European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available online at: www.oapub.org/edu

DOI: 10.46827/ejes.v13i7.6733 Volume 13 | Issue 7 | 2026

THE INFLUENCE OF 5E INSTRUCTIONAL MODEL ON SENIOR HIGH STUDENTS' PERFORMANCE IN STEREOISOMERISM IN BOLGATANGA AREA, GHANA

Kolani Nyamekye[1],
Abdullai Abukari[2i]
[1]Teacher,
Berekum Senior High School
Berekum, Bono Region,
Ghana
[2]Associate Professor,
University of Technology and Applied Sciences,
Department of Sciences Education,
School of Science, Mathematics and Technology Education,
Navrongo, Upper-East Region,
Ghana

Abstract:
This study investigated the effectiveness of the 5E instructional model in improving Senior High School students' performance in stereoisomerism in the Bolgatanga area of Ghana. The study was motivated by persistent poor performance in organic chemistry, particularly stereoisomerism, due to the continued use of teacher-centred instructional approaches with limited student participation. A quasi-experimental research design involving non-randomized pre-test and post-test control groups was employed. The study was conducted with 150 purposively selected SHS 2 science students from four selected public Senior High Schools in the Bolgatanga Municipal, Bolgatanga East, and Talensi Districts. Data were collected using self-constructed questionnaires, chemistry achievement tests, and observation checklists. The instruments were validated by experts in science education, while reliability coefficients of 0.81, 0.80, and 0.84, respectively, were obtained through pilot testing. Data were analysed using descriptive statistics (means and standard deviations) and inferential statistics (independent sample t-test and one-way ANOVA). The findings revealed that chemistry teachers largely rely on traditional lecture methods in teaching stereoisomerism. Students taught using the 5E instructional model performed significantly better in conceptual understanding, knowledge application, and skills development than students taught using the lecture method. The study concluded that the 5E instructional model is more effective for teaching stereoisomerism than the traditional lecture approach. It is therefore recommended that

[i] Correspondence: email kolaninyamekye1990@gmail.com, mabukari@utas.edu.gh

chemistry teachers adopt the 5E instructional model and other inquiry-based strategies to improve students' understanding and practical skills in organic chemistry.

Keywords: 5E instructional model, stereoisomerism, inquiry-based learning, chemistry education, Ghana, senior high school

1. Introduction

The significance of chemistry in industries, economies, and society in general is immense, as our day-to-day life largely revolves around chemistry (Amir, 2021). Chemistry is applied in many facets of life and is considered the center of science (Grosche & Peter, 2013). In Ghana, where the petroleum and petrochemical industries provide the majority of the country's wealth, the value of chemistry in growing any country cannot be overstated (Aponsah, 2014). Chemistry is a field of study that examines the compositions, structures and characteristics of matter in various forms (Amir, 2021). Through the use of its principles in the contemporary world, chemistry has contributed to the advancement of current technology (Gomollon-Bel, 2019).

Even though chemistry plays a crucial part in being the center of science, stereoisomerism in organic chemistry is important in medicine and the biochemical industry in improving the quality of life, as in all other related topics in organic chemistry (Rohan, Maaz, & Karan, 2021). Again, it helps in developing prospective teachers' and students' cognitive understanding of organic chemistry, which is very important in 3D structures and chirality (Ping, Church, & Larson, 2021). Bruke (2017) emphasised that it is taught in a variety of disciplines such as biochemistry, pharmacy, biotechnology, and molecular biology courses in addition to organic chemistry.

Furthermore, the precision in stereoisomerism concepts is the foundation for a thorough comprehension of the interaction between a pharmacological molecule and the active site of a receptor or enzyme. Hence, the performance of Ghanaian SHS students in the subject has remained a major source of concern for many years.

Studies by Adu-Gyamfi (2013) and Tajudeen (2015) have reported that, despite being an essential component of science education, chemistry is typically difficult for students to comprehend. The primary limiting problem in Ghanaian students' chemistry education, according to Hanson (2016), is their incapacity to comprehend and represent abstract matter. Most of the time, students are unable to fully comprehend these depictions of stereoisomerism in organic chemistry, which results in a flawed and inadequate foundation for future research on events that alter the composition of substances and their chemical characteristics (Boakye & Ampiah, 2017).

Taber (2018) reported that science students find it challenging to conceptualize the chemistry aspect of science education and perform poorly as a result. Furthermore, students' practical performance is also affected. Partly, the problem is associated to difficulty in understanding the language and hence the difficulty in grasping the concepts and performing well in exams (Charles *et al.*, 2023). Also, the problem has been linked to the fact that students engage in rote learning, which limits conceptual understanding and practical skills (Eurasia, 2017).

The focus of the study is stereoisomerism, which is defined as the field of organic chemistry dealing with molecular structures in three dimensions (Bruice, 2016). Studying stereoisomerism requires the use of specific stereochemical terms, visualization of structures or models (Jack, 2024). Since stereoisomerism is seen as a challenging concept, there have been more studies in recent years that address teaching stereochemical subjects like stereoisomerism. The difficulties are often linked to the rotation and reflection of structures and 3D visualisation (Burrmann & Moore, 2013; Knowles, 2017).

Again, the approach does not encourage the promotion of rote learning among science students, which tends to result in dwindling students' interests in the subject and consequently abysmal performance in organic chemistry as far as stereoisomerism is concerned. On the effect of positive chemistry achievement, creative teaching techniques must be introduced and appropriately implemented, such as the 5E instructional model (Bybee & Ruiz-Martin, 2022). Ajaja and Eravwoke (2013) investigated how well the learning model worked to raise students' performance in science classes, particularly chemistry and physics. The study's findings demonstrated that the learning model helped students learn efficiently and meaningfully arrange their scientific knowledge. Additionally, it was discovered to help students retain their knowledge over time and improve their ability to apply it in contexts other than the original one. The model helped in planning chemistry instruction that improves conceptual understanding, application and practical skills. This study investigated the effectiveness of the 5E instructional model in stereoisomerism instruction amongst SHS students in the Bolgatanga area.

Ameyaw (2015) examined how the 5E instructional approach affects SHS students' understanding of cellular respiration at Odorgonno SHS in Accra. The two concepts were presented to the 80 students in a quasi-experimental design. The examination of the two cohorts' post-interventional scores showed that, in terms of conceptual understanding, the treatment group did better. The 5E method was found to be an effective method for facilitating teaching on glycolysis and the Krebs cycle (Ameyaw, 2015).

In addition, research by Duran and Dökme (2016) in a sixth-grade secondary school in Turkey found that compared to students who were taught using lecture methods, the inquiry-based group method had a positive influence on their skills of critical thinking and accomplishment. According to Duran and Dökme (2016), the experimental group's critical-thinking skills and scores were significantly higher than those of the control group.

Correspondingly, Fletcher (2011) looked at the effects of the 6E instructional approach and found that learners who got the 6E approach teaching outperformed those who got the 5E instruction. These outcomes demonstrated that students do, in fact, significantly improve their science knowledge when using the 6E style of education.

Similarly, Abdi (2014) conducted research and discovered that children who received inquiry-based instruction outperformed those in lecture classrooms in terms of academic achievement. Throughout the study, 20 female students served as the treatment group, and 20 female students served as the control. While the control group learned a lesson through direct instruction and traditional teaching methods, the experimental group engaged in inquiry-based learning. Academic achievement pre-tests were given at the start of the study by Abdi (2014).

Akar (2005) contrasted the impact of standard chemistry training on students' grasp of acid-base concepts with instruction based on the 5E instructional approach. In the spring 2003-2004 semester at Atatürk Anatolian High School, 56 tenth graders participated in the study. While students in the control group got standard chemistry education, those in the treatment group received training based on the 5E method. Understanding Acid-Base Principles. To determine how well students understand the concepts of acid-base, both groups took the exam as a pre-test and post-test. The results revealed that the 5E group significantly got a better acquisition of the topics and produced a higher level of favourable chemistry attitudes as a subject when compared to instruction that was conventionally designed (Akar, 2005).

The 5E model, which consists of five phases: Engage, Explore, Explain, Elaborate, and Evaluate, serves as the independent variable. It is a constructivist teaching strategy designed to actively involve students in the learning process, fostering deeper understanding and retention of concepts (Hanson, 2016).

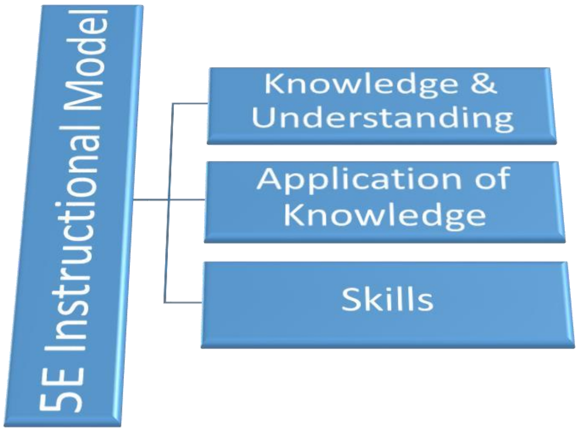
Through the Engage phase, students' prior knowledge is activated, capturing their interest and preparing them for new learning experiences. The Explore phase allows them to investigate stereoisomerism concepts through hands-on activities, promoting discovery-based learning. In the Explain phase, students clarify their understanding with teacher guidance, reinforcing their conceptual grasp. The Elaborate phase enables them to apply their knowledge to new and complex problems, strengthening comprehension and critical thinking. Finally, the Evaluate phase assesses their understanding through both formative and summative assessments, ensuring learning outcomes are met (Ruiz-Martin & Bybee, 2022).

The dependent variable, students' performance in stereoisomerism, is measured in three dimensions: knowledge acquisition, knowledge application, and skills demonstration.

Knowledge acquisition refers to students' understanding of fundamental stereoisomerism concepts, such as chirality, enantiomers, and diastereomers, while knowledge application involves the ability to use these concepts in problem-solving, including identifying and differentiating between stereoisomers. Skills demonstration reflects students' ability to use molecular models, visualize three-dimensional structures, and explain spatial arrangements, which are critical in understanding stereochemistry (Ping *et al.*, 2021).

However, the effectiveness of the 5E instructional model in improving students' performance may be influenced by other variables such as students' prior knowledge and cognitive ability, as those with a stronger foundation in chemistry may respond more effectively to the instructional approach. Also, the teacher's instructional effectiveness plays a crucial role in determining how well the 5E model is implemented, affecting students' engagement and comprehension. Lastly, classroom environment and availability of learning resources, including molecular models and interactive tools, may also impact students' ability to grasp stereoisomerism concepts (Myers, 2021).

The 5E model is a well-known variation of inquiry-based learning models that aims to capture students' interest and reveal their past knowledge of the concept, while giving the teacher a chance to evaluate their progress and giving the students a chance to consider their newly acquired knowledge. For example, chemistry teachers should have a high mastery level to use 5E instructional models alongside the concept models to elaborate more on stereoisomerism in geometric (or cis-trans) isomerism (Ruiz-Martin & Bybee, 2022).



2. Method

2.1 Research Design

This study used a quasi-experimental design, utilizing the nonrandomized control group pre-test–post-test design type. In a quasi-experimental research design, there is no provision for full control of potential confounding variables. Since participants cannot be randomly allocated to groups, complete control cannot be obtained (Lichtman, 2013). This is evident in the case of a typical school setting. It will not be proper to disrupt the educational environment while wanting to conduct a research study, thus intact classes are advised for research rather than choosing kids at random to participate in different groups (Leedy *et al.*, 2019). The quasi-experimental design for this study is shown in Table 3.1 below. A pre-test (O1 and O3) was given to participants to measure their cognitive abilities in groups 1 and 2. Thereafter, the treatment/intervention X was administered to the participants who constituted the experimental group whiles the control group participated in a conventional teaching approach. A post-test (O2 and O4) was again administered after administering the 5E intervention.

Table 1: Study Design

Grouping	Pre-test	Treatment	Post-test
Experimental group	O_1	X	O_2
Control group	O_3	X	O_4

2.2 Population

The study's population included a group of Senior High School science students from whom the research sought information and knowledge on the 5E IBL. The principal group of population of interest consisted of those individual science students in the following schools such as Bolgatanga Girls Senior High, Zuarungu Senior High, Zamse Senior High Technical, Tongo Senior High Technical, Gambibgo senior High, and Bolga Sherigu Senior High School that the researcher sought to understand and through which the findings were generalized (Casteel & Bridier, 2021). Population-generated barriers that defined the scope of the study and provided environmental and background signals for the researcher. These barriers placed a boundary line upon the research and gave the researcher the proper focus on the target population so as not to present a one-size-fits-all set of results (Casteel & Bridier, 2021). The principal group of the population for this study included all 4 selected public SHSs in the Bolgatanga area (Bolgatanga Municipal, Bolgatanga East and Talensi District). The target population for the study included 246 SHS 2nd-year science students. One hundred and fifty (150) participants were purposively selected. The choice of these schools was based on their science background, proximity, and familiarity with the researcher, and it is worthy of note that these schools are among the best science schools in the Bolgatanga area, Upper East Region.

Table 2: Representation of populations and sample sizes of various selected schools

S/N	Schools	Populations	Sample sizes
1	A	72	44
2	B	46	28
3	C	62	38
4	D	66	40
Total		**246**	**150**

Source: Field Data (2025).

2.3 Sample, Sampling Techniques, and Sampling Procedures

A good sample is a strong statistical representation of the population of interest and is large and representative enough to answer research questions, and findings are generalized to the whole population (Majid, 2018). One hundred and fifty (150) participants from four selected senior high schools made up the sample size obtained from intact classes.

Sampling was considered an essential tool for the research since the whole population of interest consisted of too many science students for the research work to include all as participants. The research adopted purposive sampling techniques. These were used to obtain a representative sample from the population of interest for the study (Enticott *et al.*, 2017). Purposive sampling was used to intentionally select schools and science students and participating schools based on their features and qualities of the best science background, proximity, and familiarity with the researcher (Etikan, 2016).

2.4 Instruments

The researcher employed close-ended self-constructed questionnaires, chemistry achievement tests and observation checklists for data collection.

2.4.1 Questionnaire

A questionnaire consists of a series of questions posed to individuals within a sample population to obtain statistical usefulness and reliable information on a given topic (Roopa & Rani, 2012). When properly constructed and accountably administered, questionnaires become a useful instrument through which the researcher can make statements about the sample and the entire population (Roopa & Rani, 2012). The self-constructed questionnaire was chosen because of its simplicity in the language used, and it is effective in obtaining data from respondents in a short time span and could be completed by the respondents at their own convenience.

Moreover, it offered assurance of anonymity. The questionnaire was administered to 150 science students from four (4) schools selected. This questionnaire included items on teaching methods, students' conceptual understanding, skills acquisition, exploration, and application. This was on a four-point Likert measurement scale with options weighing as Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). The respondents were asked to tick the most appropriate option that applied to their case.

2.4.2 Chemistry Achievement Test

This was a pre-test and post-test conducted before and after the lecture method and the 5E method of instruction in stereoisomerism. The scores obtained from the tests were compared to measure the relative effect of the two methods on the performance.

2.4.3 Observation Checklist

This was used to evaluate the skills of participants, including inquiry skills, practical skills, application skills, and collaboration during and after the learning process.

3. Analysis of Demographic Information of Participants

Table 3 presents participants' data from four schools involved in the study. The total sample size was 150. The experimental group comprises 72 participants, with 44 from Bolgatanga Girls' SHS and 28 from Zamsec SHS, while the control group consists of 78 participants, with 38 from Bolgatanga SHS and 40 from Zuarungu SHS.

Table 3: Demographic information of participants

Groups	School	Bolga Girls' SHS	Zamsec SHS	Bolgatanga SHS	Zuarungu SHS	Total
	Experimental	44	28	-	-	72
	Control	-	-	38	40	78
Total		**44**	**28**	**38**	**40**	**150**

Source: Field Data (2025).

3.1 Analysis and discussion of results

Research Question 1: What are the Current Methods Being Used by Chemistry Teachers in Teaching Stereoisomerism

Table 4 presents responses on the current methods being used by Chemistry teachers for stereoisomerism instruction. This information was solicited from students' questionnaire on a 4-point Likert scale (SA=4, A=3, D=2, SD=1).

Table 4: Responses on teaching methods for stereoisomerism

	N		
The teacher passively explains the concept of stereoisomerism to learners in the classroom during lessons	150		.30
The teacher taught the concept of stereoisomerism to learners with little or no student participation in the classroom during lessons.	150	3.94	.33
During stereoisomerism lessons, the chemistry teacher is the sole centre of information	150	3.36	.65
The method employed during stereoisomerism by the chemistry teacher is solely on recalling answers or responses.	150	3.43	.73
The method employed by the chemistry teacher during stereoisomerism lessons does not involve students in discussions	150	3.35	.79
The method employed by chemistry teachers during stereoisomerism lessons does not permit students to demonstrate their knowledge or understanding of the concept.	150	3.00	.36
A chemistry teacher uses examples of real-life applications of stereoisomerism in hospitals and industries to illustrate stereoisomerism concepts.	150	1.74	.73
A chemistry teacher involves students in skill manipulation by using models in the classroom during stereoisomerism lessons	150	1.94	.98
The teacher engages in active discussions with learners in the classroom during stereoisomerism lessons.	150	1.45	.87
The teacher provides at least one (1) practice exercise in the classroom during the stereoisomerism lesson.	150	3.55	.49
The teacher uses visual aids such as videos for effective teaching during stereoisomerism lessons in the classroom.	150	2.04	.74
The teacher uses visual aids such as pictures effectively in teaching during stereoisomerism lessons in the classroom	150	1.95	.78
The teacher uses models effectively in teaching during stereoisomerism lessons in the classroom	150	2.04	.98
The teacher incorporates technology like simulations to improve understanding of stereoisomerism	150	1.46	.50
The teacher provides timely feedback through formative assessment of students' understanding of stereoisomerism	150	3.40	.69

The teacher integrates hands-on experiments or demonstrations related to stereoisomerism	150	1.84	.83
The teacher encourages critical thinking among learners related to stereoisomerism	150	1.80	.85
The teacher encourages problem-solving among learners related to the stereoisomerism lesson	150	2.20	1.07
The teacher motivates students to explore applications of stereoisomerism in real-world contexts through the manufacturing of drugs and reagents etc.	150	1.25	.43
The teacher assesses students' understanding of stereoisomerism through projects.	150	1.36	.48
Mean of Means		**2.45**	**0.69**

Source: Field Data (2025).

From Table 4, the statement, "The teacher passively explains the concept of stereoisomerism to learners in the classroom during lessons," received a mean score of 3.96 with a very low standard deviation (0.30), indicating strong agreement. Similarly, the statement, "The teacher taught the concept of stereoisomerism to learners with little or no students' participation in the classroom during lessons," also scored high (3.94 ± 0.33). Further, teachers appear to dominate the lessons as indicated by the statement "During stereoisomerism lesson, the chemistry teacher is the sole source of information" (3.37 ± 0.66).

Similarly, the responses indicate that the methods that emphasize rote learning without active student engagement are widely used by teachers in stereoisomerism instruction as evidenced by the statements, "The method employededed during stereoisomerism by the chemistry teacher is solely on recall answers or responses," (3.43 ± 0.74) and "The method employeded by the chemistry teacher during stereoisomerism lesson does not involve students in discussions" (3.35 ± 0.79). Limited opportunities exist for students to demonstrate understanding, as shown by "The method employed by the chemistry teacher during the stereoisomerism lesson does not permit students to demonstrate their knowledge and understanding of the concept" (3.00 ± 0.37).

Statements about "The teacher engages in active discussions of learners in the classroom during stereoisomerism lessons" and "The teacher involves students in skill manipulation by using models" show very low mean scores (1.45 ± 0.88 and 1.95 ± 0.98, respectively). This indicates minimal implementation of student-centred, participatory approaches. The integration of real-life examples is rare, as reflected in the low score (1.74 ± 0.74) for "Chemistry teacher uses examples of real-life application of stereoisomerism in hospitals and industries to illustrate stereoisomerism concepts".

In addition, visual aids, such as videos and pictures, are rarely used effectively in teaching stereoisomerism. Statements like "The teacher uses visual aids such as videos" and "The teacher uses visual aids such as pictures effectively" received low mean scores (2.04 ± 0.75 and 1.95 ± 0.79). Technology, like simulations, is poorly integrated, with "The teacher incorporates technology like the use of simulations" scoring 1.47 ± 0.50. Practical approaches like experiments or demonstrations are not frequently employed as suggested by the statement, "The teacher integrates hands-on experiments or demonstrations related to stereoisomerism" (1.84 ± 0.84). Again, teachers appear to neglect to foster higher-order thinking skills. The statements, "The teacher encourages critical thinking" and "The teacher encourages problem-solving among learners," received scores of 1.80 ± 0.85 and 2.21 ± 1.07, respectively.

The lowest scores were observed for "The teacher motivates students to explore applications of stereoisomerism in real-world contexts through the manufacturing of drugs and reagents, etc." (1.25 ± 0.44) and "The teacher assesses students' understanding of stereoisomerism through projects" (1.36 ± 0.48). This suggests a gap in connecting the topic to practical, real-world scenarios. Lastly, teachers provide some practice and feedback during lessons. Statements like "The teacher provides at least one (1) practice on exercises in the classroom during stereoisomerism lesson" (3.55 ± 0.50) and "The teacher provides timely feedback through formative assessment" (3.41 ± 0.70) scored relatively high, indicating moderate implementation.

The mean of means (M = 2.45), which is low compared to the standard mean value of (4) as indicated in the Likert scale. This implies that, on average, respondents exhibit a neutral to slightly negative perception of the current (traditional) teaching methods used for stereoisomerism. The score is below the midpoint (2.5) of the scale, indicating that while some aspects of the teaching approach may be somewhat effective, there are significant areas for improvement, particularly in actively engaging students.

The relatively low mean score suggests that passive teaching methods, such as teacher-centred instruction and recall-based learning, dominate the teaching of stereoisomerism, while student-centred approaches, interactive learning, and real-world applications are underutilized. This aligns with the lower scores observed for the use of models, technology, active discussions, and real-life applications, reflecting a lack of hands-on and participatory learning experiences in stereoisomerism lessons.

Research objective one sought to identify the current methods being used by chemistry teachers in teaching stereoisomerism. The responses in Table 4.2.1 indicate a strong reliance on teacher-centred, passive learning methods with limited student engagement and practical activities. Thus, chemistry teachers heavily depend on traditional, passive teaching methods, characterized by limited student interaction, critical thinking, and practical applications. Visual aids, technology, experiments, and real-world examples are underutilized, which may hinder effective understanding of stereoisomerism. These findings are consistent with the general practice at the national level (Hanson, 2016).

In Ghana, the teaching of isomerism in chemistry typically relies on traditional approaches such as lectures, chalk-and-talk methods, and textbook-based instruction. Teachers often introduce the concept by defining isomerism, categorizing it into structural and stereoisomerism, and explaining its subtypes such as chain, positional, functional group, geometric, and optical isomerism. Lessons are frequently supplemented by drawing molecular structures on the board and solving related problems to demonstrate the differences between isomers (Adu-Gyamfi *et al.*, 2017).

Practical sessions, though less frequent, are conducted in well-equipped schools where students can observe and compare the physical and chemical properties of isomers. However, in many schools, especially in rural areas, practical demonstrations are limited due to the lack of laboratory resources. This leads to a heavy reliance on rote memorization, which often fails to foster a deep understanding of the subject (Bruice, 2016). There is therefore a clear need to adopt active, student-centred teaching strategies, such as the 5E teaching approach, which utilizes hands-on experiments, interactive discussions, and technology integration, to enhance learning outcomes.

In summary, the current methods being employed by chemistry teachers in teaching stereoisomerism are a lecture method approach of teaching, usually centred on the teacher, passive in nature and characterized by limited student engagement and practical activities.

Research Question 2: Which of these methods, the lecture and 5E instructional model inquiry base method, is best suited for teaching stereoisomerism?

Table 5: Independent sample t-test of post-test scores of control and experimental groups in the knowledge and understanding of stereoisomerism

Group	N	Mean	SD	T	df	Sig
Experimental	72	84.98	7.91	12.85	148	0.000
Control	78	70.09	6.23			

Source: Field Data, Author (2025).

Table 5 displays the independent sample t-test results for the post-test scores of the intervention and control groups in knowledge and understanding of stereoisomerism. The experimental group scored significantly higher (Mean = 84.98, SD = 7.91) than the control group (Mean = 70.09, SD = 6.23) in the post-test. The t-value (12.85) and P-value ($p < .001$) indicate a highly significant difference between the two groups' post-test scores ($p < .001$). The results highlight that the 5E intervention applied to the experimental group was far more effective in improving understanding of stereoisomerism compared to the lecture method used in the control group.

Table 6: Independent sample t-test of post-test scores of controls and the experimental group in the knowledge application of stereoisomerism

Group	N	Mean	SD	t	df	Sig
Experimental	72	71.24	4.83	43.34	148	0.000
Control	78	41.10	3.63			

Source: Field Data, Author (2025).

Table 6 presents the independent sample t-test results for the post-test scores of the intervention and control groups in the knowledge application of stereoisomerism. The intervention group achieved a much higher mean score (Mean = 71.24, SD = 4.83) than the control group (Mean = 41.10, SD = 3.63) in the post-test. The t-value (43.34) and p-value ($p < .001$) indicate a highly significant difference between the groups' post-test scores ($p < .001$). These results demonstrate the superior effectiveness of the intervention group's instructional method in improving the knowledge application of stereoisomerism compared to the control group's approach.

Table 7: Independent sample t-test of post-test scores of control and experimental group in skills of stereoisomerism

Group	N	Mean	SD	T	Df	Sig
Experimental	72	93.31	4.07	70.82	148	0.000
Control	78	26.46	6.98			

Source: Field Data, Author (2025).

Table 7 presents the independent sample t-test results for the post-test scores of the intervention and control groups in the skills of stereoisomerism. The intervention group achieved a significantly higher mean score (Mean = 93.31, SD = 4.07) compared to the control group (Mean = 26.46, SD = 6.98) in the post-test. The t-value (70.82) and p-value ($p < .001$) indicate an extremely significant difference between the post-test scores of the two groups ($p < .001$). These results highlight the impact of the instructional method employed in the intervention group on enhancing students' stereoisomerism skills compared to the lecture method used in the control group.

Table 8: One-way ANOVA for Posttest Scores in Control Group

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	76908.949	2	38454.474	1143.398	.000
Within Groups	7768.936	148	33.632		
Total	**84677.885**	**150**			

Source: Field Data, Author (2025)

The one-way ANOVA was conducted to test for significant differences in the scores of the three profile dimensions. The p-value (.000) is less than 0.05, indicating a statistically significant difference among the three dimensions. The very large F-value (1143.398) suggests that the variation between groups is much greater than the variation within groups, confirming a strong effect of the lecture method on the dimensions. Since the ANOVA test shows a significant difference, a Tukey HSD post hoc test was conducted to determine where the differences lie, as presented in Table 8.

Table 9: Tukey HSD post hoc test of the Lecture method posttest scores

(I) Profile	(J) Profile	Mean Difference (I-J)	Std. Error	Sig.
Knowledge	Application	28.98718*	.92863	.000
	Skills	43.62821*	.92863	.000
Application	Knowledge	-28.98718*	.92863	.000
	Skills	14.64103*	.92863	.000
Skills	Knowledge	-43.62821*	.92863	.000
	Application	-14.64103*	.92863	.000

Source: Field Data, Author (2025).

In Table 9, the multiple comparisons table shows the mean differences between each pair of profile dimensions and their statistical significance. It can be observed from Table 9 that the highest post-test scores indicate that students retained more factual and conceptual knowledge. The application of the knowledge dimension had significantly lower scores than knowledge but was higher than skills development, suggesting challenges in transferring knowledge to practical situations. Skills development had the lowest scores, indicating that students struggled the most in demonstrating hands-on skills after the lecture method of instruction in isomerism.

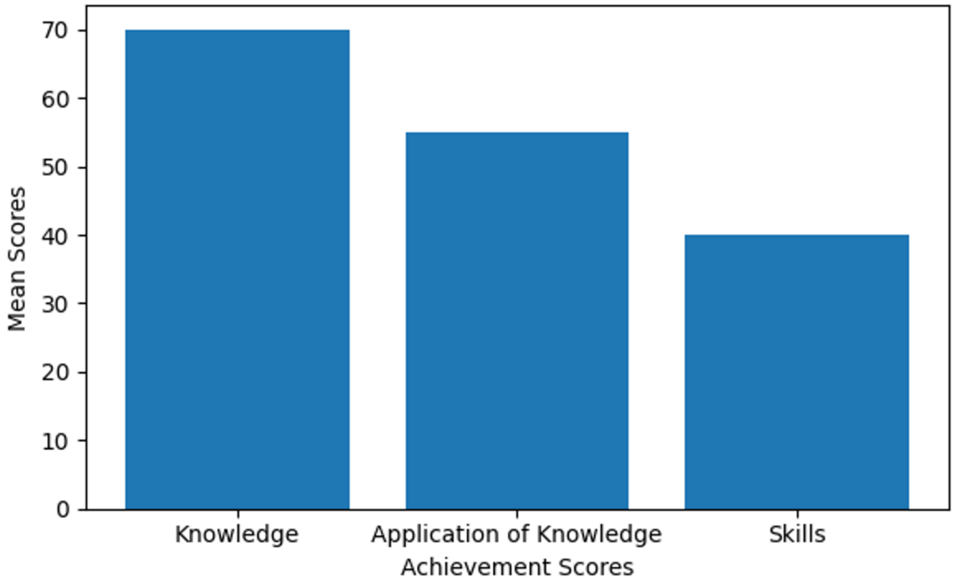


Figure 1: Ranking of profile Dimension in Control Group

Similarly, Table 10 presents a one-way ANOVA test for the posttest scores in the 5E method of the experimental group.

Table 10: One-way ANOVA for Posttest Scores in Experimental Group

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	17888.065	2	8944.032	261.426	.000
Within Groups	7287.250	148	34.212		
Total	**25175.315**	**150**			

Source: Field Data, Author (2025).

The one-way ANOVA in Table 10 was conducted to test for significant differences between the three profile dimensions. The p-value (.000) is less than 0.05, indicating a statistically significant difference among the three dimensions. The very large F-value (261.426) suggests that the variation between groups is much greater than the variation within groups, confirming a strong effect of the 5E method on the dimensions. Since the ANOVA test shows a significant difference, a Tukey HSD post hoc test was conducted to determine where the differences lie, as presented in Table 11.

Table 11: Tukey HSD post hoc test of 5E-method Posttest Scores

(I) Profile	(J) Profile	Mean Difference (I-J)	Std. Error	Sig.
Knowledge	Application	13.75000*	.97486	.000
	Skills	-8.31944*	.97486	.000
Application	Knowledge	-13.75000*	.97486	.000
	Skills	-22.06944*	.97486	.000
Skills	Knowledge	8.31944*	.97486	.000
	Application	22.06944*	.97486	.000

Source: Field Data, Author (2025).

In Table 10, the multiple comparisons table shows the mean differences between each pair of profile dimensions and their statistical significance. It can be observed from Table 7 that Skills Development had the highest mean score (93.31), followed by Knowledge (84.99) in Table 5 and Application of Knowledge (71.24) in Table 6 and Figure 2, since all comparisons are statistically significant.

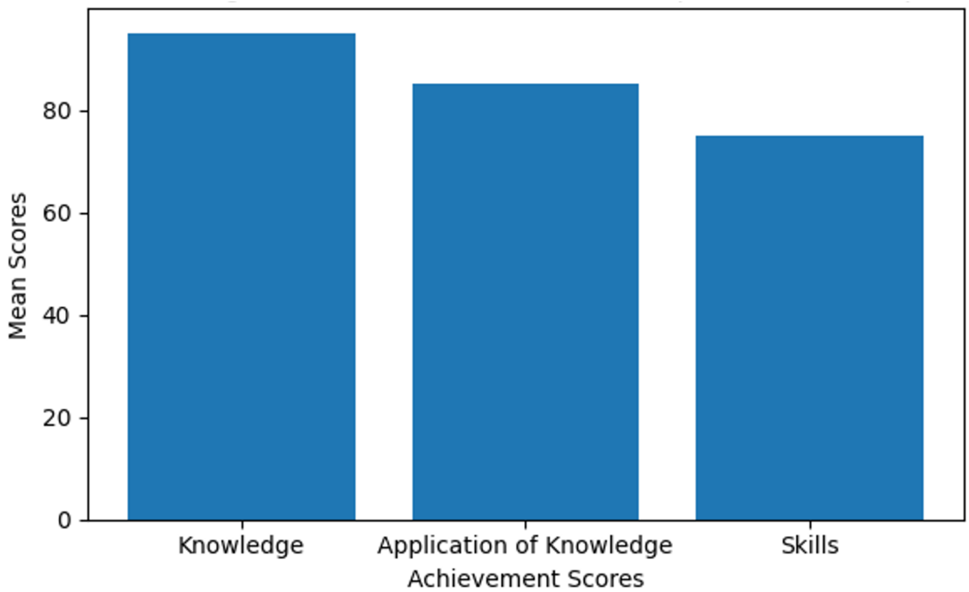


Figure 2: Ranking of Profile Dimensions in the Experimental Group

Research objective four was to determine whether the lecture method or the 5E instructional model is best suited for teaching stereoisomerism. The higher scores in the experimental group in Table 7 suggest that the intervention or teaching strategy applied to this group significantly enhanced their knowledge of stereoisomerism compared to the control group. The experimental group displays greater consistency in scores, while the control group shows more variation, with several participants scoring on the lower end. This highlights the effectiveness of the experimental intervention (5E model) in improving participants' knowledge of stereoisomerism.

Similarly, the higher scores in the experimental group in Table 6 indicate the success of the 5E intervention in enhancing their ability to apply knowledge of stereoisomerism. The experimental group shows consistently high performance, while the control group's scores are lower and more varied. This highlights that the intervention for the experimental group significantly improved their skills in applying knowledge of stereoisomerism compared to the control group. The findings demonstrate a clear advantage of the experimental approach in enhancing participants' knowledge and understanding of stereoisomerism. This suggests that innovative teaching methods or interventions may be significantly more impactful than traditional approaches for this topic.

Also, the 5E intervention appears highly effective in enhancing the experimental group's skills, as evidenced by their uniformly high scores in Table 7. The experimental group exhibits consistently high performance, while the control group displays variability and lower overall achievement. The results reflect the exceptional effectiveness of the 5E intervention in developing stereoisomerism skills among the experimental group. The substantial difference in mean scores demonstrates the superiority of the experimental teaching strategy, suggesting that it could be a model for improving stereoisomerism skills in educational settings.

Furthermore, in the lecture-based control group, knowledge was the strongest profile dimension (Table 5), as students effectively retained factual content. Application of knowledge was significantly weaker (Table 6), indicating difficulties in transferring theoretical knowledge to real-world problems. Skills development was the weakest (Table 7), confirming that lecture-based teaching alone does not sufficiently enhance hands-on or problem-solving abilities. These findings suggest that while lectures can effectively impart foundational knowledge, they are insufficient for fostering application and skills development. To improve outcomes in application and skills, integrating interactive strategies, problem-solving exercises, and practical demonstrations is necessary.

Knowledge was the second-best profile dimension (Table 11), confirming that the 5E model supports conceptual understanding better than traditional lecture methods. In application of knowledge, while still significantly improved, it was the weakest dimension (Table 11), suggesting that more emphasis may be needed on activities that bridge conceptual understanding with real-world application. The 5E model is highly interactive and inquiry-based, engaging students in hands-on activities that emphasize experimentation, exploration, and problem-solving. This explains why students performed best in skills development, as the method actively involves them in constructing knowledge and applying concepts in practical scenarios.

4. Conclusion

The study concludes that the predominant use of traditional lecture methods in teaching stereoisomerism limits students' conceptual understanding, practical skills, and active participation in chemistry lessons.

The findings demonstrated that students exposed to the 5E instructional model achieved significantly higher scores in knowledge acquisition, knowledge application, and skills development than students taught using the lecture method. The inquiry-based and student-centred nature of the 5E instructional model enhanced students' engagement, critical thinking, and problem-solving abilities in stereoisomerism.

The study therefore establishes that the 5E instructional model is more effective than the lecture method for teaching stereoisomerism at the Senior High School level.

It is also concluded that the 5E learning approach is best suited for teaching stereoisomerism since it highly impacts conceptual understanding, knowledge application, and scientific skills development than the lecture method.

4.1 Recommendations

Chemistry teachers should adopt the 5E instructional model in teaching stereoisomerism and related organic chemistry concepts.

Teacher training institutions and educational authorities should organise workshops and in-service training on inquiry-based instructional approaches.

Schools should provide instructional resources such as molecular models, simulations, and audio-visual materials to support effective chemistry teaching.

Lecture-based teaching should be complemented with practical and learner-centred activities to improve students' scientific skills.

Conflict of Interest Statement

I hereby declare that this thesis is my original research whose findings have not been presented for another degree in this university or elsewhere and that all citations in the work have been duly acknowledged.

About the Author

Kolani Nyamekye is a Chemistry teacher at Berekum Senior High School in the Bono Region, Ghana. He is a postgraduate researcher in Science Education at the University of Technology and Applied Sciences. His research interests include chemistry education, inquiry-based learning, the 5E instructional model, stereoisomerism, students' conceptual understanding, and science teaching and learning at the senior high school level.

Abdullai Abukari is an Associate Professor in the Department of Science Education, School of Science, Mathematics and Technology Education at the University of Technology and Applied Sciences, Navrongo, Ghana. His research interests include chemistry education, science education, curriculum and instruction, teacher professional development, educational assessment, and science education research.

References

Abdi, A. (2014). The effect of the inquiry-based learning method on students' academic achievement in the science course. *Universal Journal of Educational Research*, 2(1), 37-41. https://dio.org/1013189/ujer.2014.020104.

Adu-Gyamfi, K., & Appiah, J. Y. (2013). Senior high school chemistry students' performance in IUPAC nomenclature of organic compounds. *Cypriot Journal of Educational Sciences*, 8(1), 472–483. Retrieved from https://www.researchgate.net/publication/305827296_Senior_high_school_chemistry_students'_performance_in_IUPAC_nomenclature_of_organic_compounds

Adu-Gyamfi, K., Ampiah, J. G., & Appiah, J. Y. (2017). Students' difficulties in IUPAC naming of organic compounds. *Journal of Science and Mathematics Education*, 6(2), 77-106. Retrieved from https://www.researchgate.net/publication/324797375_Students'_Difficulties_in_IUPAC_Naming_of_Organic_Compounds

Ajaja, O.P. & Eravwoke, U.O. (2013). Effect of the 5E learning cycle on students' achievement in biology and chemistry. *Cypriot Journal of Educational Sciences*,7(3), 244-262. Retrieved from https://www.researchgate.net/publication/265795594_Effects_of_5E_learning_cycle_on_students'_achievement_in_biology_and_chemistry

Akar, E. (2005). *Effectiveness of 5e Learning Cycle Model on Students' Understanding of Acid-Base Concepts*. Master's Thesis, Middle East Technical University. Retrieved from https://etd.lib.metu.edu.tr/upload/12605747/index.pdf

Ameyaw, Y. (2015). Learning Cycle Approach (LCA) for Effective Teaching and Learning of Glycolysis and the Krebs Cycle. *International Journal of Sciences*, https://doi.org/10.18483/Ijsci.708

Amir, H., Shahzeb, M. W. & Nawaz, T. M. R. (2021). Modern Herbal Medicine. 4(3), 22, 202. https://doi.org/10.53388/MHM2021A0506002

Amponsah & Opei, (2014). Ghana's downstream petroleum sector: Assessment of key supply chain challenges and prospects for growth *Int. J. Manag. Bus. Stud.*, 2167-0439, 7 (3) (2014), pp. 441-448. Retrieved from https://www.internationalscholarsjournals.com/articles/ghanas-downstream-petroleum-sector-an-assessment-of-key-supply-chain-challenges-and-prospects-for-growth.pdf

Bruice, P. Y. (2016). *Organic Chemistry, Eight Edition.* Upper Saddle River, NJ: Pearson Education, Inc. Retrieved from https://www.pearson.com/nl/en_NL/higher-education/subject-catalogue/chemistry/bruice-organic-chemistry-8e-ge.html

Burke AD, *et al.* (2017). Among authors: Burke Wj. Prim Care Companion CNS Disord. *PMID:* 28453236. https://dio.org/10.4088/PCC.16br02097

Burrmann, N. J., & Moore, J. W. (2015). Implementation and Student Testing of a Web-Based, Student-Centered Stereochemistry Tutorial. *J. Chem. Educ*., 92(7), 1178–1187. https://doi.org/10.1021/ed500635d

Casteel, A., & Bridier, N. L. (2021). Describing populations and samples in doctoral student research. *International Journal of Doctoral Studies*, 16, 339–362. https://doi.org/10.28945/4766

Enticott, J. C., Shawyer, F., Vasi, S., Buck, K., Cheng, I. H., Russell, G., Kakuma, R., Minas, H., & Meadows, G. (2017). A systematic review of studies with a representative sample of refugees and asylum seekers living in the community for participation in mental health research. *BMC Medical Research Methodology*, Vol. 17, Issue 1. *BioMed Central Ltd.* https://doi.org/10.1186/s12874-017-0312-x

Etikan, I. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1. https://doi.org/10.11648/j.ajtas.20160501.11

Eurasia, (2017). *Journal of Mathematics Science and Technology Education ISSN:* 1305-8223 (online) 1305-8215 (print) 2017 13(7):3599-3620. https://dio.org/10.12973/eurasia.2017.00748a](https://dio.org/10.12973/eurasia.2017.00748

Fletcher, S. (2010). *The Impact of the 6e Model in A Third Grade Science Classroom*. Master's thesis, Green State University. http://rave.ohiolink.edu/etdc/view

Gomollon–Bel, F. (2019). Ten chemical innovations that will change our world: *IUPAC identifies emerging technologies in chem. Int.* 41(2), 12-17, https://dio.org/10.1515/ci-2019-0203](https://dio.org/10.1515/ci-2019-0203

Grosche O. & Peter, W. (2013). Enhancing Students' Achievement in Chemistry through the Piagetian Model: The Learning Cycle. *International Journal for Cross-Disciplinary Subjects in Education (IJCDSE),* 4(4), 70-78. https://dio.org/10.20533/ijcdse.2042.6364.2013.0178.

Hanson, R. (2016). Using an embedded conceptual strategy to enhance students' understanding of Lechatelier's summation of some stress factors on equilibrium position. *International Journal for Cross Discilinary Subjects in Education (IJCDSE),* 7(3), 2889–2899. https://dio.org/10.20533/ijcdse.2042.6364.2016.0394

Knowles, T. H. (2017). Using eye-tracking and molecular modeling to explore students' strategies for solving organic stereochemical problems. *Doctor of Philosophy Dissertation, The Graduate School of the University of Northern Colorado, Greeley, Colorado.* https://digscholarship.unco.edu

Majid, U. (2018). Research Fundamentals: Study Design, Population, and Sample Size. *Undergraduate Research in Natural and Clinical Science and Technology (URNCST) Journal*, 2(1), 1–7. https://doi.org/10.26685/urncst.16

Myers, S. (2021), "References", Meaning Making and Education for Conflict Resolution, *Emerald Publishing Limited, Leeds*, pp. 81-90. https://doi.org/10.1108/978-1-80071-074-020211010.

Ping, R., Church, R. B., Decatur, M. A., Larson, S. W., Zinchenko, E., & Goldin-Meadow, S. (2021). Unpacking the Gestures of Chemistry Learners: What the Hands Tell Us About Correct and Incorrect Conceptions of Stereochemistry. *Discourse Processes*, 58(3), 213–232. https://doi.org/10.1080/0163853X.2020.1839343.

Rohan, K., Maaz, H. & Karan, P. (2021). Effects of Stereoisomers on Drug Activity. *Am J Biomed Sci & Res.* 13(3). https://doi.org/10.34297/AJBSR.2021.13.001861.

Roopa, S., & Rani, M. (2012a). Questionnaire Designing for a Survey. *The Journal of Indian Orthodontic Society*, 46, 273–277. https://doi.org/10.5005/jp-journals-10021-1104

Ruiz-Martín, H., & Rodger, W. B. (2022). The cognitive principles of learning underlying the 5E Model of Instruction. *International Journal of STEM Education 9*, no. 1 NA. Gale in Context: Science. https://dio.org/10.1186/s40594-022-00339-z.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, 48(6), 1273–1296. https://dio.org/10.1007/s11165-016-9602-2.