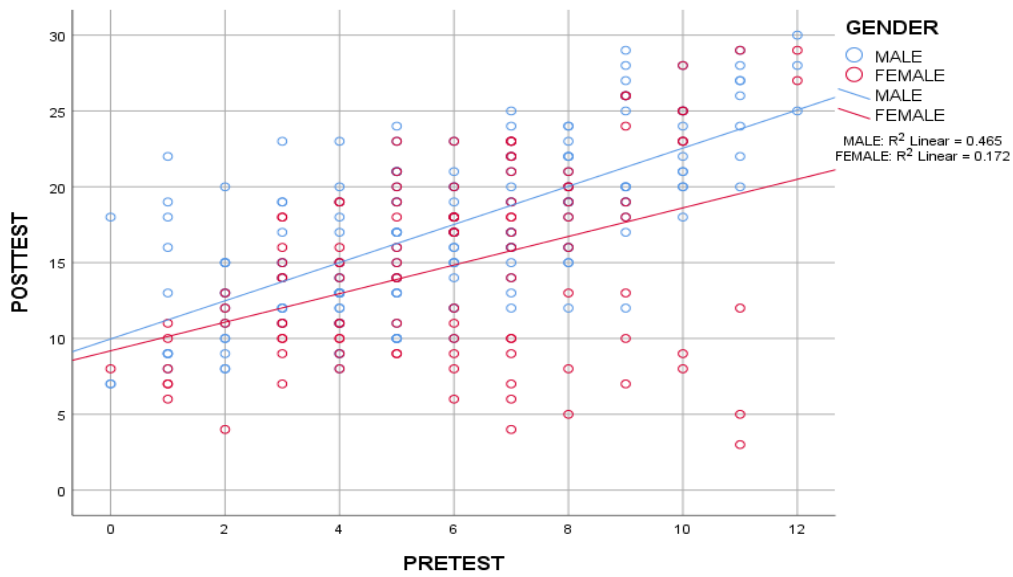
Source	df	F	p	Partial Eta Squared
Group	2	.316	.730	.002
Gender	1	.012	.913	.000
Group * Gender	2	3.788	.024*	.026
Error	285			

*P<0.05

Appendix P1

Results for Assumption of Linearity Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Male and Female SHS Physics Students

Within All Groups



Appendix P2

Results for Assumption of Homogeneity of Regression Slopes Between Covariate (Pretest Scores) and Dependent Variable (Posttest Scores) for Male and Female SHS

Physics Students Within All Groups

Source	Type III Sum of Squares	df	Mean Square	F	p
Gender	7.480	1	7.480	.344	.558
Pretest	2570.276	1	2570.276	118.212	.000
Gender * Pretest	52.936	1	52.936	2.435	.120
Error	6240.232	287	21.743		

Appendix Q

Results for Levene's Test of Equality of Error Variances of Male and Female SHS

Physics Students Within All Groups

F	df1	df2	Sig.
2.618	5	285	.075

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

Design: Intercept + Pretest + Group + Gender + Group * Gender

Appendix R

Student's Interest Inventory

School and career

What is your favorite class or activity in school and why?

What is your least favorite class or activity in school and why?

Which school subject is most challenging to you? Is the challenge positive or negative to you? What makes it challenging?

In which school subject do you feel like you learn the most? Why do you think this is?

What can teachers do to capture your interest?

Give an example of a classroom activity where you felt you really learned a lot. Why do you think that was?

Do you prefer to work alone, in small groups, or in large groups? Why?

What do you want to do after high school? What careers can you picture yourself in?

Extracurricular Activities

Besides socializing with friends, what do you like to do in your spare time?

How many hours per day do you use technology such as a computer, tablet, or smart phone?

What do you mainly use it/them for? (for example, socializing, research, games etc.)

Do you belong to any organizations, teams, or clubs in and out of school? Which ones?

Do you have any particular responsibilities outside of school? (for example, watching siblings, chores etc.)

Do you have a part-time job? If so, what is it and how many hours do you work per week?

What do you like most about your job?

General interest

Describe yourself using six words.

Do you like to read? Why/why not?

Briefly say something about a favorite book or movie and why you liked it.

If you could learn more about any subject, what would it be? Why are you curious about this subject?

If you could interview anyone, dead or alive, who would it be and why?

If you could travel anywhere in the world, where would you go and why?

Do you have a special talent or an interest that you know a lot about? If so, what is it?

Briefly describe a past accomplishment that made you feel proud of yourself.

Is there anything else you want me to know about you?

[Adopted from Shumow and Schmidt (2013)]

Appendix S

Learning Style Questionnaire

This questionnaire seeks to explore the learning styles of Senior High School (SHS) Physics students as part of a research titled “*Comparative Effects of 5E Instructional Model, Differentiated Instruction and Conventional Teaching Method on the Academic Performance of Senior High School Physics Students in Thermal Physics*”. Please, respond to each of the following statements as accurately as possible by checking the box corresponding to your response. Your response is confidential.

Direction: For each statement, check the box that best describes you.

Item No.	Statement	Often	Sometimes	Seldom
1	I can remember best by listening to a lesson that includes information, explanations and discussions.			
2	I prefer to see information written on the board and supplemented by visual aids and assigned readings			
3	I like to write things down or take notes for visual review.			
4	I prefer to use posters, models, or actual practice and other activities in class.			
5	I require explanations of diagrams, graphs, or visual directions			
6	I enjoy working with my hands or making things.			

7	I am skillful with and enjoy developing and making graphs and charts			
8	I can tell if sounds match when presented with pairs of sounds.			
9	I can remember best by writing things down several times.			
10	I can easily understand and follow directions on a map.			
11	I do best in academic subjects by listening to lectures and videos of content taught on YouTube.			
12	I play with coins or keys in my pocket.			
13	I learn to spell better by repeating words out loud than by writing the words on paper.			
14	I can understand a news article better by reading about it in the newspaper or online rather than by listening to a report about it on the radio or television.			
15	I chew gum, or take in snack while studying.			
16	I think the best way to remember something is to picture it in my mind.			
17	I learn the spelling of words by “finger spelling” them.			
18	I would rather listen to a good lesson or speech than read about the same material.			

19	I am good at working and solving jigsaw puzzles and mazes.			
20	I grip objects in my hands during learning periods.			
21	I prefer listening to the news on the radio or online rather than reading about it in a newspaper or on the internet.			
22	I prefer obtaining information about an interesting subject by reading about it.			
23	I feel very comfortable touching others, hugging, handshaking, etc.			
24	I follow oral directions better than written ones.			
25	I remember key information from a text when highlighted or underlined.			
26	I learn to add numbers using my fingers.			
27	I understand best a recorded lesson when I listen to it more than once.			

Scoring: The points in each column were added to obtain the learning preference score under each heading. The learning preference with the highest score indicated a student's learning style.

Often = 5 points

Sometimes = 3 points

Seldom = 1 point

Visual		Auditory		Kinesthetic	
No.	Pts.	No.	Pts.	No.	Pts.
2		1		4	
3		5		6	
7		8		9	
10		11		12	
14		13		15	
16		18		17	
19		21		20	
22		24		23	
25		27		26	
Visual Preference Score:		Auditory Preference Score:		Kinesthetic Preference Score:	

Appendix T

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 U

Introductory Letter



**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/01/07

NOVEMBER 28, 2022

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

INTRODUCTORY LETTER FOR MR. KENNETH ATEKO DARKO

We write to introduce Mr. Kenneth Ateko Darko, who is an M.Phil. (Science Education) student of this Department. Mr. Darko is working on a project titled "A comparative effect of the 5e instructional model and differentiated instruction on the academic performance of senior high school physics students in the Ashanti Region, Ghana" 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
AKENTEN APPIAH-MENKA
UNIVERSITY OF SKILLS TRAINING & ENTREPRENEURIAL DEV'T
MAMPRONG ASHANTI



www.aamusted.edu.gh

✉ dise@aamusted.edu.gh

Appendix V

Formula for Eta Squared

$$\text{Eta Squared} = \frac{t^2}{t^2 + (N1 + N2 - 2)}$$

Where N1 = Number of students in group 1

N2 = Number of students in group 2

t = calculated t-value

Source: (Pallant, 2011)