e-ISSN 3050-9599
p-ISSN 2795-3264

10.5281/zenodo.15301619 Vol. 08 Issue 03 March - 2025 Manuscript ID: #01876

DEVELOPING THE ABILITY TO GAIN KNOWLEDGE AND COMMUNICATE THROUGH STEM EDUCATION: RESULTS FROM A PRACTICAL SURVEY

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Abstract

This study investigates the current state of STEM education in high school Chemistry and its role in developing students' abilities to gain knowledge and communicate. STEM (Science, Technology, Engineering, and Mathematics) education integrates interdisciplinary approaches to enhance students' inquiry skills, critical thinking, and problem-solving abilities. The research, conducted through a survey of 82 Chemistry teachers, reveals that while educators recognize the value of STEM in fostering students' scientific exploration, challenges such as insufficient resources, time constraints, and a lack of professional development hinder effective implementation. Despite these barriers, teachers expressed strong support for STEM education and a desire for additional training and resources. The findings suggest that providing teachers with more resources, flexible teaching time, and targeted professional development would improve the integration of STEM in Chemistry education, thus fostering a deeper gaining knowledge and communication among students.

Keywords:

STEM, Chemistry, Scientific inquiry, Competence, Education challenges.

How to cite: Do, N. (2025). DEVELOPING THE ABILITY TO GAIN KNOWLEDGE AND COMMUNICATE THROUGH STEM EDUCATION: RESULTS FROM A PRACTICAL SURVEY. *GPH-International Journal of Educational Research*, 8(03), 276-288. https://doi.org/10.5281/zenodo.15301619

1. Introduction

STEM (Science, Technology, Engineering, and Mathematics) education has become a focal point in modern education, particularly as it provides an interdisciplinary approach to learning that mirrors real-world challenges. The integration of STEM fosters critical thinking, problem-solving skills, and an enhanced gaining knowledge and communication. Among the various subjects(Joyner & Parks, 2023; Sommier et al., 2022), Chemistry plays a vital role in helping students investigate and comprehend the complexities of the natural world, from molecular structures to the reactions that shape everyday phenomena(Akcan et al., 2023; Ardoin et al., 2023; Arshad, 2021). Therefore, developing students' abilities to gain knowledge and communicate through Chemistry is an essential aspect of education, especially in preparing them for future scientific and technological challenges(Aikenhead, 2005; Bakhurst, 2021; Batdi et al., 2019).

The implementation of STEM education in Vietnam has gained momentum, with the aim of improving students' scientific inquiry abilities. However, the integration of STEM into school curricula, particularly in Chemistry, remains a challenging endeavor(Martin & Scantlebury, 2009). Research shows that while STEM initiatives are being embraced, significant obstacles still hinder the effective application of these approaches in secondary school Chemistry education. STEM education has the potential to transform student learning by bridging theoretical concepts with practical applications(Bozkurt Altan & Tan, 2021; Chiang et al., 2020), yet teachers often face difficulties in translating this potential into effective classroom practices(Martin & Scantlebury, 2009; Rickey & Stacy, 2000).

In the context of Chemistry, STEM approaches can significantly enhance the development of students' inquiry skills(Rickey & Stacy, 2000). STEM education allows for the exploration of Chemistry in conjunction with other disciplines such as Physics, Biology, and Technology, creating a more holistic view of scientific phenomena. Priyambodo et al(2020) emphasize the importance of inquiry-based learning in Chemistry, arguing that it fosters deeper engagement and a more profound understanding of the subject matter(Martin & Scantlebury, 2009). However, the extent to which STEM methods are currently integrated into Chemistry teaching varies widely(Priyambodo et al., 2020). While some educators successfully incorporate STEM activities, many face challenges in designing and implementing effective STEM curricula.

This research aims to assess the current state of STEM education in Chemistry, particularly in high school classrooms, and to investigate the teachers' ability to foster students' inquiry skills in the natural world(Epstein & Hundert, 2002; Nguyen et al., 2024). Successful STEM teaching in Chemistry is largely dependent on teachers' confidence and competence in integrating various scientific disciplines and applying inquiry-based methods. The study will explore key research questions:

1. What is the level of awareness and competence of Chemistry teachers in implementing STEM education in their classrooms?
2. What barriers hinder the effective integration of STEM into Chemistry teaching?

3. How can the development of students' inquiry skills in Chemistry be enhanced through STEM approaches?

The findings of this study will provide valuable insights into the challenges and opportunities of STEM in Chemistry education and suggest practical recommendations for improving its integration into the curriculum. By addressing the issues surrounding the implementation of STEM in Chemistry, this research seeks to contribute to the improvement of teaching practices and the enhancement of students' abilities to gain knowledge and communicate through Chemistry.

2. Research Methodology

2.1. Data collection method

The data for this research were collected using a structured questionnaire, designed to gather information on Chemistry teachers' practices, attitudes, and challenges related to the implementation of STEM education in their classrooms. The questionnaire consisted of both closed and open-ended questions, enabling the collection of both quantitative and qualitative data.

Closed-ended questions used a Likert scale to assess teachers' perceptions of STEM education, their level of confidence in implementing STEM activities, and the frequency with which they incorporate STEM into their teaching practices. This approach allows for the collection of measurable data on teachers' engagement with STEM and their self-assessment of their abilities. Additionally, multiple-choice and yes/no questions were included to capture specific details about the availability of resources, institutional support, and the barriers teachers face when attempting to integrate STEM into Chemistry education.

Open-ended questions were included to allow teachers to provide detailed, qualitative feedback regarding their experiences with STEM education. These questions aimed to capture the challenges teachers encounter, the resources they require, and their suggestions for improving the integration of STEM in Chemistry teaching. By including these open-ended questions, the study sought to gather in-depth insights into the teachers' perspectives that may not be fully captured through quantitative measures.

The questionnaire was distributed online to facilitate easy access and participation from a diverse sample of Chemistry teachers across different schools. To ensure anonymity and encourage honest responses, participants were assured that their identities would not be linked to their answers.

2.2. Data analysis method

The collected data were analyzed using both quantitative and qualitative methods to provide a comprehensive understanding of the current state of STEM implementation in Chemistry education.Data from the closed-ended questions were analyzed using descriptive statistics to identify trends, frequencies, and patterns in teachers' practices and perceptions of STEM

education. Statistical measures, such as means and standard deviations, were used to assess the general attitudes of teachers toward STEM, as well as their reported levels of confidence in applying STEM methods in their classrooms. In addition, the reliability of the questionnaire was evaluated using Cronbach's Alpha to ensure internal consistency, with a score above 0.7 considered satisfactory for this type of analysis.The open-ended responses were analyzed thematically to identify common themes and recurring patterns in teachers' experiences with STEM education. Thematic analysis allowed the researcher to examine teachers' personal accounts of the challenges they face, the support they need, and their suggestions for improving STEM implementation. This approach helps to contextualize the quantitative findings by providing a deeper understanding of the underlying factors affecting STEM integration in Chemistry education.

The combination of these two methods quantitative and qualitative ensures that the data analysis offers both broad patterns and nuanced insights, enabling a comprehensive evaluation of STEM education in the context of Chemistry teaching.

3. Survey results

3.1. Survey subjects

Table 1. Classification of survey subjects by gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	29	35.4	35.4	35.4
	female	53	64.6	64.6	100.0
	Total	82	100.0	100.0	

The results show that the majority of the survey participants are female, comprising 64.6% of the total respondents, while 35.4% are male. This gender distribution is reflective of the overall demographic trends in the teaching profession, where there tends to be a higher proportion of female educators, especially in subjects such as Chemistry. The gender imbalance in the sample does not significantly impact the research, as the focus is on understanding general trends in STEM education practices and challenges across all teachers, regardless of gender. However, it is worth noting that future research could explore gender-related differences in STEM teaching practices, particularly in the context of Chemistry education.

Table 2. Classification of survey subjects by level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bachelor's	63	76.8	76.8	76.8
	Master's	19	23.2	23.2	100.0
	Total	82	100.0	100.0	

The majority of the survey participants hold a Bachelor's degree in Chemistry (76.8%), while 23.2% have a Master's degree. This distribution suggests that the majority of teachers in this sample have foundational qualifications in the field, with a smaller proportion having advanced academic training. This finding is significant because it indicates that while many teachers may have strong disciplinary knowledge, a smaller proportion may have received specialized training in advanced educational methods or STEM teaching practices. It is important for the study to consider the potential correlation between educational level and the teachers' confidence and ability to implement STEM education in Chemistry.

Table 3. Classification of survey subjects by number of years of work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under 5 years	29	35.4	35.4	35.4
	From 5 to 10 years	14	17.1	17.1	52.4
	Overs 10 years	39	47.6	47.6	100.0
	Total	82	100.0	100.0	

The survey reveals that a substantial portion of the participants (47.6%) have over 10 years of teaching experience, followed by 35.4% with less than 5 years of experience, and 17.1% with 5-10 years. This distribution reflects a broad range of teaching experience, ensuring that the study captures perspectives from both novice and seasoned educators. The diverse experience levels are important because they may influence the teachers' approaches to STEM education, with more experienced teachers potentially having more established practices or greater confidence in integrating STEM concepts, while newer teachers might bring fresh perspectives or more recent training in modern educational techniques. Understanding these variations helps the study address the challenges teachers face at different stages of their careers when implementing STEM education in Chemistry.

3.2. Assessment of scale reliability

Table 4. Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.767	.763	24

The reliability analysis of the survey data, measured by Cronbach's Alpha, resulted in a score of 0.767, indicating acceptable internal consistency of the questionnaire. A Cronbach’s Alpha value above 0.7 is generally considered satisfactory, confirming that the items used in the survey are reliable and consistently measure the constructs they were designed to assess. The slightly lower value for "Cronbach's Alpha Based on Standardized Items" (0.763) also supports this conclusion, suggesting that the items on the questionnaire are appropriately constructed and are functioning as intended. This high level of reliability ensures that the

results of the survey can be considered valid and trustworthy, which is critical for drawing conclusions about the state of STEM education in Chemistry.

Table 5. Item Statistics

	Mean	Std. Deviation	N
Q1	4.0366	1.08235	82
Q2	3.8537	1.00765	82
Q3	3.8902	.99388	82
Q4	4.1220	.90799	82
Q5	4.1341	.84272	82
Q6	3.8049	.98681	82
Q7	3.7561	1.03710	82
Q8	4.3537	.70923	82
Q9	3.7317	1.14449	82
Q10	4.0366	.93551	82
Q11	4.1707	.76666	82
Q12	4.2561	.75049	82
Q13	4.3537	.72643	82
Q14	4.0732	.88583	82
Q15	4.2561	.78270	82
Q16	4.4634	.65159	82
Q17	4.3537	.86598	82
Q18	4.3415	.72384	82
Q19	4.2073	.79718	82
Q20	4.3049	.79643	82
Q21	3.7927	1.16256	82
Q22	4.1585	.85302	82
Q23	4.1098	1.03048	82
Q24	4.4024	.79907	82

The item statistics table presents the mean and standard deviation for each of the 24 survey items. The mean scores generally indicate a high level of agreement among respondents, with many items scoring above 4.0 on the Likert scale, suggesting that teachers tend to agree with the statements about the integration of STEM into Chemistry teaching. Items with higher means, such as Q8 (4.3537) and Q16 (4.4634), indicate strong agreement with the perceived importance and effectiveness of STEM education in developing students' inquiry skills in Chemistry. Conversely, items with slightly lower mean values, like Q3 (3.8902) and Q21 (3.7927), suggest that while teachers recognize the importance of inquiry-based learning, there may be some reservations or challenges in implementing certain aspects of STEM education effectively, particularly related to specific teaching methods or available resources.

The standard deviations indicate a moderate spread of responses, with values generally ranging from 0.65 to 1.16, reflecting some variability in teachers' experiences and

perceptions. This suggests that while many teachers strongly support STEM education, there are also differing views on its implementation, highlighting areas where further training or resources may be needed to increase consistency across the sample. Overall, the item statistics reinforce the conclusion that while teachers are largely positive about STEM education, there remain key areas for improvement, particularly in terms of practical implementation and teacher confidence.

3.3. Current status of teaching to develop students' ability to gain knowledge and communicatefrom the chemistry perspective

The results from the survey reveal the current state of Chemistry teachers' implementation of teaching practices that aim to develop students' ability to gain knowledge and communicate, specifically through the integration of STEM approaches in their teaching. The survey questions in the appendix focused on the frequency with which teachers integrate activities and examples that allow students to connect Chemistry concepts with real-world phenomena, and how they assess students' inquiry abilities.

One key observation from the results is that a significant number of teachers report regularly integrating activities that help students understand natural phenomena through Chemistry. For example, item Q1, which asks if teachers frequently incorporate content and activities that help students explore natural phenomena related to Chemistry, has a high mean score of 4.0366 (SD = 1.08235). This indicates that most teachers agree or strongly agree with the statement, suggesting that they actively incorporate real-world examples and inquiry-based activities into their lessons.

Similarly, teachers show a strong emphasis on using practical examples to help students recognize the role of Chemistry in explaining natural phenomena. Item Q2, which asks whether teachers use real-world examples to illustrate the significance of Chemistry, received a mean score of 3.8537 (SD = 1.00765). Although slightly lower than Q1, this still reflects a positive trend towards utilizing contextualized examples to connect theoretical Chemistry knowledge with everyday life, which is essential for fostering students' curiosity and understanding.

Furthermore, when asked about encouraging students to ask questions, form hypotheses, and conduct experiments to explore Chemistry-related issues in nature (Q3), the mean score of 3.8902 (SD = 0.99388) indicates a strong tendency to promote active student engagement in scientific inquiry. However, there appears to be room for further improvement in fostering this inquiry mindset, as this score is slightly lower than that of Q1 and Q2, suggesting that while teachers encourage student exploration, they may face challenges in providing enough hands-on opportunities for students to practice scientific inquiry fully.

Teachers also report using various assessment methods to evaluate students' ability to gain knowledge and communicate through Chemistry. Item Q4, which inquires about using assessment methods such as observation, Q&A, and project-based tasks to evaluate students'

inquiry skills, shows a mean score of 4.1220 (SD = 0.90799). This indicates that teachers are incorporating diverse assessment strategies to gauge how well students are developing their inquiry skills, with project-based assignments likely playing a key role in fostering deeper learning.

Despite the positive findings, the results also suggest some areas for improvement. The mean score of 3.8049 (SD = 0.98681) for item Q6, which asks whether the current Chemistry curriculum facilitates the development of students' ability to gain knowledge and communicate, indicates that some teachers feel that the existing curriculum may not always provide sufficient support for these teaching goals. This could reflect a gap between the theoretical aspirations of the curriculum and the practical challenges teachers face in implementing STEM-focused activities in the classroom.

In conclusion, while the survey results suggest that many Chemistry teachers are integrating STEM approaches into their teaching to develop students' ability to gain knowledge and communicate, there are varying degrees of success across different areas. Teachers are generally positive about using real-world examples and encouraging inquiry-based learning, yet challenges remain in fully utilizing these approaches consistently and effectively. Further professional development, curriculum adjustments, and resource enhancements are needed to support teachers in enhancing their ability to foster students' inquiry skills and deepen their gaining knowledge and communication through Chemistry.

3.4. Current status of STEM education implementation in chemistry teaching

The survey results highlight the current state of STEM education integration into Chemistry teaching. A significant proportion of teachers report a strong understanding of the role and importance of STEM in the educational process. Item Q7, with a mean score of 4.3537 (SD = 0.70923), reflects that most teachers acknowledge the value of STEM education in enhancing students' learning experiences. Additionally, item Q8 shows that a majority of teachers (mean = 3.7317, SD = 1.14449) work in schools that encourage or have plans to integrate STEM into their curriculum.

However, challenges persist in the effective implementation of STEM in Chemistry classrooms. Item Q9, which asks about the frequency of teachers organizing STEM activities, shows a relatively lower mean score of 3.8049 (SD = 0.98681), indicating that while STEM activities are being introduced, they may not be consistent or widespread across all lessons. Furthermore, difficulties in organizing STEM-related projects are reflected in item Q14 (mean = 4.0732, SD = 0.88583), where teachers express challenges in developing engaging and appropriate STEM topics for students.

The availability of resources and institutional support also appears to be a concern. Items such as Q11, which assesses the adequacy of school resources for STEM activities (mean = 4.1707, SD = 0.76666), suggest that while some schools provide sufficient resources, many

teachers still face limitations. This is further supported by responses to Q12, where a significant number of teachers report inadequate support from school administration.

In conclusion, while there is a general understanding and support for STEM in Chemistry education, the integration of STEM practices remains uneven, with notable challenges related to resource availability, time constraints, and support from school management. To enhance the effectiveness of STEM education in Chemistry, further support and training are needed to help teachers overcome these barriers.

3.5. Challenges and needs of teachers

The survey results highlight several challenges that teachers face when implementing STEM education in Chemistry instruction. One of the primary issues is the lack of adequate resources and equipment necessary to conduct effective STEM activities. As shown in item Q11 (mean = 4.1707, SD = 0.76666), there is a noticeable disparity between schools in terms of resource availability. Many teachers reported that the equipment and materials needed for STEM projects and experiments are insufficient, making it difficult to engage students in hands-on, real-world activities that are central to STEM learning. This lack of resources significantly impacts the quality of STEM teaching and students' learning experiences.

Another major challenge is time constraints, as teachers struggle to integrate STEM activities within the existing Chemistry curriculum. Item Q13 (mean = 4.0732, SD = 0.88583) indicates that many teachers feel limited by the time available in the school schedule to carry out STEM-related projects and experiments. The existing curriculum, with its already packed content, leaves little room for in-depth, inquiry-based activities, which are essential for developing students' scientific inquiry skills. This time limitation reduces the potential for teachers to fully implement STEM teaching strategies, hindering the overall educational experience.

Additionally, teachers expressed a strong need for further professional development in STEM teaching methods. As indicated in item Q17 (mean = 4.3537, SD = 0.86598), many teachers are eager to receive more specialized training in designing and implementing effective STEM activities in Chemistry. Teachers indicated that professional development opportunities would be instrumental in improving their ability to integrate STEM into their lessons, ultimately helping to enhance students' ability to gain knowledge and communicate.
In summary, while teachers recognize the importance of STEM education, they face significant barriers related to resources, time, and professional development. Providing additional support, training, and resources will be critical to overcoming these challenges and improving STEM education in Chemistry.

5. Conclusion

This research provides valuable insights into the current state of STEM education in Chemistry and its role in developing students' abilities to gain knowledge and communicate. The study reveals that while many Chemistry teachers acknowledge the importance of STEM education, challenges remain in fully integrating STEM approaches into classroom practices. Teachers report using real-world examples and inquiry-based activities, but they face barriers such as insufficient resources, time constraints, and a lack of professional development opportunities. Despite these challenges, there is strong support among teachers for STEM education and a clear desire for additional training and resources to enhance their teaching practices.

The significance of this study lies in its identification of the factors influencing the successful implementation of STEM in Chemistry teaching. It underscores the importance of providing teachers with better access to resources, more flexible teaching time, and specialized training to strengthen their ability to teach STEM effectively. This research highlights the need for school administrators and policymakers to prioritize STEM education by offering ongoing professional development and ensuring the availability of necessary resources. By addressing these issues, STEM education can more effectively develop students' inquiry skills, fostering a deeper gaining knowledge and communication from a Chemistry perspective.

However, there are limitations to this study. The sample size, though representative, is limited to a specific region and may not fully capture the experiences of all Chemistry teachers across the country. Furthermore, the survey primarily focuses on teachers' self-reported practices, which may not always align with actual classroom behavior. Future research could expand the sample size to include a more diverse range of schools and regions. Additionally, it would be beneficial to observe classroom practices directly to gain a deeper understanding of how STEM is implemented in practice.

Future research should also explore the long-term impact of STEM education on students' learning outcomes and attitudes towards Chemistry. Investigating the effectiveness of specific STEM teaching strategies, as well as the role of collaborative teaching across subjects, would offer further insights into how to optimize STEM education to meet the needs of students and prepare them for future scientific challenges.

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7. Appendix

TEACHER SURVEY

(Regarding: The current status and needs of implementing teaching to develop the ability to gain knowledge and communicate from the chemistry perspective through STEM education in secondary schools)

Dear Teachers,

My name is Do Hong Ngoc, and I am currently a PhD candidate at Hanoi University of Education. I am conducting research for my doctoral thesis on "DEVELOPING THE ABILITY TO GAIN KNOWLEDGE AND COMMUNICATE THROUGH STEM EDUCATION IN GRADE 11 CHEMISTRY LESSONS."

The purpose of this research is to examine the current state of the attention given to and the implementation of activities aimed at developing students' ability to gain knowledge and communicate through Chemistry in the context of STEM education. The study will assess the status of STEM education implementation in secondary school Chemistry classrooms and identify the needs and concerns of teachers in effectively carrying out this teaching method.

The information collected from this survey will serve as an important basis for completing my research and will help propose appropriate solutions to enhance the quality of Chemistry teaching based on student capability development and STEM education.

I kindly ask you to take about 10-15 minutes to complete this survey. All personal information and responses will be kept confidential and used solely for the purpose of my research.

Your participation and candid feedback will be invaluable to my study.

If you have any questions, please feel free to contact me at [Phone number 0348.997.673] or email: dohongngoc224@gmail.com

Thank you very much for your cooperation!

PART A: PERSONAL INFORMATION

(Please check ✓ or X in the corresponding box or fill in the blank spaces)

- Gender: ☐ Male ☐ Female
- Years of teaching experience in Chemistry: ☐ Less than 5 years ☐ 5 to 10 years ☐ Over 10 years
- Highest level of education: ☐ Bachelor's degree ☐ Master's degree ☐ PhD
- Type of school: ☐ Public High School ☐ Private High School ☐ Specialized High School ☐ Continuing Education Center

Please read each statement carefully and indicate your level of agreement by marking ✓ or X according to the following scale:

1 = Strongly Disagree; 2 = Disagree; 3 = Neutral/No Opinion; 4 = Agree; 5 = Strongly Agree

PART B: CURRENT STATUS OF DEVELOPING THE ABILITY TO GAIN KNOWLEDGE AND COMMUNICATE THROUGH CHEMISTRY

Q1. I regularly integrate content and activities that help students explore natural phenomena related to Chemistry into my lessons.

Q2. I emphasize using real-world examples to help students understand the role of Chemistry in explaining natural phenomena.
Q3. I encourage students to ask questions, propose hypotheses, and perform experiments/observations to explore Chemistry issues in nature.
Q4. I use various assessment methods (e.g., observation, Q&A, project-based tasks) to assess students' abilities in this area.
Q5. I feel confident in my ability to design and organize activities that develop these skills for students.
Q6. The current Chemistry program and textbooks facilitate the development of these abilities in students.

PART C: CURRENT STATUS OF STEM EDUCATION IMPLEMENTATION IN CHEMISTRY TEACHING

Q7. I understand the nature and role of STEM education in the current educational context.
Q8. My school has plans or policies to encourage the implementation of STEM education.
Q9. I have organized STEM activities/topics in my Chemistry lessons (especially in Grade 11 Chemistry).
Q10. The STEM activities I organize often integrate Chemistry knowledge and skills with other fields (Physics, Biology, Technology, etc.).
Q11. My school provides sufficient resources, equipment, and materials to implement STEM teaching in Chemistry.
Q12. I receive full support from the administration and colleagues in implementing STEM education.
Q13. I face time constraints when implementing STEM projects/topics in the Chemistry curriculum.
Q14. I encounter challenges in developing engaging and appropriate STEM topics for students.
Q15. I struggle with assessing students' learning outcomes in STEM activities/projects.
Q16. I believe that teaching through STEM topics is an effective way to develop students' ability to gain knowledge and communicatefrom a Chemistry perspective.

PART D: TEACHER NEEDS TO IMPLEMENT STEM EDUCATION AND DEVELOP STUDENT CAPABILITIES

Q17. I would like to receive in-depth training on STEM teaching methods in Chemistry.
Q18. I would like training on how to design activities to develop the "Ability to gain knowledge and communicate from a Chemistry Perspective."
Q19. I would like access to reference materials and sample STEM lesson plans for Chemistry (especially for Grade 11).
Q20. I would like to receive support in terms of resources, equipment, chemicals, and lab materials to implement STEM education.
Q21. I would appreciate more flexible time allocations in the curriculum to implement STEM projects.
Q22. There should be mechanisms and policies that encourage and motivate teachers to actively innovate teaching methods and implement STEM education.
Q23. I would like more opportunities to exchange and share experiences on STEM education implementation with colleagues within and outside my school.
Q24. I would like clear guidance on how to assess student capabilities (especially the ability to gain knowledge and communicate) through STEM education.

PART E: OTHER COMMENTS

Do you have any other suggestions or comments related to the development of the ability to gain knowledge and communicate through Chemistry and the implementation of STEM education?

Thank you again for your valuable cooperation and feedback!