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Research Article

Exploring Effective Approach to Teaching Thermal Physics: Comparing 5E Model, Differentiated Instruction and Conventional Teaching

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Abstract
In this study, the effects of 5E Instructional Model (5E), Differentiated Instruction (DI) and conventional teaching method on Senior High School (SHS) physics students' academic performance in Thermal Physics were compared. Method: By employing a quasi-experimental pretest/posttest non-equivalent control group design, 291 SHS 2 physics students were used from six intact classes which were randomly selected from three SHSs in the Mampong Municipality and Sekyere South District. The hypotheses were tested using one-way ANCOVA and two-way ANCOVA at $\alpha=0.05$. The results showed that there was a significant effect of at least one of the teaching methods on the academic performance of students ($F(1,287)=150.766$, $p=0.001<0.05$), with students taught using DI obtaining the highest adjusted mean scores of 18.978 (std. error = 0.437), followed by those taught using 5E group (adjusted mean = 16.373, std. error=0.430), and those taught using the conventional teaching method (adjusted mean score = 13.734, std. error = 0.452). Also, there was a significant interaction between gender and teaching method ($F(1,284)=241.395$, $p=0.001<0.05$) with no significant difference observed between male and female students taught using DI (mean difference=0.233, $p=0.765$) and 5E (mean difference=0.75, $p=0.532$), but a significant difference in academic performance between male and female SHS students taught using conventional teaching method (mean difference=8.284, $p=0.000$). It was therefore recommended, amongst others, that SHS physics teachers in Mampong Municipality and Sekyere South District should consider differentiating their students in order to tailor Thermal Physics lessons to all students, which will help them perform better.

Keywords: 5E Instructional Model, Conventional Teaching Method, Differentiated Instruction, Gender, Thermal Physics

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1. INTRODUCTION

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, of which physics is no exception. Thermal Physics is studied as one of the major concepts in the Ghanaian Senior High School (SHS) physics curriculum (Ministry of Education, 2023). 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).

Considering the relevance of Thermal Physics, it is expected that the academic performance in the subject would be on the increase. Contrary to this, 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 Examination 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).

Furthermore, in their study, Appiah-Twumasi et al. (2021a) 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 in the Ashanti Region of Ghana regarding Thermal Physics, was observed to be 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 final year physics students in their mock exams, failed to attempt questions related to Thermal Physics, while the few students who attempted struggled to provide appropriate answers. It is therefore necessary 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.

According to the Organisation for Economic Cooperation and Development (OECD), classroom atmosphere has an impact on students' learning outcomes (OECD, 2018). This is evident in Ghana, as studies (Assem et al., 2023; Azigwe et al., 2016; Bonney et al., 2015; Kwaah & Palojoki, 2018) reveal the poor academic performance students demonstrate in physics as a result of inappropriate instructional methods employed by teachers. As part of the philosophy of the Ghanaian standard-based curriculum, it is stipulated that students should be actively involved in the learning process in learner-centered classrooms as a result of teachers using "appropriate" planning and classroom management strategies (Ministry of Education, 2023). This means that not all teaching methods are suitable in teaching every concept as Heinich et al. (2002) and Marcourt et al. (2022) argue. 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 (5E) (Bybee, 2018) and Differentiated Instruction (DI) (Tomlinson et al., 2003).

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. Each stage serves a particular purpose and aids in the development of students' comprehension of scientific and technological information, attitudes, and skills (Bybee et al., 2006). At this engagement stage, 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 and interested in a new idea (Ahmad et al., 2018; Bybee, 2018). In the exploration phase students are given a shared set of tasks through exploratory experiences (guided inquiry activities), which allow for the identification of present concepts, which may be misconceptions or alternative conceptions, processes, and skills as well as the facilitation of conceptual change (building new explanations that make sense to them) (Ünlü & Dökme, 2022). During the explanation phase, students are given the chance to demonstrate their conceptual knowledge, communication skills, or behaviors through expression of their understanding of concepts (Muhammad et al., 2019). 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). 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 of concepts through formative or summative assessment techniques, is used to assess the knowledge and skills they have acquired (Appiah-Twumasi et al., 2021b).

DI is also another learner-centered approach to teaching, which can be thought of as the modification of teaching and learning strategies, to address a range of learners' characteristics such as readiness levels, interests, and learning styles, where teachers proactively alter curricula, teaching strategies, resources, learning activities, and student work to meet the varied needs of individual students in order to maximize each student's learning opportunities in a classroom (Tomlinson et al., 2003). In Differentiating an instruction, Tomlinson et al. (2003) suggested five key elements that are differentiated in the classroom, and they include content, process, product, affect, and learning environment.

The content is the knowledge students need to acquire in the classroom including concepts, generalisations, principles and skills (Awofala & Lawani, 2020). 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 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 using a variety of assessment tools (Thakur, 2014). The "affect" refers to feelings and affections that are a result of a concept or experience (Sönmez, 2017), while the learning environment is described by Kótay-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. Thus, the flexible organisation of time, resources, and space in the classroom, as well as the atmosphere therein, make up the learning environment (Awofala & Lawani, 2020).

These elements are differentiated according to the students' characteristics which are readiness, interest and learning styles (Kotob & Abadi, 2019). 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. The interest, according to Awofala and Lawani (2020) refers to topics that evoke a student's attention, involvement and curiosity. That is, what a student finds engaging to study about, contemplate, and do; and the learning style is a student preferred mode of learning (Brunello & Brunello, 2022), that is either auditory, visual, kinesthetic; and verbal (Şener & Çokçalışkan, 2018).

In this study, the moderating effect of gender on 5E, DI, and the conventional teaching method was examined. The selection of this variable was made because there exists 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 females, as well as enhancing their performance in physics and other physics-related fields, it is necessary, as Babajide and Folasade (2013) and Kalender et al. (2019) suggested, to test teaching approaches, which maintain gender-neutral classroom environment.

A review of literature revealed the effectiveness of employing 5E over the conventional teaching method, which is supported by studies conducted by Appiah-Twumasi et al. (2021b), Sam et al. (2018) and Bunkure (2019), who showed that the application of the 5E improves retention, motivation, knowledge transfer and sustains learners' interest in the teaching and learning process. Also, research has shown that DI affects learners' academic performances positively more than the conventional teaching method, as revealed by studies conducted by Kotob and Abadi (2019), Awofala and Lawani (2020), Kamran et al. (2019), and Nurasiah et al. (2020). However, comparing 5E, DI and the conventional teaching method presents a gap in the existing literature, particularly in the Ghanaian context. Salar and Turgut (2021) in Turkey however, compared DI and 5E in three different schools with different backgrounds with respect to courses offered. Salar and Turgut (2021) discovered that both the 5E and DI were equally effective in schools where science lessons dominated the curriculum. However, in schools where science and social science courses were equally distributed, as well as in those with a greater emphasis on social science courses, DI proved to be more effective. This study therefore extends Salar and Turgut's (2021) study by adding the conventional teaching method to the comparison focusing on the concept of Thermal Physics, since studies such as Heinich et al. (2002) and Marcourt et al. (2022) argue that not all teaching methods are suitable for every concept regardless of it being student-centered or teacher-centered. Also, to support the global quest of gender equity and equality in academic performance, which is still lacking in physics as revealed in the preceding paragraph, this study extends existing studies by ascertaining the differential effect of 5E, DI, and conventional teaching method on gender. Filling these gaps will inform physics educators about the appropriate instructional approach which must be employed in order to maximise the academic performance of physics students in the teaching and learning of Thermal Physics. Based on the gaps identified, this study sought to test the following null hypotheses;

H_{01}: There is no significant difference in academic performance between SHS physics students taught Thermal Physics using 5E Instructional Model, Differentiated Instruction and conventional teaching method.

H_{02}: There is no significant difference in academic performance between male and female SHS physics students taught Thermal Physics using at least one of 5E Instructional Model, Differentiated Instruction, and conventional teaching method.

2. METHODS

2.1. Research Design

This study is situated in the positivist paradigm, which emphasises the collection and analysis of quantitative data to arrive at a conclusion. Therefore, the quasi-experimental pretest/posttest non-equivalent control group design was employed. With this design, six intact classes were selected from three different schools, and assigned experimental and comparison groups.

2.2. Participants

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 the study areas, since the Thermal Physics concepts considered in this study were studied in SHS 2 (Ministry of Education, 2023). Multi-stage sampling technique was employed to select a sample of 291 SHS 2 physics students from three different schools, where two intact classes were selected from each school. Thus, purposive and simple random sampling procedures were used to select participating schools and intact classes respectively. Students in the same school were exposed to the same teaching method to reduce diffusion of treatment (Cohen et al. 2018). In effect, there were a total of 181 males and 110 females who participated in the study.

2.3. Research Instruments

The research instrument used in collecting data was an achievement test named Thermal Physics Concept Test (TPCT). This instrument which was prepared by the researchers, and was used as pretest and posttest, comprised multiple-choice items and open-ended items, from the concepts of heat, temperature and its measurement, thermometers, thermometric substances, thermal expansion and heat transfer. Therefore, in scoring the test items, the multiple-choice items were scored dichotomously, while the open-ended items were scored polytomously.

2.4. Validity and Reliability

Face validity and content validity were employed to determine the validity of the TPCT. Thus, the TPCT was given to a panel of six physics educators (experts), as recommended by Lynn (1986), who were invited to evaluate the items in the TPCT to assess their accuracy, and ability to measure the academic performance of SHS physics students, and when needed, offered insightful critiques. The information gathered from the physics educators (experts) helped to revise, delete, or substitute inappropriate items. After the evaluation of the TPCT by the experts, the content validity of the TPCT was evaluated using the ratings by the experts to determine the Content Validity Ratio (CVR), an item statistic proposed by Lawshe (1975). The CVR for the TPCT was 0.954. According to Obilor and Miwari (2022), the closer the CVR is to 1, the higher the overall content validity of a test instrument, rendering the TPCT a valid instrument. The reliability analyses, specifically internal consistency of the scores from a pilot study was statistically assessed using Cronbach alpha coefficient, for the multiple-choice section, and inter-rater reliability using Cohen's kappa for the open-ended section. An alpha value of 0.808 and a kappa value of 0.780 (p=0.000) were obtained. These values rendered the scores from the pilot test reliable (Pallant, 2011), and the instrument deemed sufficient to be used in the study.

2.5. Procedures

The various groups (experimental and comparison groups) were instructed in the Thermal Physics using the same content but different treatments (teaching methods). The intervention phase lasted for eight weeks. The treatment of each teaching method to respective groups was done by in-service teachers who were given training on the implementation of the various teaching methods. Tables 1, 2 and 3 highlight how the various teaching methods were used to teach the Thermal Physics concepts to each group.

Table 1. Activities for 5E 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 teaching and learning resources 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 understanding.
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 ideas and experiences by using thermal physics terminologies	Applied definitions, fresh knowledge, and conclusions to related thermal physics situations.	Broader understanding thermal physics 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.

In the DI group, prior to the treatment of the teaching method, first steps were taken to administer students' interest inventory adopted from Shumow and Schmidt (2013) as well as learning style questionnaire, also adopted from Bright (2006), 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 2.

Table 2. Activities for DI 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.

Element of Differentiation	Students' Characteristics	Activities
Process	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 gender groups.
	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.
Product	Learning Profile	Gave students the choice to express what they learned.
		Blended independent and collaborative works.
	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	Students worked independently or in groups on assignments and exercises.

Teaching method introduced to the conventional group was predominantly teacher-centered, as presented in Table 3.

Table 3. 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 into their notebooks.
Stage 3 Application	The teacher gave students in-class examples and questions to solve.
Stage 4 Evaluation	The teacher used both formative and summative assessment techniques to determine the achievement of lesson objectives.

2.6. Ethical Procedures

Ethical practices such as confidentiality and anonymity were ensured, as well as the seeking of informed consent from students to willingly participate without any punitive action upon withdrawal or non-participation.

2.7. Data Analysis

Statistical methods used for data analyses in this study were one-way between groups analysis of covariance (one-way ANCOVA) to test hypothesis 1, and two-way analysis of covariance (two-way ANCOVA) to test hypothesis 2 using version 26 of the Statistical Package for Social Sciences (SPSS). The hypotheses were tested at 0.05 level of significance. 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).

3. RESULTS

3.1. Testing of Hypothesis 1

With the pretest scores as covariate, Hypothesis 1 was tested using one-way ANCOVA on the posttest scores of Thermal Physics Concept Test (TPCT) for 5E, DI and the conventional groups at an alpha level of 0.05, after ensuring non-violation of assumptions for one-way ANCOVA. The results are presented in Table 4.

Table 4. One-Way ANCOVA on Posttest Scores for All Groups

Source	df	F	p	Partial Eta Squared
Pretest	1	150.766	.001	.344
Teaching Method	2	34.752	.001	.195
Error	287			

df – degrees of freedom

As indicated in Table 4, the effect of the pretest scores on the posttest scores was significant ($F_{(1,287)}$=150.766, p=0.001<0.05) with a large effect size (Partial Eta Squared) of 0.344 (Pallant, 2011). Thus, after controlling for the effect of the pretest scores on the posttest scores, there was a significant difference in posttest scores among the three groups ($F_{(2,287)}$=34.752, p=0.001<0.05), with a partial eta squared of 0.195, which according to Pallant (2011), is a large effect size. As a result, we fail to accept the null hypothesis. The significant effect of teaching method on the posttest scores warranted a post-hoc test to be conducted to ascertain between which groups do the significant difference lay. The results of the post-hoc analysis are presented in Table 5.

Table 5. Post-hoc Analysis for One-Way ANCOVA on Posttest Scores for All Groups

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
5E	DI	-2.605*	.613	.001	-3.811	-1.398
	Conventional	2.639*	.625	.001	1.409	3.869
Conventional	DI	-5.243*	.629	.001	-6.482	-4.005

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

DI – Differentiated Instruction

As shown in Table 5, the post-hoc analysis revealed a significant difference in adjusted posttest mean scores between 5E group and DI group (mean difference = 2.605, p=0.001). Also, there was a significant difference in adjusted posttest mean scores between 5E group and conventional group (mean difference = 2.639, p=0.001), and between DI group and conventional group (mean difference = 5.243, p=0.001). Also, Table 5 indicates that the post-hoc analysis was based on the estimated marginal means also known as adjusted mean scores. Therefore, the adjusted mean scores are presented in Table 6.

Table 6. Adjusted Posttest Mean Scores for All Groups

Group	Adjusted Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
5E	16.373[a]	.430	15.526	17.220
DI	18.978[a]	.437	18.118	19.837
Conventional	13.734[a]	.452	12.845	14.623

a. Covariates appearing in the model are evaluated at the following values: Pretest = 5.89.

The results as indicated in Table 6 reveals that after controlling for the effect of the pretest on the posttest scores, students taught using Differentiated instructed obtained the highest adjusted mean score of 18.978 (std. error = 0.437), followed by 5E group (adjusted mean = 16.373, std. error=0.430). Table 6 shows that students taught using conventional teaching method obtained the least adjusted mean score of 13.734 (std. error = 0.452).

3.2 Testing of Hypothesis 2

Hypothesis 2 aimed to determine any significant difference in academic performance between male and female SHS physics students within 5E, DI, and the conventional groups. A 2 by 2 between-groups analysis of covariance (two-way ANCOVA) was conducted at an alpha level of 0.05, and the results are presented in Table 7.

Table 7. Two-Way ANCOVA of Male and Female SHS Physics Students Within All Groups

Source	df	F	p	Partial Eta Squared
Pretest	1	241.395	0.001	0.459
Teaching Method	2	61.669	0.001	0.303
Gender	1	35.771	0.001	0.112
Teaching Method * Gender	2	37.444	0.001	0.209
Error	284			

Table 7 reveals that the effect of the pretest scores was significant ($F_{(1,284)}=241.395$, $p=0.001<0.05$), with a large effect size of 0.459 (Pallant, 2011). However, after adjusting for pretest scores, there was a significant interaction ($F_{(2,284)}=37.444$, $p=0.001<0.05$), with a large effect size (partial eta squared=0.209). Therefore, it can be said that there was not enough evidence to accept the null hypothesis. The interaction between teaching method and gender can further be inspected graphically by a plot of estimated marginal means for the posttest scores of the TPCT, split for males and females and for the three teaching methods as shown in Figure 1.

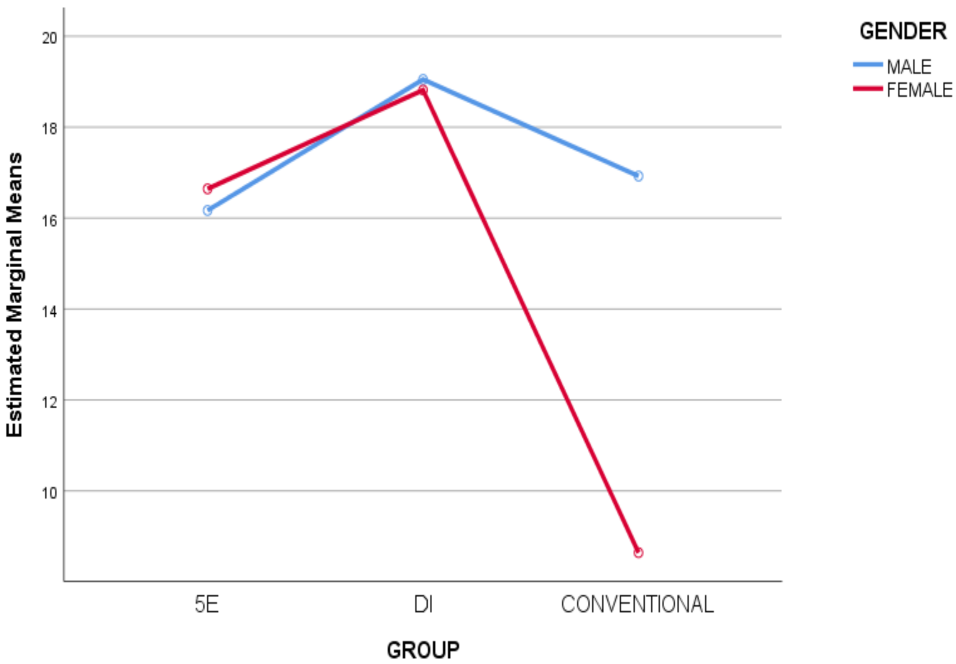

Figure 1. Estimated Marginal Means Plot of Posttest Scores of the TPCT for Male and Female SHS Physics Students for 5E, DI, and Conventional Groups

It can be seen from Figure 1 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 8, which shows the adjusted means for male and female SHS physics students within all groups.

Table 8 reveals that after controlling for the effect of the pretest scores on the posttest, SHS male physics students within the 5E 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 DI 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).

Table 8. Adjusted Posttest Mean Scores of Male and Female SHS Physics Students

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

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, 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 by dividing the level of significance, 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 9 are less than 0.0167. The results of the simple effect analysis are presented in Table 9.

Table 9. Simple Effect Analysis of Posttest Scores of Male and Female SHS Students

Group	(I) Gender	(J) Gender	Mean Difference (I-J)	Std. Error	Sig.[b]
5E	Male	Female	-0.475	0.759	0.532
DI	Male	Female	0.233	0.777	0.765
Conventional	Male	Female	8.284*	0.802	0.001

Based on estimated marginal means.
*p< 0.0167
b. Adjustment for multiple comparisons: Bonferroni.
5E- 5E Instructional Model
DI – Differentiated Instruction

As revealed in Table 9, 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 group (mean difference=0.75, p=0.532) and DI group (mean difference=0.233, p=0.765). However, it can be observed from Table 9 that the difference between male and female SHS physics students in the conventional group was significant (mean difference=8.284, p=0.001).

4. DISCUSSION

This study sought to explore an effective approach to teaching Thermal Physics in The Ghanaian SHS teaching context by comparing 5E, DI and conventional teaching method. In this study, it was found that after exposure to the treatments, there was a significant difference in posttest scores between students exposed to 5E, DI and conventional teaching method. Specifically, students taught using DI performed best, followed by students exposed to 5E. Students exposed to the conventional teaching method performed least. This indicates that compared to 5E and the conventional teaching method in the teaching and learning of Thermal Physics, the use of DI seemed to enhance students' performance most. This finding thus extends previous finding in existing literature (Salar & Turgut, 2021) by providing evidence to support the appropriate teaching method amongst 5E, DI and the conventional teaching method that can be employed in the teaching and learning of Thermal Physics. However, Salar and Turgut (2021) revealed that both the 5E and DI were equally effective in schools where science lessons were predominant. However, DI proved to be more effective in schools with an equal distribution of science and social science courses, as well as in schools where social science courses predominated.

According to Ismajli and Imami-Morina (2018), DI offers different entry points into complicated topics, teachers can adapt their instruction to meet the needs of students with varying levels of difficulty. Therefore, through personalised challenges and support for various learning styles, prompts, as well as targeted feedback, this approach encourages engagement. Also, Thermal Physics and the 5E's emphasis on experiential learning and organised learning phases are complementary. Through experiments, the 5E allows students to actively participate in the instructional process, fostering critical thinking and a greater comprehension of ideas (Bybee, 2019) like conductivity and thermal energy transfer. However, with the conventional teaching method, while familiar and structured, fell short in engaging students deeply in Thermal Physics. Without the personalised and hands-on elements found in DI and 5E, these traditional approaches, according to Appiah-Twumasi (2020), might struggle to convey the abstract nature of thermal concepts effectively.

Moreover, this study revealed that gender did not have any significant effect on the use of both 5E and DI, while gender had significant effect on the use of the conventional teaching method. Similar to previous findings, Appiah-Twumasi et al. (2021b) found that 5E significantly reduced 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, even after controlling for the effect of pretest on the posttest scores. With regards to using DI, 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 in Mathematics.

Researchers such as 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. Likewise, the use of 5E 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 DI, 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.

The findings of this study have added to the body of knowledge in education and pedagogy by providing evidence to support the employment of appropriate teaching method in the teaching and learning of Thermal Physics, especially in the Ghanaian SHS context. Since the literature revealed diverse difficulties exhibited by Ghanaian students in Thermal Physics, though the syllabus (Ministry of Education, 2023) advocate for active participation of students, employing the appropriate teaching method can help maximise the performance of students in Thermal Physics. Also, with the global quest to bring gender equity and equality in the field of physics, this study's findings have provided evidence to support the need for adopting gender-friendly teaching approach leading to equivalent levels of performance.

5. CONCLUSIONS

The study set out to explore the most effective teaching approach for enhancing SHS students' academic performance in Thermal Physics, comparing 5E, DI, and conventional teaching method. In line with the first null hypothesis stated in this study, the findings revealed a significant difference in academic performance among the students taught using the three approaches. Specifically, DI emerged as the most effective instructional method, outperforming both the 5E and conventional teaching.

Regarding the second null hypothesis, which examined potential gender-based differences in academic performance, this study's findings demonstrated that both the 5E and DI contributed substantially to minimising the gender gap in student outcomes. In contrast, the conventional teaching method did not have a similar effect, showing limited success in bridging gender disparities.

Thus, it can be concluded that DI holds significant potential for improving students' performance in Thermal Physics within Mampong Municipality and Sekyere South District, while both 5E and DI show promise in promoting gender equity in academic performance in Thermal Physics.

In this study, the use of intact classes, though necessary, posed a limitation in the form of non-randomised group assignments, which required careful consideration in the interpretation of the results. Nonetheless, this approach ensured ecological validity, as the study was conducted in natural classroom environments.

One of the key challenges faced during the study was ensuring that all teachers involved in the implementation of the instructional methods adhered strictly to the lesson plans designed for each method. To mitigate this, regular observations and feedback sessions were incorporated to maintain consistency and fidelity across the different instructional groups. Furthermore, decisions regarding the selection of districts (Mampong Municipality and Sekyere South District) were influenced by the need to capture a diverse student population while maintaining logistical feasibility. This ensured that the study's findings could be reasonably generalised to similar educational contexts.

Despite these challenges, the rigorous approach to data collection and analysis ensured the validity of the results, and the findings contribute meaningfully to the body of knowledge on effective teaching strategies in the teaching and learning of Thermal Physics.

6. RECOMMENDATIONS

From the findings and conclusions of this study, it is recommended that physics teachers in Mampong Municipality and Sekyere South District should be encouraged to regularly differentiate their lessons in order to achieve better students' performance in Thermal Physics. Also, differentiating their lessons, as well as employing 5E could provide the solution to SHS physics teachers in the Mampong Municipality and Sekyere South District to assist male and female students perform at equivalent levels in the teaching and learning of Thermal Physics. Furthermore, although this research was focused on Thermal Physics, it would be valuable to investigate whether the 5E and DI are equally effective when applied to other topics in physics. Moreover, comparative studies across various physics topics could provide a more comprehensive understanding of the broader applicability of these methods. In addition, while this study focused on quantitative measures of academic performance, future research could adopt qualitative methods to provide deeper insights into students' perceptions and experiences with the 5E, DI, and the conventional teaching method. This approach would allow researchers and educational stakeholders to gain a more nuanced understanding of how students experience learning under different instructional methods, as well as providing information about why certain teaching methods are more effective for certain groups of students.

7. LIMITATIONS

The study was delimited to only SHS 2 physics students in Mampong Municipality and Sekyere South District. Also, because the participants in each group were not randomly selected, the sample may not fully represent all SHS 2 physics students, making it difficult to confidently generalise the findings beyond Mampong Municipality and Sekyere South District. Accordingly, generalisations of the findings from this study were made with extreme caution.

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