

# Effect of ChatGPT on the Academic Performance of Chemistry Students in Thermodynamics: A Case Study of Federal College of Education (Special), Oyo

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## ABSTRACT

This study investigated the effects of ChatGPT on the academic performance, attitudes, and perceptions of students studying thermodynamics at the Federal College of Education (Special), Oyo. A quasi-experimental design with pre-test and post-test control group measurements was adopted. One hundred and twenty NCE III students were selected using purposive sampling, with half assigned to the experimental group and the rest to the control group. The experimental group was taught using ChatGPT, and the control group was taught using traditional pedagogical methods. Three data collection tools were used: The Thermodynamics Achievement Test (TAT), the Attitude Towards ChatGPT Usage Questionnaire (ATCUQ), and the Perceived Effectiveness of ChatGPT Questionnaire (PECQ). Then the data were analyzed using both descriptive and inferential statistical analysis. Results showed that students maintained a positive attitude toward using ChatGPT, as they felt it was an entertaining, confidence-boosting, and efficient learning tool. The perception metrics also showed that most participants considered ChatGPT a supportive, interactive, and interesting platform that supplements learning and academic achievement in thermodynamics. There was no significant difference in pre-test scores between the groups ( $p = 0.834$ ,  $p > 0.05$ ), indicating baseline equivalence. On the other hand, a statistically significant difference was observed in the post-test gain score ( $p = 0.000$ ,  $p < 0.05$ ), with the experimental group (34.00) scoring higher than the control group (26.10). The study concludes that integrating ChatGPT into chemistry education has a significant positive effect on students' understanding and achievement in thermodynamics. It was suggested that AI-driven tools should be integrated into science education, alongside teacher training and improved digital infrastructure.

**Keywords:** ChatGPT, Thermodynamics, Chemistry Education, Academic Performance, Artificial Intelligence, Science Teaching.

## INTRODUCTION

Technology and science have been incredibly important for world development and have been helpful in solving major problems in areas considered the environment, economy, and society. More recently, the way science and technology have been used in addressing problems has been used in alternative and sustainable development, as well as green growth (Luo, 2021). It has also been impacting industries and environmental problems by creating eco-friendly solutions, including biofertilizers, biodiesel, and bioplastics, and has been changing the framework of global interactions politically, economically, and socio-culturally (Ganesan et al., 2022; Isinkaye, 2023). The impact of these innovations, however, is also a consequence of the science literacy of the entire population impacted and the ability of the population impacted to think and reason around scientific issues and control exposure and engagement to false information (Luo, 2021; Duchaeva & Magomadov, 2023).

Within this context, science, and more importantly, chemistry education, is of critical importance, as it provides the opportunities for the development of the competencies for meaningful participation in a

technology-based society. The effect of the quality of chemistry teaching on students' understanding of concepts, problem-solving, and performance in a subject is well-documented. The problem of teaching the abstract concept of thermodynamics has persisted. Many students have perceived thermodynamics as complex, leading to a decline of interest and subsequently, a decline of academic performance. This is a consistent observation in academic literature. As stated by Harackiewicz, Smith, and Priniski (2016), students' interest plays an integral role in motivating them to become more involved in the learning process, attain higher academic results, and influence future occupational selections. In the absence of such interest, students are more inclined to avoid the engagement required to understand sophisticated ideas in science.

The issue is made worse by standard methods of teaching, which are likewise textbook-centered and teacher-centered. They often ignore innovative teaching and learning strategies that help improve learning and cognitive engagement and fail to address an array of teaching and learning preferences. The attached research states that students' low interest and poor performance in chemistry, especially in challenging topics like thermodynamics, is due to the dependence of teachers on outdated teaching methods and the absence of teaching with new technologies - like generative artificial intelligence (Babalola, Ahmad, & Tafida, 2024). Therefore, more research is needed on teaching methods that enhance active learning and students' conceptual understanding of the subject (Boesdorfer, 2019).

Recent developments in artificial intelligence (AI) have brought revolutionary possibilities for education in response to these challenges. Among these developments, ChatGPT, a cutting-edge generative AI model created by OpenAI, has drawn a lot of interest due to its potential to enhance the processes of teaching and learning. ChatGPT can produce human-like responses, clarify difficult ideas, and give students quick, tailored feedback. It provides special chances to make complex subjects like thermodynamics, chemical equilibrium, and reaction kinetics easier for students to understand in the context of chemistry education (Bettayeb et al., 2024; Rojas, 2024).

Academic research reveals positive outcomes affiliated with ChatGPT coordination in academic practices (i.e., student engagement, self-directed learning, and performance). What sets the tool apart is that it allows students to have an interactive experience where they can ask questions, get step-by-step explanations, and even explore other approaches to solving the problem. Additionally, ChatGPT is capable of interpreting chemical nomenclature and generating appropriate assessment material (Araújo & Saúde, 2024; Kodkin & Artem'eva, 2024), which can assist both teaching and learning. These features make ChatGPT a potentially useful teaching tool for contemporary science education. ChatGPT can improve students' cognitive performance and critical thinking abilities, according to the study on the role of ChatGPT in education: Applications, challenges and insights from a systematic review (Dimeli, M., & Kostas, 2025). Perceived usefulness and ease of use were found to be significant predictors of users' attitudes toward ChatGPT for smart education in a study that examined factors influencing the acceptance of ChatGPT in higher education. Furthermore, it was discovered that users' behavioural intentions to use ChatGPT for intelligent educational purposes were positively influenced by feedback quality, assessment quality, and subject norms (Almogren, Al-Rahmi, & Dahri, 2024). Additionally, the actual adoption of ChatGPT was substantially supported by users' attitudes toward use and behavioural intentions. Finally, a meta-analysis revealed that ChatGPT had a positive impact on students' learning performance, learning perception, and higher-order thinking (Wang & Fan, 2025).

The use of ChatGPT in education is not without restrictions, despite these encouraging opportunities. Concerns have been expressed by academics about how well it performs in higher-order cognitive tasks, especially those that call for in-depth knowledge analysis, interpretation, and application. Furthermore, there are still important ethical issues that need to be carefully addressed, such as academic integrity, excessive dependence on AI, and the possibility of misuse (Bettayeb et al., 2024; Fergus et al., 2023). These issues underscore the need for empirical studies that critically assess ChatGPT's advantages and drawbacks in particular educational settings. More significantly, there is a clear lack of information in the literature about ChatGPT's application in chemistry education in developing nations, especially Nigeria. There is little context-specific data on how it affects students' academic performance in specialized subjects like thermodynamics, despite the fact that studies conducted worldwide have examined its general efficacy. The significance of localized research that takes into account learner characteristics, institutional realities, and contextual challenges is highlighted by this gap.

In light of this, this study examines the effect of ChatGPT on the academic performance of chemistry students in thermodynamics at the Federal College of Education (Special), Oyo. The study aims to provide empirical evidence on the pedagogical value of ChatGPT and contribute to the ongoing conversation on the integration of artificial intelligence in science education by analyzing students' performance, attitudes, and perceptions.

### **Statement of the Problem**

Student performance in thermodynamics remains significantly poor, despite chemistry's central role in science and technology. Such courses feature complex mathematical equations and advanced theoretical models that are often difficult for students to grasp. Old-fashioned lecture-based pedagogies have failed to sufficiently alleviate these barriers to instruction. The impact of artificial intelligence applications like ChatGPT, which provide contextualized and interactive support, on the academic performance of chemistry students warrants empirical study. This study aims to bridge the performance gap by comparing the impact of ChatGPT on the academic success of a group of chemistry students at the Federal College of Education (Special), Oyo.

### **Aim and Objectives of the Study**

The main aim of the study is to investigate the impact of ChatGPT on the academic achievement of chemistry students in thermodynamics.

These specific objectives are to:

1. Compare the academic results of students who learned thermodynamics using ChatGPT and those who learned the subject using traditional pedagogical tools.
2. Explore the attitude of the students toward the use of ChatGPT in a chemistry classroom.
3. Test the perceived effectiveness of ChatGPT as a teaching tool in chemistry students.

### **Research Questions**

1. How do students feel about the application of ChatGPT to learn chemistry?
2. What do chemistry students think about the effectiveness of ChatGPT as a thermodynamics learning tool?

### **Research Hypotheses**

H<sub>0</sub>1: There was no statistically significant difference in the academic performance of the control and the experimental group before the intervention.

H<sub>0</sub>2: No statistically significant difference was found in the academic performance of students taught thermodynamics using ChatGPT and those taught using traditional teaching methods.

### **Significance of the Study**

There are many important things about this study. It provides real-world evidence that AI-based tools can help Chemistry students perform better in school, which can help teachers figure out how to use technology in science classes. It will also help curriculum developers and policymakers choose new ways to teach. The results may also encourage students to explore AI tools as additional learning tools, helping them learn independently and think critically.

### **Scope of the Study**

This research is limited to Chemistry students at the Federal College of Education (Special), Oyo, with a particular emphasis on thermodynamics. The study assesses students' academic performance, attitudes, and perceptions regarding the use of ChatGPT in this context.

## Research Design

The research employed a quasi-experimental framework featuring pre- and post-test evaluations for control groups. This method makes it easier to compare the academic performance of students who learned through ChatGPT with those who learned through traditional lectures.

## Population of the Study

The study population comprised all NCE III Chemistry students enrolled in the 2022/2023 and 2023/2024 academic sessions at the Federal College of Education (Special), Oyo.

## Sample and Sampling Techniques.

A purposive sampling method was used to select two intact groups of Chemistry students, comprising NCE III students, which were further separated into two groups. These groups were randomly assigned to an experimental group (60 students) and a control group (60 students). The relatively larger sample size enhances the generalizability and reliability of the findings.

## Research Instruments

The tools used in data collection included:

1. Chemistry Achievement Test (CAT), which focuses on issues of chemical equilibrium and thermodynamics.
2. The Attitude Towards ChatGPT Usage Questionnaire (ATCUQ).
3. Perceived Effectiveness of ChatGPT Questionnaire (PECQ).

## Validity of the Instruments

Both face and content validation procedures were conducted on the instruments by three experts in chemistry education and educational technology, thereby ensuring their appropriateness, comprehensiveness, and alignment with the research goals.

## Instruments Reliability.

Twenty students of Chemistry of a similar institution, but with a lower NCE level (NCE 2), were the pilot group. Cronbach's Alpha was used to test internal consistency; a coefficient of 0.76 or above was considered acceptable.

## Data Collection Procedure

Data collection was done with the permission of the Dean and Head of the Chemistry Department and course lecturers prior to the data collection. The students were informed about the aim of the study, and such ethical issues as confidentiality and voluntary participation were taken into account. An achievement test, a well-tested Thermodynamics Achievement Test (TAT) was used, as a pre-test to determine equality of a baseline between groups. The experimental group applied an organized ChatGPT-assisted learning model, which included problem-solving sessions, concept clarification via AI-mediated dialogues, assignment support via ChatGPT queries, discussions based on AI-generated responses, and traditional lecture-based instruction, and a post-test using the same TAT in four weeks, compared to the control group, which only took traditional lecture-based instruction and a post-test using the same TAT in four weeks. The experimental group and control group also took the ATCUQ and the PECQ to measure their perception of ChatGPT.

## Method of Data Analysis

Descriptive statistics (mean and standard deviation) were used to summarize the attitudes and perceptions of the students, whereas inferential statistics, especially independent samples t-tests, were used to test the hypotheses at a 0.05 level of significance.

## DISCUSSION OF RESULTS

Research Question 1: What are the attitudes of students concerning the use of ChatGPT in learning Chemistry?

Table 1: Students' Attitude to ChatGPT (N = 120)

Attitudes	Strongly Agree	Agree	Disagree	Strongly Disagree	M	SD
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)		
Using ChatGPT as a learning tool for studying thermodynamics is enjoyable	32 (26.7%)	38 (31.7%)	28 (23.3%)	22 (18.3%)	2.67	1.06
ChatGPT makes learning thermodynamics topics easier and more interesting.	40 (33.3%)	30 (25.0%)	28 (23.3%)	22 (18.3%)	2.73	1.11
ChatGPT helps me feel more confident when solving thermodynamics problems.	36 (30.0%)	44 (36.7%)	30 (25.0%)	10 (8.3%)	2.88	0.94
Using ChatGPT has Improved my understanding of difficult concepts in thermodynamics.	42 (35.0%)	38 (31.7%)	22 (18.3%)	18 (15.0%)	2.87	1.05

Source: Researcher's Field Survey 2025)

**Note:** M= Mean; SD = Standard Deviation; Standard Reference Mean = 2.50; Mean Response Rating Classification: High = 3.00 - 4.00; Moderate = 2.00 – 2.99; Low = 1 – 1.99.

As it was shown in Table 1, students tend to have positive attitudes towards using ChatGPT to study thermodynamics. All the item mean scores were between 2.64 and 2.93, which is above the benchmark mean of 2.50, implying moderate to high acceptance. This showed that ChatGPT is effective in clarifying the hard concepts and gave them more confidence in their ability to solve problems.

**Research Question 2:** How effective do Chemistry students perceive ChatGPT as a learning tool for thermodynamics?

Table 2: ChatGPT Perceived Effectiveness (N = 120).

Perceptions	Strongly Agree	Agree	Disagree	Strongly Disagree	M	SD
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)		
ChatGPT is a helpful tool for supporting my learning in thermodynamics,	52 (43.3%)	44 (36.7%)	10 (8.3%)	14 (11.7%)	3.12	0.99
ChatGPT provides clear and understandable explanations for thermodynamics concepts.	30 (25.0%)	54 (45.0%)	22 (18.3%)	14 (11.7%)	2.83	0.95
Using ChatGPT in learning thermodynamics can enhance students' academic performance	28 (23.3%)	60 (50.0%)	22 (18.3%)	10 (8.3%)	2.88	0.86
ChatGPT is an engaging and interactive platform for learning Chemistry topics.	40 (33.3%)	38 (31.7%)	28 (23.3%)	14 (11.7%)	2.87	1.02

Source: Researcher's Field Survey 2025

**Note:** M= Mean; SD = Standard Deviation; Standard Reference Mean = 2.50; Mean Response Rating Classification: High = 3.00 - 4.00; Moderate = 2.00 – 2.99; Low = 1 – 1.99.

As it was shown in Table 1, students perceived ChatGPT to be very very good learning tool for thermodynamics. All the item mean scores were between 2.83 and 3.12, which is above the benchmark mean

of 2.50, implying moderate to high acceptance. The positive perceptions expressed by students further reinforce its educational potential.

### Test of Hypotheses

**H<sub>01</sub>:** There is no significant difference in academic performance between the two groups before intervention

Table 3: Independent Sample t-test (Pre-test Scores)

Variable	Group	N	Mean	SD	t	Df	p-value
Pre-test	Control	60	18.20	4.10			
	Experimental	60	18.35	4.05	-0.21	118	0.834

Source: Researcher’s Field Survey 2025

Table 3 shows the results of an independent samples t-test comparing the pre-test scores in the experimental and control groups of students. These results indicate that the mean scores of the control group (M=18.20, SD=4.10) and experimental group (M = 18.35, SD = 4.05) were similar at the baseline. According to the t-test (t = -0.21, df = 118, p = 0.834), the difference between the two groups is not significant at the level of 0.05, and hence, both groups were homogeneous in terms of the prior knowledge and academic competence before the instructional intervention. This finding is methodological as it provides baseline equivalence, which strengthens the internal validity of the study. As such, it is possible to attribute any differences found after the tests with a greater degree of confidence to the ChatGPT-supported instructional intervention in favour of previously existing group differences.

**H<sub>02</sub>:** There is no significant difference in academic performance between students taught thermodynamics using ChatGPT and those taught through conventional methods.

Table 4: Independent Sample t-test (Post-test Scores)

Variable	Group	N	Mean	SD	t	Df	p-value
Post-test	Control	60	26.10	4.20			
	Experimental	60	34.00	3.90	-9.12	118	0.000

Source: Researcher’s Field Survey 2025

Table 4 shows the independent samples t-test analysis of post-test scores between the experimental and control groups after the instructional intervention, showing a significant difference (M = 34.00, SD = 3.90) with the experimental group outperforming the control group (M = 26.10, SD = 4.20). The computed t-value (t = -9.12, df = 118) with a p-value of 0.000 indicates that the observed difference is statistically significant at the 0.05 level. Importantly, the magnitude of the mean difference (approximately 7.90 points) indicates not only statistical but also practical and educational significance. This suggests that incorporating ChatGPT into instruction led to a significant improvement in students' understanding of thermodynamic concepts. The findings back up the claim that AI-assisted learning environments can improve cognitive engagement, conceptual clarity, and academic outcomes in science education.

Table 5: Group Statistics (Gain Score)

Group	N	Mean Gain	SD	Std. Error
Control Group	60	7.90	4.10	0.53
Experimental Group	60	15.65	3.95	0.51

Table 5 above shows the group means, which shows the approach that has given a larger Table 5 shows the descriptive statistics for gain scores, which are the differences between pre-test and post-test performance in both groups. The experimental group achieved a significantly higher mean gain score (M = 15.65, SD = 3.95) than the control group (M = 7.90, SD = 4.10). This suggests that students who received ChatGPT-supported

instruction learned nearly twice as much as those who were taught using traditional methods. The relatively low standard deviations in both groups indicate a reasonable level of consistency in performance improvements, with the experimental group showing slightly more stability.

## DISCUSSION OF FINDINGS

This study demonstrates that ChatGPT can be an effective instructional tool for improving students' academic performance in thermodynamics. The students' attitudes in Table 1 indicate that students had a favorable attitude towards the use of ChatGPT as a tool for learning thermodynamics, with all mean scores above 2.50. Students stated that ChatGPT created a positive environment for learning and facilitated their comprehension of complex concepts while also contributing to their confidence in problem-solving. This supports the notion proposed by Harackiewicz et al. (2016) that students' interest is an important factor of academic engagement and achievement. The interactive and user-friendly nature of ChatGPT motivated students and diminished the anxiety that is commonly associated with the study of thermodynamic concepts, and is in agreement with the findings of Dimeli and Kostas (2025) that ChatGPT improves students' cognitive engagement and critical thinking in education.

In perceived effectiveness (Table 2), students considered ChatGPT to be a useful, comprehensible, and informative learning tool. The high average scores demonstrated the appreciation of learners of the platform in the explanation of abstract concepts and the facilitation of autonomous learning. This result supports the findings of Almogren, Al-Rahmi, and Dahri (2024) who stated that perceived usefulness and ease of use dominate students' acceptance of ChatGPT in higher education. In the same way, Araújo and Saúde (2024) stated that ChatGPT has the potential to improve teaching and learning processes by providing clear explanations and promoting students' active learning in chemistry teaching.

From the hypothesis testing, we have proof of the effectiveness of the intervention. From the pre-test results (Table 3), we observe no significant differences for the experimental and control groups ( $p = 0.834$ ), confirming the equivalence of the means. This strengthens the internal validity of the study and affirms that the observed differences after the intervention are due to ChatGPT-assisted instruction as opposed to differences in prior knowledge. The post-test data in Table 4 demonstrated a statistically significant difference in favor of the experimental group ( $p = 0.000$ ), meaning participants who received instruction that integrated ChatGPT outperformed participants who received instruction that was purely traditional. This result is in line with Wang and Fan (2025), whose meta-analysis showed a positive effect of ChatGPT on students' learning outcomes and higher-order thinking skills. Bettayeb et al. (2024) also mentioned that ChatGPT helps students stay engaged and gives them instant feedback, thus improving their academic performance.

The gain score analysis (Table 5) reinforces these findings. The experimental group achieved nearly double the learning gains of the control group. This shows that ChatGPT not only boosts immediate performance but also supports deeper and lasting learning. ChatGPT's ability to provide step-by-step explanations and different problem-solving approaches may account for this significant improvement. This observation matches what Kodkin and Artem'eva (2024) noted about ChatGPT's role in aiding understanding and problem-solving in chemistry education. Additionally, these findings support earlier studies, like those by Babalola, Ahmad, and Tafida (2024), which highlighted that technology-based learning environments can greatly improve students' interest, critical thinking, and academic success in chemistry. The current study builds on this evidence by offering context-specific data from Nigeria, addressing the gap in the literature about using AI tools in developing countries. However, these positive outcomes also connect with concerns raised by Fergus et al. (2023) about potential limits of ChatGPT, especially in more complex cognitive tasks and issues around academic honesty. This highlights the need for careful implementation and effective instructional design when adding AI tools into classrooms.

In summary, the results show that ChatGPT significantly improves students' academic performance, encourages positive learning attitudes, and is seen as an effective teaching tool. These findings are well-supported by existing studies and strengthen the growing belief that AI technologies can change science education when used properly

## CONCLUSIONS

According to the results of the research, it can be concluded that the attitude of Chemistry students towards using ChatGPT in learning Thermodynamics is positive. Students find ChatGPT useful, entertaining, and helpful as a tool that enhances conceptual knowledge and academic achievement. Moreover, the use of ChatGPT as an auxiliary learning tool has demonstrated a considerable improvement in the academic outcomes of the students in comparison to traditional approaches. These results show the possibility of AI-based educational technologies to be used to supplement traditional classroom teaching, especially in advanced science subjects.

## RECOMMENDATIONS

Based on the results of the study, it is possible to suggest the following recommendations:

1. Schools and higher-education institutions are advised to introduce AI tools, including ChatGPT, to science education to help students in their better understanding of complicated subjects and improve their academic outcomes.
2. To ensure the optimal educational effects on learners, chemistry instructors need to be trained on how to use AI-based applications such as ChatGPT in their teaching.
3. The policymakers in education should reform the science curriculum and include AI tools since they have the potential to promote personalized and interactive learning.
4. It is recommended to conduct further studies at various levels of education and in different classes to assess the effectiveness and difficulties of AI-based products like ChatGPT in the classroom.
5. To deploy AI technologies in education, school authorities need to ensure that there is proper digital infrastructure and resources, such as a good internet connection and computing equipment.

## REFERENCES

1. Almogren, A. S., Al-Rahmi, W. M., & Dahri, N. A. (2024). Exploring factors influencing the acceptance of ChatGPT in higher education: A smart education perspective. *Heliyon*, 10(11).
2. Araújo, J. L., & Saúde, I. (2024). Can ChatGPT enhance chemistry laboratory teaching? Using prompt engineering to enable AI in generating laboratory activities. *Journal of Chemical Education*, 101(5), 1858-1864.
3. Babalola, V. T., Ahmad, S. S., & Tafida, H. S. (2024). ChatGPT in Organic Chemistry Classrooms: Analyzing the Impacts of Social Environment on Students' Interest, Critical Thinking and Academic Achievement. *International Journal of Education and Teaching Zone*, 3(1), 60-72.
4. Bettayeb, A. M., Abu Talib, M., Sobhe Altayasinah, A. Z., & Dakalbab, F. (2024, July). Exploring the impact of ChatGPT: conversational AI in education. In *Frontiers in Education* (Vol. 9, p. 1379796). Frontiers Media SA.
5. Boesdorfer, S. B. (2019). Advancing Professional Knowledge and Skills for Chemistry Teaching through an Online Master's Degree for Secondary-Level Chemistry Teachers. In *Best Practices in Chemistry Teacher Education* (pp. 53-66). American Chemical Society.
6. Bradford, A., & Hamer, A. (2022). Science and the scientific method: Definitions and examples. Published January, 17, 2022.
7. Dimeli, M., & Kostas, A. (2025). The role of ChatGPT in education: Applications, challenges, and insights from a systematic review. *Journal of Information Technology Education. Research*, 24, 2.
8. Duchaeva, R., & Magomadov, S. (2023). Current Environmental Problems and their Solutions with the Help of New Technologies. In *BIO Web of Conferences* (Vol. 63, p. 07012). EDP Sciences.
9. Fergus, S., Botha, M., & Ostovar, M. (2023). Evaluating academic answers generated using ChatGPT. *Journal of Chemical Education*, 100(4), 1672-1675.
10. Ganesan, S., Padmapriya, G., & De Zoysa, A. S. A. (2024). Conscientiousness of environmental concepts in sustainable development and ecological conservation. *Physical Sciences Reviews*, 9(1), 227-234.
11. Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education. *Policy insights from the behavioral and brain sciences*, 3(2), 220-227.

12. Isinkaye, K. A. (2023). The Impact of Scientific and Technological Innovations on International Relations in the Age of Globalization. *NIU Journal of Social Sciences*, 9(4), 51-57.
13. Klayklung, P., Chocksathaporn, P., Limna, P., Kraiwanit, T., & Jangjarat, K. (2023). Revolutionizing education with ChatGPT: Enhancing learning through conversational AI. *Universal Journal of Educational Research* 2 (3):217-225
14. Kodkin, V. L., & Artem'eva, E. V. (2024). ChatGPT: Application in chemistry education and challenges. *Journal of Computer and Communications*, 12(3), 196-206.
15. Luo, H. (2021). Working together to address global issues: Science and technology and sustainable development. *Cultures of Science*, 4(1), 3-5.
16. Rojas, A. J. (2024). An investigation into ChatGPT's application for a scientific writing assignment. *Journal of Chemical Education*, 101(5), 1959-1965.
17. Wang, J. & Fan, W. (2025). The effect of ChatGPT on students' learning performance, learning perception, and higher-order thinking: insights from a meta-analysis. *Humanities and Social Sciences Communications* 12, 621.