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From Theory to Practice: Exploring the Synergy between Chemo-Entrepreneurial-Motivated-Approach and Students' Achievement in Senior Secondary Chemistry Practical

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A B S T R A C T

This study addresses the persistent challenge that impedes meaningful learning and acquisition of practical skills in chemistry due to the limitations of traditional teaching methods. It explored the potency of the Chemo-Entrepreneurial-Motivated-Approach (CEMA) in enhancing senior secondary students' achievement in chemistry practical. A non-randomized pre-test, post-test quasi-experimental design with a 2x2 factorial matrix was used, involving 118 senior secondary II students from two purposively selected secondary schools using two intact classes in Education District V, Lagos State, Nigeria. The experimental group (58 students) received CEMA-based instruction, while the control group (60 students) was taught using the lecture method over seven weeks. Data collected through the Chemistry Practical Achievement Test (reliability index = 0.76) were analyzed using mean, standard deviation and analysis of covariance. Results revealed that students taught with CEMA significantly outperformed those in the lecture method group, indicating that CEMA effectively improved practical skills and achievement ($F(1,113)=24.55$; $p<0.05$). However, no statistically significant gender differences [$F(1,56)=.08$; $p>0.05$] and interaction effects between the treatment and gender were observed [$F(1,113)=.25$; $p>0.05$]. The study concluded that CEMA enhanced students' achievement and skills in chemistry practical, and recommended its adoption in senior secondary school chemistry instruction to improve students' achievement and entrepreneurial competence.

1. Introduction

The rapidly evolving educational landscape demands a shift in education paradigms, emphasizing the development of innovative pedagogical approaches to enhance students' learning particularly in Science, Technology, Engineering and Mathematics (STEM) disciplines. These approaches aim to equip students with problem-solving, creative thinking and entrepreneurial skills necessary for thriving in the 21st century (Ogunmade et al., 2024; De Pablo et al., 2019). Central to the discipline of science is chemistry which occupies a pride place in the SSS curriculum to provide students with a comprehensive foundation in preparing them for advanced science studies and equipping them with analytical and practical skills relevant across various STEM fields.

Chemistry as a discipline provides students with a deep understanding of material properties and chemical processes, which are pivotal for technological advancements and innovations in science and technology (Ogunmade et al., 2020). Its contribution to sustainable development is also significant, laying the groundwork for progress in energy, environmental conservation, and healthcare (Olude et al., 2024; Saibu, 2023). Chukwu and Adolphus (2022) underscored the importance of chemistry in developing students' critical thinking and problem-solving skills. Thus, the teaching of chemistry in schools is extremely important in shaping students' perspectives of the natural world and their engagement with global sustainability challenges confronting humans.

In Nigerian senior secondary schools, chemistry is taught as both theoretical and practical, and as such, students' achievement in the subject is determined by how well they can do in these two areas. While the theoretical component fosters cognitive development, the practical component is essential for acquiring science process skills (Saibu & Oginni, 2024). Academic achievement in chemistry influences students' future educational and career prospects, with achievement typically assessed through internal and external examinations such as the Senior School Certificate Examination (Ademola et al., 2023). A student who earns good grades in chemistry has been accorded to achieve high in the subject. However, literature have identified persistent challenges in students' comprehension and application of chemistry concepts, particularly due to its abstract nature and the perceived difficulty of integrating theoretical knowledge with practical skills (Maya et al., 2021; Aldahmash et al., 2019).

Recent study by Ademola et al., (2023) confirmed that the study of chemistry is pricked by the persistent unimpressive performance of the students in the last decade and the possible effect that the students' understanding of chemistry plays in the learning of the two other subjects (biology and physics) rated compulsory for senior school science students in Nigeria. Oladejo et al. (2023) and Nzewi (2020) further stressed that in Nigeria secondary schools, most students find the learning of chemistry not interesting to them and as such many of the students performed poorly and showed no enthusiasm or positive attitude towards learning the subject. Ibe et al. (2021) reported poor academic performance in senior secondary school chemistry in West African Senior School Certificate Examination (WASSCE) hinging on the summary of West African Examinations Council's chief examiner's reports (WAEC, 2016 - 2021) which indicated low mean scores (43.0, 47.0, 29.0, 40.0, 54.0 and 18.0 respectively) coupled with high standard deviations (15.36, 16.00, 13.78, 14.46, 17.83 and 12.41 respectively), suggesting widespread underachievement and variability in students' performance. Similarly, Olojo et al. (2022) study on comparative analysis of secondary school students' performance in science subjects reported a decline in students' academic performance in senior secondary chemistry in WASSCE in the last four years.

This trend has been attributed to common factors which include but are not limited to low enrolment, poor practical skills, chemistry teachers' inability to communicate the economic significance of chemistry, insufficient content knowledge and poor teaching methodologies, classroom interaction patterns and students' learning styles (Mohsenipouya, 2024; Saibu, 2023; Nduudee & Shedrack, 2021). Nzewi (2020) and WAEC (2020) identified poor acquisition of science process skills, use of non-chemical terms, inadequate or non-existent exposure to practical activities, inadequate preparation for the examination, lack of familiarity with the syllabus, and the inability to present their answers in a systematic manner as major factors contributing to low academic achievement in chemistry at the secondary school level. In line with this, Dike and Avwiri (2020) and Achimugu (2018) gave a clue that many chemistry teachers do not teach practical chemistry, and some are indifferent towards how hands-on activities are conducted and how efficiently laboratory programmes run. Similarly, Junaidi et al. (2021) and Mentari et al. (2017) emphasized that many chemistry concepts are inherently abstract and challenging to visualize, necessitating the use of analogies or practical activities to aid understanding. Hence, the lack of rich or inadequate engaging learning activities provided by teachers has resulted in students struggling to grasp chemistry concepts effectively (Muderawan et al., 2019).

Another notable mitigating factor against this underachievement as noted in the literature is gender. Several studies including Saibu et al. (2024), Jial et al. (2021) and Hsin-Hui (2015) identified gender disparities in students' achievement in chemistry. These disparities often linked to differences in instructional exposure and interaction with learning materials (Uzezi & Deya, 2020). However, at the centre of these preponderant factors constituting impediments to effective learning and students' performance in chemistry are the methods or approaches used in teaching and poor practical skills by students. Thus, students' application of chemical knowledge learnt in the class to utility depends on the teacher's use of appropriate teaching technique that will help them understand the relevance of the concepts learnt to daily life.

Despite the central applications of chemistry in daily activities such as entrepreneurship and its potential to address global challenges, gaps remain in effectively engaging students and improving their academic achievement in chemistry practical. This knowledge gap underscores the importance of conducting rigorous research to inform evidence-based strategies in chemistry. Studies have called for empirical research to evaluate the effectiveness of such pedagogical strategies in enhancing students' practical skills, motivation and overall achievement (Oludipe et al., 2022). Thus, there is a need for a chemistry teaching approach that can attract students' interest with emphasis on practical activities, hands-on learning and linking chemistry concepts to entrepreneurial opportunities, one of which is Chemo-Entrepreneurial-Motivated-Approach (Saibu, 2023; Ni'mah & Suwardi, 2023; Ni'mah & Kamaludin, 2023).

The approach termed Chemo-Entrepreneurial-Motivated-Approach seeks to bridge the gap between theoretical knowledge and practical application, fostering a more holistic and comprehensive grasp of chemistry concepts (Purnama et al., 2020). In the words of Saibu (2023), CEMA is a teaching approach that emphasizes learners-centred instruction by assigning learning task to students through production so as to be constructive in knowledge and skill acquisition. Through the application of chemistry theories to visualisation, this technique equips students with the knowledge and skills necessary to transform raw materials into valuable products. Chemo-entrepreneurship-based learning according to Amalana et al. (2019) makes students more active in learning, creative in solving problems, making products and practice being entrepreneurs. Through the integration of entrepreneurial ideas and practical applications, Chemo-entrapreneurship-based fosters students' innovative thinking, problem-solving abilities, creative thinking, and enhances students' motivation, interest and academic performance in chemistry (Dewi & Mashami, 2019).

The Chemo-Entrepreneurship-Motivated-Approach to learning chemistry is a contextual method that connects theoretical concepts with real-life phenomena and tangible objects, enabling students to relate classroom material to everyday experiences (Afwa, 2018). Bridging the gap between theory and practice, CEMA offers a holistic framework to evaluate students' mastery of chemistry concepts, practical skills and entrepreneurial creativity through hands-on activities and product-oriented tasks. It allows students to explore the transformation of raw materials into valuable, economically significant products while fostering essential skills and an entrepreneurial mindset (Nirwana & Yenti, 2021; Kurniawati et al., 2021). Ni'mah and Suwardi (2023) stressed that Chemo-Entrepreneurial-based learning integrates the manufacture, packaging and marketing of products related to the subject matter, providing students with opportunities to develop entrepreneurial skills alongside mastering essential concepts. This approach bridges chemistry and entrepreneurship through practical, hands-on activities. According to Astuti et al. (2019), incorporating practicum activities grounded in students' daily experiences leads to more meaningful learning, enhances their understanding of chemistry concepts and broadens their awareness of real-world phenomena.

Chemo-Entrepreneurial-Motivated-Approach consists of four key stages: classroom activities (lecture and discussion with integration of CEMA), laboratory activity (guided discovery and demonstration methods), product-making activity (skills and competence in entrepreneurship), and presentation activity (group discussion on the outputs/products) (Saibu, 2023; Hilario, 2017). The classroom activities blend traditional lectures with real-world applications, actively engaging students to explore chemical concepts. In Laboratory activity stage, students apply the concepts learned in the classroom through hands-on practical experimentation in the laboratory. The product-making phase translates classroom and laboratory learning into tangible products, focusing on developing skills like manufacturing and packaging. Finally, the presentation phase simulates entrepreneurial pitching, with students presenting their products and business plans to peers and teachers, fostering collaboration, communication and critical feedback.

Chemo-Entrepreneurial-Motivated Approaches have been highlighted as effective in improving students' academic achievement and motivation. For instance, Ojobola et al. (2024) investigated how entrepreneurial skills influence the academic achievements of chemistry students in the field of chemical production and the result revealed that students who participated in hands-on exercises related to chemical production exhibited superior performance compared to those who did not engage in practical activities. Oludipe et al. (2022) explored the use of Entrepreneurial Motivated Approach in chemistry teaching and learning in senior secondary school study and found statistically significant effects of entrepreneurial motivated approach on students' cognitive achievement than those taught using conventional strategy. A study conducted by Yulita and Prayitno (2023) showed that entrepreneurship-based chemistry learning improved students' vocational skills and learning outcomes. Nduudee and Shedrack (2021) using a quasi-experimental design with students who took Chemistry found a significant difference in the mean score between students who were taught saponification as an example of entrepreneurship in science education did better than those who are not.

The influence of gender on students' achievement has also been explored in the context of entrepreneurial education. While studies by Saibu et al. (2022), Oladejo et al. (2022), Delmang (2019) and Muhammed (2019) found no significant gender differences in chemistry achievement, contrasting findings by Saibu et al. (2024) and Jial et al. (2021) suggested gender may influence performance in science subjects. The inconsistent findings underscore the need for further investigation into the role of gender in chemistry education and practical achievement in particular.

However, despite the abundance of studies on general achievement and self-reliance in chemistry, there remains a gap in literature specifically addressing practical skills development and achievement in chemistry through Chemo-Entrepreneurial-Motivated-Approach, particularly in Nigerian secondary schools. This study therefore aims to bridge that gap by investigating the effect of Chemo-Entrepreneurial-Motivated-Approach on students' achievement in chemistry practical while also addressing gender disparity. The following research questions guided the conduct of this study:

1. Is there a statistical difference in the achievement of chemistry students when taught using Chemo-Entrepreneurial-Motivated-Approach and lecture method?
2. Is there a statistical difference in the achievement of male and female students in chemistry practical when taught using Chemo-Entrepreneurial-Motivated-Approach?

Theoretical Underpinning

This study was anchored on Vygotsky's social constructivist theory which suggests that interacting with people in a social setting aid learning in giving knowledge context. According to Vygotsky (1978) students may create a certain degree of meaning on their own, but it can increase considerably via interaction with peers and teachers. As a result, the Vygotsky theory emphasizes tight teacher-learner contact as a fundamental element of learning while also taking the socio-cultural milieu into consideration. The teacher moulds and oversees each student's individualized learning process, and the students communicate, share ideas and analyse problems. Thus, social constructivism emphasizes the value of interactions, disagreements and learning in context.

Chemo-Entrepreneurial-Motivated-Approach as a strategy used in this study shares a strong relationship with the theory. In the CEMA, social interactions among students, peers and teachers play a significant role in the learning process. Group discussions, collaborative projects and peer mentorship encourage learners to exchange ideas, challenge assumptions and co-construct knowledge. Additionally, CEMA emphasizes learning within meaningful contexts, thus, by linking chemistry concepts to entrepreneurial activities, students see the relevance of theoretical knowledge in addressing real-world challenges.

2. Methodology

This study employed a non-randomized pre-test, post-test quasi-experimental with a 2x2 factorial design consisting of the two levels of instructional strategies (CEMA and lecture method) and gender (male and female). The study was conducted among 118 chemistry students from Senior Secondary II (SS II) in two purposively selected senior secondary schools within Education District V, Lagos State, Nigeria. The selected schools shared similar characteristics in terms of functional chemistry laboratories, students' population and geographic location within two distinct zones of the district. The choice of District V was because of the reported high failure rate of students in the major science subjects, including chemistry and their general lack of interest in science (Ademola, 2020).

One school was designated as the experimental group, implementing the Chemo-Entrepreneurial-Motivated-Approach while the other served as the control group, using the lecture method. Each of the groups was an intact class as randomisation was not feasible due to district administrative regulations. The experimental group consisted of 58 students (30 male, 28 female) and the control group had 60 students (27 male, 33 female), (see figure 1). These students who were between ages 14 to 16. Due to district administrative regulations, randomization was not feasible hence, intact classes were used for the study.

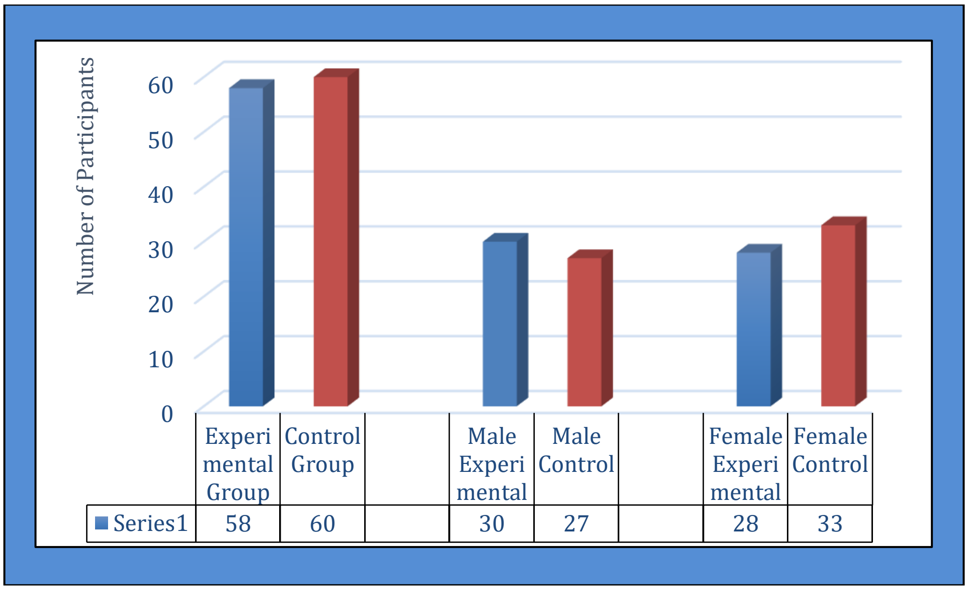

Figure 1. Participants for the study

The Chemistry Practical Achievement Test (CPAT) was the instrument employed in the study to collect data. Its content included six real-world questions designed to measure the practical knowledge and skills in the concepts of the chlorine and saponification that were taught. For example, students were assessed on their ability to accurately follow chemical procedures, understand reaction mechanisms and adhere to safety protocols. Practical evaluations also focused on technical accuracy, such as proper measurement of reagents, effective handling of equipment and successful execution of chemical reactions to produce quality products.

This instrument was validated by SS II chemistry teachers who are currently employed in senior secondary schools and a chemistry entrepreneurship specialist. The valid instrument was modified in accordance with their views and suggestions regarding the use of straightforward language free of ambiguity and the relevance of the practical questions to the curriculum. The CPAT's reliability was determined using the test-retest approach. In order to make the required adjustments before the second administration, students were asked to identify any question or questions that they felt were unclear or extremely difficult to grasp after the first administration. Two weeks after the first test, the second one was given. Data generated from the trial tests were analysed using Kuder Richardson (K-21) which yielded a reliability index of 0.76.

Before the commencement of the study, we sought permission from the appropriate authorities in order to have access and to obtain consent from the chemistry teachers who were briefed on the study's objectives and the timeline for its execution. Likewise, the students' consent to voluntarily participate in the study was also sought. Following approval, we gave a pretest to both the experimental and control groups which lasted 80 minutes on different days to ascertain the initial differences among the subjects prior to the treatment using the CPAT.

The students in the experimental group were taught using the Chemo-Entrepreneurial-Motivated-Approach, while the control group was taught using the lecture method. To prevent any prejudice that might have arisen if the researchers had a direct contact with the students, their usual chemistry teachers were employed to teach the students as they served as research assistants. However, the teachers for the experimental group were trained by the researchers and an expert in chemistry entrepreneurship using the Teachers' Instructional Guide on Chemo-Entrepreneurial-Motivated-Approach (TIGCEMA). This is to enable them acquire necessary entrepreneurial skills to be adopted as intervention in the study. The daily training lasted for one week. The two teachers for control group were also briefed on the adoption of lecture method based on the validated Teachers' Instructional Guide on Lecture Method (TIGLM). Thus, the interventions were implemented with the aid of these Instructional Guides which consisted of seven lessons each that lasted for seven weeks and in each lesson, there was a teaching contact of 80 minutes per week.

The lesson delivery in the CEMA classroom and laboratory encompassed four steps implementation procedures which covered classroom activities, laboratory activities, products making activities and presentation of product activities (see figure 2).

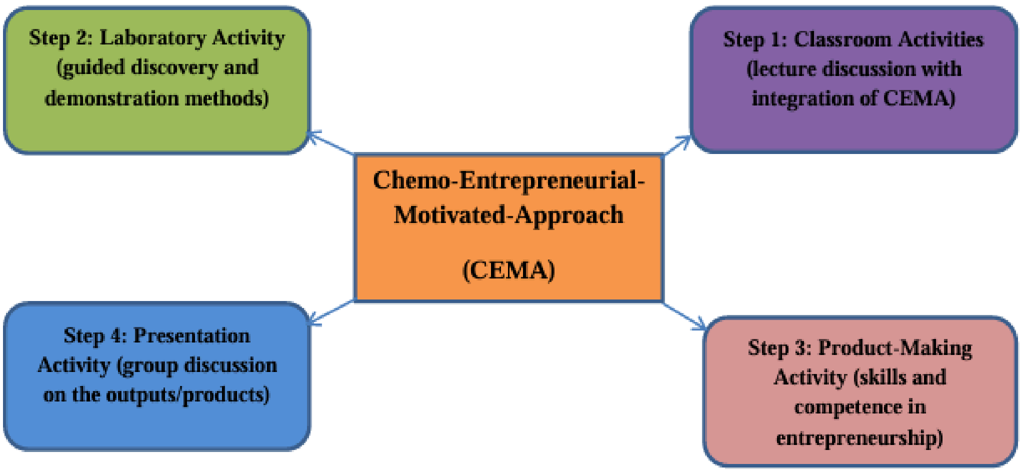

Figure 2. CEMA implementation steps at a glance (Saibu & Oginni, 2024)

Step 1: Classroom Activities
The lesson began with a lecture discussion where the teacher introduced the topic of chlorine, properties of chlorine, compounds of chlorine and its importance in various industries. The teacher used visual aids, such as periodic table, diagrams and illustrations to explain the properties and uses of chlorine. To integrate the Chemo-Entrepreneurial-Motivated-Approach, the teacher highlighted the entrepreneurial opportunities related to chlorine, such as the production of

chlorine-based products, like bleach, disinfectants and sanitizers while he shared success stories of entrepreneurs who have made a fortune from chlorine-based businesses. In another lesson, the teacher introduced the concept of saponification and explain the process of soap making and the chemical reactions involved. The teacher integrated CEMA by highlighting the entrepreneurial opportunities related to soap making, such as the production of soaps.

Step 2: Laboratory Activities
The laboratory activity began with the teachers demonstrating the step-by-step process to prepare and conduct an experiment on the production of sodium hypochlorite (bleach) through the reaction of chlorine gas with sodium hydroxide. Additionally, the teacher showed the students the chemicals used to produce bleach, explained the act of bleach making, carried out accurate measurement and production of bleach with the students using the reagents and apparatuses provided. Consequently, in the sixth lesson, the teacher introduced the chemical reagents/apparatuses for saponification reaction, explained the act of liquid soap making and carried out accurate measurement. Next, teachers illustrated liquid soap making experiment using the teaching reagents/apparatuses provided.

Step 3: The Product Making Activities
This stage began with students preparing their own bleach following teachers' illustration in step 2 (see figure 3). The students were grouped into small mixed experimental groups of twelve with each group comprising five members. To ensure effectiveness, the twelve groups were further divided into two sets. The first set was allowed to carry out their production and follow by the second set. The students in each small group replicated the practical activities by producing the household bleach and the productions were carried out simultaneously to prevent threat to external validity. As they conduct the experiment, students focused on the chemical reactions involved in bleach production and develop practical skills in measurement, mixing and safety protocols.

Figure 3. A sample of group pictures of the laboratory production of bleach

Similarly, students participated in a liquid soap-making where they used sodium hydroxide and other ingredients to produce liquid soap (see figure 4). Like in the production of bleach, the students were in the small experimental groups of twelve with each group comprising five members replicating the practical activities demonstrated by the teachers by producing liquid soap on their own. The twelve groups were split into two sets for maximum efficiency. The first set was allowed to complete their production before the second set took over. To avoid endangering the internal validity, the productions were done concurrently.

Figure 4. A sample of group pictures of the laboratory production of liquid soap

To develop entrepreneurial skills, the teacher discussed packaging, quality control and customer preferences, encouraging students to consider sustainable practices like eco-friendly packaging.

Step 4: Presentation Activities
This began with students grouped based presentation on their outputs from the bleach and liquid soap production activities. Each group is tasked with making a presentation that highlighted both the technical aspects of their products and the entrepreneurial strategies they would employ to bring it to market. During the presentation, each group started by describing the steps they followed in the laboratory to produce their products. The groups employed samples of their products to make their explanations engaging. They, then shifted to the entrepreneurial aspect by presenting a business plan that included the potential market for their product, proposed pricing and marketing strategies. As part of the discussion, the teacher encouraged peer feedback, fostering critical thinking and collaboration.

The control group on the other hand was also taught the two concepts using the lecture method for the period of 7 weeks like the experimental group. The teacher taught the concept of chlorine and saponification using the lecture method. The lectures provide a thorough theoretical understanding but lack of practical demonstrations and production to fully grasp its real-world applications. The absence of hands-on production activities reduced opportunities for students to connect theory with practice.

After the seven weeks of teaching in both the experimental and control groups, we conducted a post-test using a reshuffled version of the same instrument and this took one week. The test was conducted on different day to each of the groups.

3. Results and Discussion

We analysed data ccollected using mean, standard deviation and one-way analysis of covariance (ANCOVA). ANCOVA was employed because the participants were not divided into groups at random. However, we conducted preliminary checks on the data to make sure that the parametric assumptions were met. The results showed linearity, Levene's test of homogeneity of variances [F=.69; p>.05], homogeneity of regression slopes (linear slope), normality [F=2.65; p>.05] and Box's test of reliable measurement of the covariate [F=2.45; p>.05]. Meeting these required parametric assumptions, we proceeded to apply the ANCOVA statistics to the test scores of the students in each group.

Research question one sought to determine the statistical difference in the achievement of students in chemistry practical taught using Chemo-Entrepreneurial-Motivated-Approach and the lecture method. In answering this question, Table 1 reveals that students taught using the CEMA had a higher practical mean (13.76) and SD difference (5.06) than students taught using the lecture method (mean difference of 7.79 and SD difference of 2.71). As a result, when comparing the post-test performance to the initial baseline, the instructional treatment showed improvement in their achievement.

Table 1. Mean and standard deviation of the effect of treatments on achievement of students in chemistry practical

Groups	**Mean**		**Mean Diff.**	**SD**		**SD Dif.**
	Post-test	**Pre-test**		**Post-test**	**Pre-test**	
CEMA	27.86	14.10	13.76	7.80	2.74	5.06
LM	20.05	12.26	7.79	5.39	2.68	2.71

To determine whether the difference was statistically significant, the univariate F-value in Table 2 shows that CEMA has a statistically significant effect on students' achievement in chemistry practical [F(1,113)=24.55; p<.05]. The partial eta squared estimate shows that the treatment was responsible for 29.1% of the variance in the students' achievement in chemistry practical as seen in the post-test. This indicates that after treatment, students' achievement in chemistry practical have tremendously improved more than that of their counterparts in the lecture method group.

Table 2. ANCOVA of students' achievement in chemistry practical

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	ηp²
Corrected Model	2673.04[a]	4	668.26	17.53	.00	.44
Intercept	537.91	1	537.91	14.11	.00	.30
Groups	935.88	1	935.88	24.55	.00	.29
Error	4308.52	113	38.13			
Total	74327.00	118				

a. R Squared = .383 (Adjusted R Squared = .361)

Research question two sought to find out the difference in the achievement of male and female students in chemistry practical when taught using Chemo-Entrepreneurial-Motivated-Approach. According to Table 3, female students taught using the CEMA had a marginally higher practical mean and SD differences (13.79 and 4.68 respectively) than male with mean difference of 12.36 and SD difference of 4.69. The finding also shows that while the female students slightly outperformed the male students in the lecture method group.

Table 3. Mean and standard deviation of gender differences in chemistry practical

Group	Gender	Mean		Mean Diff.	SD		SD Diff.
		Post-test	Pre-test		Post-test	Pre-test	
CEMA	Male	27.53	15.17	12.36	7.93	3.24	4.69
	Female	28.21	14.42	13.79	7.80	3.12	4.68

Further analysis on the result, Table 4 reveals no statistically significant difference in the achievement of male and female students in chemistry practical [F(1,56)=.08; p>.05]. This suggests that the use of the CEMA has no interception effect on gender disparity in students' achievement in chemistry practical. According to the partial eta squared estimate, the treatment only contributed 1% of the variance in the students' achievement in chemistry practical.

Table 4. ANCOVA of gender difference in students' achievement in chemistry practical

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	ηp²
Corrected Model	2673.04[a]	4	668.26	17.53	.00	.54
Intercept	537.91	1	537.91	14.11	.00	.32
Gender	2.85	1	2.85	.08	.79	.01
Error	4308.52	56	38.13			
Total	74327.00	58				

a. R Squared = .383 (Adjusted R Squared = .361)

To determine whether the groups and gender have statistically interacted with students' achievement in chemistry practical, the univariate F-value in Table 5 reveals no statistically significant interaction effect of groups and gender on students' achievement in chemistry practical [F(1,113=.25; p>.05]. The partial eta square (0.004) which is infinitesimally small also shows no significant interaction effect.

Table 5. ANCOVA of interaction effect of groups and gender on students' achievement in chemistry practical

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	ηp^2
Corrected Model	2673.04[a]	4	668.26	17.53	.00	.53
Intercept	537.91	1	537.91	14.11	.00	.40
Groups * Gender	9.54	1	9.54	.25	.62	.00
Error	4308.52	113	38.13			
Total	74327.00	118				

a. R Squared = .383 (Adjusted R Squared = .361)

Discussion

The first research question revealed that students taught using the CEMA had a higher achievement than their counterparts taught using the lecture method. The ANCOVA analysis confirmed that CEMA has a statistically significant effect on students' achievement in chemistry practical. This finding aligns with Yulita and Prayitno (2023) who reported the positive influence of Chemoentrapreneurship-based learning in enhancing vocational skills and learning outcomes. Ojobola et al. (2024) study on entrepreneurial skills influence the academic achievements of chemistry students in the field of chemical production revealed that students who participated in hands-on exercises related to chemical production exhibited superior performance compared to those who did not engage in practical activities. Consistent with study's finding is Ogunmade et al. (2024), and Nwaleke and Okoli (2019) who found that using laboratory-based instruction improved students' manipulative skills, acquisition of production skills and academic achievement in science dramatically. A study by Saibu et al. (2024) discovered that students taught separation techniques using indigenous vocational practices performed significantly better than those taught through lectures. Similarly, Purnama et al. (2020) study proved that chemo-entrepreneurship-based inquiry learning is effective in increasing student's science process skills and interest in the concept of acid-base.

The alignment of this study's finding with previous research findings reflects shared theoretical foundations, particularly the value of hands-on, contextualized and student-centered approaches. The CEMA group's regular chemistry practical activities and the sufficiency of the teaching and learning materials offered might have played also a significant role in the students' increased practical achievement. We believed that CEMA's practical orientation and hands-on activities provided students with opportunities to apply theoretical knowledge in real-world contexts, similar to these studies. The hands-on and project-based learning models resonated with the emphasis on student-centered learning environments and entrepreneurial skills development. Crucially, the students might have come to the realisation that the majority of the hands-on activities they are taught in chemistry laboratories are insufficient to equip them with the practical and entrepreneurial skills necessary for self-sufficiency. As a result, the CEMA has integrated practical and entrepreneurial chemistry skills, better preparing students for improved achievement and independence

The finding from second research question shows no statistically significant difference between the achievement of male and female students in chemistry practical. This finding implied that the use of the CEMA has no interception effect on gender disparity in terms of students' achievement in chemistry practical. This finding corroborates Saibu and Oginni (2024), Saibu et al. (2022) and Ajayi and Ogbeba (2017), who found no gender differences in achievement in chemistry when employing hands-on and entrepreneurial-oriented methods. In relation to these findings, we conjectured that the improved equal gender participation and achievement observed in this study was attributed to the inclusive nature of CEMA, which promoted collaboration, teamwork and active participation, creating an environment where both male and female students engage equally. Unlike traditional methods, which sometimes marginalize female students due to stereotypes about their hesitance in handling chemicals and apparatus, CEMA fostered collaborative and engaging environment that bridges such disparities. This approach reduces gender disparities typically observed in traditional lecture-based methods.

However, the finding contrasts Ojobola et al. (2024) who found that female students performed better than their male counterparts when engaged in practical activities on chemical production. Consequently, Saibu et al. (2024) reported significant gender difference when students were taught science using indigenous vocational-based practice, and Uzezi and Deya (2020) found statistically significant difference in the performance of male and female students taught acid-base reactions using computer simulation instructional strategy. The misalignments with these findings stem from variations in the study context, such as cultural factors, socialization effects, access to resources or prior exposure to entrepreneurial tasks that might have influenced gender specific achievement. These variations highlight the adaptability of CEMA in promoting equity while underscoring the need to consider contextual factors when interpreting gender-related outcomes. However, our equal focus on practical skills in CEMA might have neutralized the socialization effects, leading to equitable performance across gender.

This study further found no statistically significant interaction between teaching method and gender on students' achievement in chemistry practical. This finding is consistent with Oladejo et al. (2020), who used computer simulation to determine that the influence of the interaction between groups and gender was not statistically significant. Additionally, Ajayi and Ogbeba (2017) reported no significant interaction effects of teaching method and gender when using hands-on activities in science. The non-significant interaction effect of treatment and gender on students' practical achievement in this study may be a result of mixed-gender group practical activities and discussions which might have fostered collaborative learning, enhanced understanding and bridging potential gender disparities. However, this result did not align with Olude et al. (2024), who found a significant interaction between gender and instructional method on entrepreneurial skills acquisition in chemistry. This discrepancy underscores the importance of context and instructional design in determining interaction effects.

4. Conclusion

This study highlights the transformative potential of Chemo-Entrepreneurial-Motivated-Approach in students' achievement in practical chemistry. Thus, by combining practical activities with entrepreneurial training, CEMA enhanced students' practical achievement and promoted equitable gender achievements. The method addressed gaps in traditional teaching by offering a hands-on, real-world learning experience, making it a valuable tool for fostering the skills and mindsets needed in today's workforce.

Based on the finding and within the limitation of the study we recommended that:

1. Teachers and policymakers consider adopting CEMA in senior secondary chemistry instruction to improve students' achievement and entrepreneurial competence.
2. Teachers emphasize hands-on and project-based learning in their teaching approaches to promote deeper understanding and acquisition of skills in chemistry practical.
3. Chemistry teachers adopt CEMA in teaching to create inclusive learning environments that promote equal participation and engagement among all students.
4. A chemistry curriculum that focuses on purposeful entrepreneurial skills acquisition should be developed for to equip students with self-reliance skills.

Secondary schools should always organize and promote project exhibitions to help students gain job skills and business ownership aspirations.

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