Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

# Scientific Communication: An Opportunity for Enhancing Pre-service Science Teachers' Implementing Scientific Communication in School Contexts

Witsanu Suttiwan[1]*, Thapana Choicharoen[1], Eliyawati Eliyawati[2], Ananta Ardyansyah[3]

[1]Department of Science Education, Faculty of Education Valaya Alongkorn Rajabhat University under the Royal Patronage, Pathum Thani, Thailand
[2]Department of Biology Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
[3]Chemistry Departement, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia

*Corresponding author: witsanu@vru.ac.th

**ABSTRACT** This study explored pre-service science teachers' views on s scientific communication. Ten participants from Valaya Alongkorn Rajabhat University, enrolled in a Scientific Communication course, were interviewed using open-ended questions. Findings revealed that while they understood the importance of scientific communication, their understanding was largely limited to classroom settings, focusing on teacher-student interactions. They prioritized visuals, multimedia, and simplified language as communication strategies. However, their awareness of broader applications, like public engagement and policymaking, was limited. Many lacked experience in tailoring messages for diverse audiences, including avoiding jargon. The study highlights a need for comprehensive scientific communication training in teacher education. Experiential learning, collaboration with science communicators, and digital media integration are recommended. Future research should examine the impact of structured training on long-term skill development. Enhancing these skills will better equip future teachers to effectively communicate science in various contexts, improving public scientific literacy.

**Keywords** Scientific communication, Science teaching, Pre-service science teachers, Public engagement, Teacher education

## 1. INTRODUCTION

Scientific communication plays a crucial role in bridging the gap between scientific knowledge and society by making complex scientific concepts accessible, engaging, and relevant to diverse audiences (Burns et al., 2003; Cormick, 2022; O'neill & Holmes, 2022). It encompasses various strategies and platforms, including traditional classroom instruction, media-based communication, and public engagement initiatives, to ensure that scientific information is effectively conveyed to students, policymakers, and the general public (Elmi et al., 2024; Jucan & Jucan, 2014; Mccallie et al., 2009). In more specific terms, scientific communication is also interpreted as a complex and interconnected system of delivering research results through journals (Gass, 2014; Hurd, 2004). However, regardless of its meaning, scientific communication is crucial and has become a significant concern in the post-truth era, where the continuity between scientists, policymakers, and the public is essential (Iyengar & Massey, 2019). In an era of abundant information and rapid technological advancements, effectively communicating with the public is highly challenging, which in turn influences public opinion (Leach, 2013). Effective scientific communication helps reduce intuitive assumptions, enables the public to gain a better understanding, and increases public trust in science (Committee on the Science of Science Communication, 2017; Intemann, 2023; Scheufele, 2013). Given the increasing societal reliance on scientific literacy for informed decision-making in areas such as health, climate change, and technology, science educators must be equipped with strong communication skills to effectively convey scientific knowledge beyond academic settings (Fischhoff, 2013; Rowe & Frewer, 2005).

**Received:** 04 March 2025
**Revised:** 12 April 2025
**Published:** 30 June 2025

Scientific communication involves conveying scientific ideas, findings, and concepts effectively across various audiences, including peers, policymakers, and the public. According to Burns et al. (2003), it includes the use of skills, media, and activities to promote awareness, enjoyment, interest, opinions, and understanding of science and its societal implications. Effective scientific communication bridges the gap between complex scientific knowledge and the public's need for accessible, relevant information. It plays a pivotal role in fostering informed decision-making, especially on pressing global challenges such as climate change and emerging technologies. As Fischhoff and Scheufele (2012) emphasize, it requires identifying critical knowledge gaps, designing clear messages, and evaluating their impact. Additionally, the two-way nature of communication, as described by McCallie et al. (2009), ensures that scientists not only disseminate information but also consider public perspectives, enabling collaborative dialogue and learning. Scientific communication is integral to establishing trust between science and society, ensuring ethical transparency, and addressing societal concerns about the risks and benefits of scientific advancements (Committee on the Science of Science Communication, 2017; Jucan & Jucan, 2014). Its multidimensional framework includes methods such as direct communication, consultation, and participatory engagement, tailored to the needs of specific audiences (Rowe & Frewer, 2005). Within the education system, the development of science teachers must prioritize the cultivation of strong scientific communication skills and competencies.

As future educators, pre-service science teachers must develop a comprehensive understanding of scientific communication, including its meaning, importance, and effective strategies. However, research suggests that many teacher education programs primarily focus on content knowledge and pedagogy, with limited emphasis on communication training (Goh et al., 2008; Khaokhajorn & Srisawasdi, 2024). A study also indicates that current training in scientific communication cannot fully achieve all learning objectives. There are gaps in training outcomes, particularly in the areas of affective learning and identity formation (Baram-Tsabari & Lewenstein, 2017). Consequently, many pre-service teachers perceive scientific communication narrowly, associating it mainly with classroom instruction rather than recognizing its broader implications in public engagement and policymaking (Guidotti, 2016). Addressing this gap in teacher education is essential for ensuring that future science teachers are well-prepared to communicate scientific concepts effectively in diverse contexts.

I (first author), a lecturer in the Faculty of Education, work within a field focused on producing competency-based science teachers in Thailand. During the 2024 academic year, I was responsible for teaching a Scientific Communication Course to students pursuing degrees in Chemistry and General Science education. The course curriculum, as outlined by Faculty of Education, Valaya Alongkorn Rajabhat University Under the Royal Patronage (VRU) (Faculty of Education, 2019), encompasses the study of principles and theories of scientific communication, the utilization of information technology in communication, and exploration of various communication formats such as infographic communication, augmented reality (AR) communication, application communication, science drawing with technology, the presentation of scientific knowledge through science shows, and the design of engaging learning activities. My curiosity drives me to find answers regarding the perception of concepts related to scientific communication. Understanding students' scientific communication skills will inform the planning and design of activities aimed at promoting their learning.

While I (Witsanu) possess some experience in the field of scientific communication, this is my first time teaching a dedicated course on this subject. To enrich this research and broaden our perspectives, I invited Thapana (second author), to collaborate on this project. He has extensive experience in teaching and developing science teachers, with a strong background in scientific communication, including writing and designing science textbooks for Thai schools and developing online teaching materials for small school sizes in Thailand. Through our combined, we aim to collaboratively address the research questions and identify opportunities to enhance the learning experiences of our students.

Therefore, it is important for pre-service science teachers to have knowledge, understanding, and the ability to use scientific communication skills in their future work. This research aims to explore how pre-service science teachers view the meaning, importance, and strategies for effective scientific communication. The results of this study will help to better understand their perceptions of scientific communication and could also provide a basis for improving similar skills in science teacher education programs at other universities in similar situations.

## 2. METHOD

### 2.1 Research aim

This research aims to investigate the perspectives of pre-service science teachers on the conceptualization, significance, and effective strategies for scientific communication.

### 2.2 Method of inquiry

This qualitative-interpretive study (Chinasa et al., 2021; Taylor & Medina, 2013) was designed to investigate the perceptions of science teacher candidates in Thai universities regarding the meaning, importance, and strategies related to scientific communication. We hope that the findings of this study will help us design

instructional strategies to develop our students' scientific communication skills. The research adopts a qualitative methodology centered on evidence-based interpretation (responses from science teacher students), employing thematic analysis informed by the conceptual framework of scientific communication. Both the research methodology and the findings are presented through a narrative method to contextualize the evidence.

Additionally, it is expected that this research can be adapted by instructors in other universities with similar contexts. We have rigorously followed qualitative research methodologies and presented detailed data to ensure the credibility and trustworthiness of our findings (Chummongkol et al., 2023; Cohen et al., 2000; Loo, 2017; Suttiwan et al., 2022).

During the study we collaborated with science educators, including lecturers at VRU and overseas scholars. The first author (Witsanu) is a lecturers at faculty of education, VRU, Thailand and interested about perspective of pre-service science techers' scientific communication. Thapana is a my peer and collaborator. We consulted closely with international scholars with expertise in scientific communication and science education: Eliyawati Eliyawati (Universitas Pendidikan, Indonesia) and Ananta Ardyansyah (Universitas Negeri Malang, Indonesia) who also served as third and fourth authors of this article.

Our study focused on the meaning, importance, and effective strategies of scientific communication. Ten science student teachers (A1-A10) were selected using purposive sampling from the scientific communication class taught by the first author. These participants were enrolled in the Scientific Communication course during the second semester of the 2024 academic year and voluntarily participated in this research. As part of their participation, they were required to answer three open-ended questions about scientific communication to ascertain their perceptions.

The concept of scientific communication varies depending on the scientists' or science educators' background and perspective. This study conducted a preliminary literature review to synthesize the key aspects of scientific communication, identifying two primary themes: 1) the meaning and significance of scientific communication, and 2) effective strategies for scientific communication. Scientific communication involves effectively sharing scientific knowledge and concepts with diverse audiences, including peers, policymakers, and the public, using various skills, media, and activities to foster awareness, understanding, and interest (Burns et al., 2003; Guidotti, 2016). It bridges the gap between complex scientific information and the public's need for accessible insights, playing a key role in informed decision-making on global issues like climate change and emerging technologies (Fischhoff & Scheufele, 2012). Beyond delivering information, it emphasizes two-way engagement, incorporating public perspectives to foster collaboration and mutual learning (McCallie et al., 2009). Scientific communication builds trust between science and society by ensuring transparency, addressing ethical concerns, and highlighting the societal implications of advancements, utilizing methods like direct interaction, consultation, and participatory approaches tailored to audience needs (Jucan & Jucan, 2014; Rowe & Frewer, 2005).

Effective scientific communication involves delivering complex scientific knowledge to diverse audiences in a clear, engaging, and accessible manner. Key strategies include simplifying language without oversimplifying content, using visuals like diagrams and maps to enhance understanding, and avoiding jargon and acronyms to maintain clarity (Goh et al., 2008). Providing context is essential to answering questions like "Why does this matter?" and connecting scientific insights to real-world issues. Combining data visualization with clear narratives ensures that information is relatable and actionable. Scientists are encouraged to engage in two-way communication, considering audience needs and feedback, to foster trust and collaboration. These practices demystify science and empower decision-makers and the public to apply scientific insights effectively.

Following the synthesis of documents related to scientific communication, a conceptual framework for this research was developed, as illustrated in Figure 1.

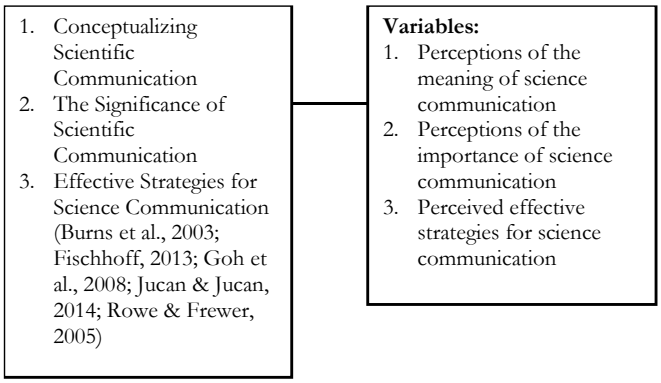


**Figure 1** The theoretical framework

After the conceptual framework for the study was created, the principal investigator designed three open-ended questions to collect data. These questions were reviewed by co-researchers to ensure they were clear and appropriate for pre-service science teachers. Based on the feedback, the questions were revised to enhance their clarity and ease of understanding.

1. Describe the concept of scientific communication and provide specific examples to support your explanation.
2. Describe the importance of scientific communication and provide specific examples to support your explanation.
3. When communicating scientific content or news to students or the general public, what strategies would

you employ to ensure effective and successful communication? Please describe your approach in detail and provide specific examples.

Finally, after the students provided their responses to the open-ended questions, the data were collected and reviewed for completeness. Subsequently, the data were organized and analyzed within the framework of the conceptual framework developed for this study. The data were analyzed using semantic thematic analysis. The responses to the open-ended questions were read repeatedly to ensure familiarity. Initial codes were then generated based on meaningful phrases related to the participants' perceptions. These codes were organized into preliminary themes guided by the conceptual framework on scientific communication. Themes were refined through peer debriefing and member checking to ensure accuracy and credibility. Emphasis was placed on explicit, surface-level meanings of the participants' responses rather than underlying assumptions, aligning with the semantic approach. This process supported the identification of patterns reflecting pre-service teachers' views and communication strategies.

To ensure the trustworthiness of the research findings, the data analysis process followed to criteria of credibility and dependability (Chummongkol et al., 2023; Lincoln & Guba, 1985; Suttiwan et al., 2022). Preliminary interpretations of the data were shared with selected peers (third and fourth authors) for feedback and with the study participants themselves for member checking to enhance the credibility and trustworthiness of the findings. To ensure the transferability of the findings, comprehensive descriptions of the studied aspects were included, along with sample quotations for reader verification. The meticulous detailing of the research process, spanning from data collection to interpretation, is provided in the Methods section to guarantee dependability and confirmability.

## 3. RESULT AND DISCUSSION

Interviews with pre-service science teachers revealed limited understandings of the concept of scientific communication. While participants recognized the importance of scientific communication, their examples were often confined to traditional modes such as teacher-student interactions and warning labels on medications. Additionally, participants exhibited a limited repertoire of strategies for promoting effective scientific communication, primarily relying on visual aids like images, videos, and audio. The findings suggest a need for more comprehensive instruction on the multifaceted nature of scientific communication, including a broader range of strategies and contexts.

### 3.1 The concept of scientific communication

The responses from the 10 science student teachers were particularly insightful. They provided valuable data for understanding their perceptions of the meaning of scientific communication. For instance, they highlighted that scientific communication facilitates the dissemination of scientific information, involves using simple language to discuss scientific content, and aims to make science accessible to the general public. However, it is evident from their responses that their understanding of scientific communication is somewhat limited, as further detailed in the following examples.

A1: *"Scientific communication is about making science simple to understand, like explaining dangers or concepts in a way everyone gets. For example, teaching science or talking about chemicals."*

A2: *"It means using easy words instead of complicated terms, like saying "tree" instead of a scientific plant name."*

A3:*"It's about talking to others about science, like explaining molecular shapes."*

A4: *"Science communication is sharing science knowledge, like making teaching materials, brochures, or cool projects about experiments or inventions."*

A5: *"It's showing science clearly so people get it, like using visuals for hard concepts like space and time relationships."*

A6: *"It's about explaining things so others understand, like using a model to show what an atom looks like."*

A7: *"It's sharing science in an understandable way, like posters or videos about healthy eating or experiments."*

A8: *"It's sharing facts and ideas so people get them. Social media is great for this, like showing experiments in videos."*

A9: *"It's teaching science through talking, reading, writing, or videos, like giving a lecture or writing a book."*

A10:*"Good scientific communication needs evidence, not just opinions, like explaining a medicine with facts, not just beliefs."*

The responses from the students strongly suggest that a majority of them have a solid understanding of the concept of scientific communication. For instance, students A1, A4, A5, A7, and A9 accurately defined scientific communication as the process of sharing scientific information, knowledge, and facts with others. Even though most of the students seemed to get the basic idea of scientific communication, their answers showed us that they might not have the whole picture. For example, students A2, A3, A4, and A9 seemed to think that scientific communication was mainly about what happens in the classroom or during science lessons. But there's actually a lot more to it than that. Furthermore, the responses from students A7 and A10 demonstrated a more comprehensive understanding of scientific communication. Their answers indicated that they recognized scientific communication as extending beyond the confines of the science classroom and encompassing a broader range of topics such as health, scientific risks, and the use of drugs and chemicals. However, they also suggested that effective scientific communication often requires the use of various media and technologies, supported by credible evidence.

We can see that teachers' understanding of 'scientific communication' primarily focuses on the aspect of

'understanding.' Based on Burns et al. (2003), scientific communication encompasses at least four other aspects: awareness, enjoyment, interest, and opinion forming. This suggests that pre-service teachers may overlook other essential elements of communication and place too much emphasis on understanding. However, some participants perceive scientific communication as not only involving skills and dialogue but also the use of media (e.g., A5, A6, and A7) and engagement in activities (e.g., A4 and A9). This finding confirms other research stating that training on scientific communication is less effective in the affective aspect (in this case, such as awareness, enjoyment, and interest) (Baram-Tsabari & Lewenstein, 2017). This also highlights that teachers today are less capable of forming opinions. Yet, convincing others of valid findings and persuading public understanding is one of the key aspects of scientific communication (Edge, 1979). Therefore, in the future, training on the meaning of scientific communication needs to be conducted, not only covering how to educate the public but also other related aspects.

### 3.2 The significance of scientific communication

Scientific communication serves multiple purposes, including general communication, policymaking, and public engagement (Burns et al., 2003). Science teacher candidates play a pivotal role in this process. Their responses reveal a common misconception that scientific communication is primarily about simplifying complex scientific information for the general public. Additionally, many participants held a narrow view of scientific communication, confining it solely to the science classroom.

A1: *"Scientific communication helps people understand science better, like using pictures in lessons or warning about lab dangers."*
A2: *"It's important because it makes science easy for everyone to get using clear visuals and simple words."*
A3: *I think it's like a universal language that makes science easier to understand.*
A4: *"To explain science well, you need to really know your stuff. For example, in a lab, you have to show how to use tools safely and wear the right gear."*
A5: *"It's about making tough science ideas simple, like teaching why self-medicating is risky without a doctor's advice."*
A6: *"It helps people picture tricky ideas, like what an atom looks like, even if you can't see it."*
A7: *"Good communication explains risks clearly, like labels on chemicals to show how to use them safely."*
A8: *"It connects scientists and people, teaching big topics like climate change or helping with decisions about renewable energy."*
A9: *"It makes sure people get the message, like reading medicine instructions or knowing food expiration dates."*
A10: *"It's important for explaining science to everyone, like using easy words when teaching kids."*

Many pre-service teachers (A1, A2, A3, and A10) recognized the importance of scientific communication primarily in terms of simplifying complex information and effectively conveying it to an audience. Additionally, a strong emphasis was placed on the role of scientific communication in teaching and learning (A4, A5, A8, A9, and A10), suggesting that the students' experiences with scientific communication were largely confined to classroom settings. Finally, a smaller group of students (A1, A7, and A8) demonstrated a broader understanding of scientific communication, recognizing its role in shaping public perceptions on issues such as safety, climate change, and healthcare.

An interpretation of the pre-service teachers responses revealed a notable omission regarding the significance of scientific communication in policymaking. This absence highlights a gap in the students' understanding and a need for further development in their knowledge and skills related to scientific communication in this context.

### 3.3 The effective strategies for scientific communication

Effective scientific communication can lead to significant advancements in both science and society. Key strategies highlighted by scholars include the use of simplified language without sacrificing content, the incorporation of visual aids such as diagrams and maps to enhance comprehension, and the avoidance of jargon and acronyms to maintain clarity (Goh et al., 2008). When asked open-ended questions about strategies to enhance scientific communication, the pre-service science teachers' responses were revealing. Their answers indicated a limited understanding of effective scientific communication strategies, and some students were unable to provide a response, highlighting a need for further exploration of this topic.

A1: *"I think before experiments, teachers explain stuff like the steps, equipment, and details."*
A2: *"No idea."*
A3: *"Don't know."*
A4: *"Using pictures and explaining them helps students understand better."*
A5: *"Maybe it's about making videos to teach science topics."*
A6: *"Use simple language and examples, like explaining atoms with easy words and visuals."*
A7: *"Speak confidently and show you know your stuff—this makes students trust you. Also, keep it simple so everyone gets it."*
A8: *"Use pictures, videos, and gestures to make ideas super clear and easy to understand."*
A9: *"Show visuals like images or videos—they're way easier to understand and remember than just words."*
A10: *"No clue."*

Many students (A4, A5, A8, and A9) expressed the belief that using images or videos is an effective strategy for scientific communication. They may have reached this conclusion because such materials are readily available from various learning resources, are relatively easy to use, and may be familiar to them from their own experiences. Student A7 presented a unique perspective on scientific

communication strategies. He highlighted the importance of the communicator's confidence and personality in building credibility and trust with the audience. Additionally, he emphasized the use of simple and clear language as a key factor in successful scientific communication. Furthermore, a number of students were unable to provide answers regarding scientific communication strategies. This may be due to a lack of relevant experience or a lack of confidence in identifying their knowledge as specific strategies for scientific communication.

From these results, it can be seen that some pre-service teachers understand that an effective scientific communication strategy not only involves dialogue and a teacher's abilities but also the use of media (e.g., A4, A5, A8, and A9). However, these results also indicate that teachers still focus on aspects of dialogue and skills, such as simplifying concepts and methods of conveying understanding to students (e.g., A1 and A7). Moreover, some teachers still do not understand what constitutes an effective strategy in scientific communication (e.g., A2 and A3). The use of various methods is certainly not the only aspect that influences communication strategy, but it remains important according to (Burns et al., 2003).

## 4. CONCLUSION

### 4.1 Conclusion

This study examined pre-service science teachers' perceptions of scientific communication in terms of its meaning, importance, and effective strategies. The findings reveal that while students recognize the value of clear communication, their understanding is mostly limited to classroom contexts. Many view scientific communication as merely simplifying complex concepts for teaching, with limited awareness of its broader societal roles, such as engaging the public or informing policy.

Their knowledge of effective strategies also remains narrow, focusing mainly on visuals and simplified language. Some were unaware of key practices like avoiding jargon or tailoring messages to diverse audiences. This limited understanding reflects a need for more comprehensive training in scientific communication.

Only a few students identified media use as a valuable strategy, showing that practical and digital communication tools are underutilized. Overall, the study highlights the need to expand pre-service teachers' perspectives beyond classroom instruction to include the broader implications of communicating science to society. Enhancing their awareness and skills can better prepare them to become effective science communicators in both educational and public settings.

The findings of this study offer valuable insights into pre-service science teachers' perceptions of scientific communication, revealing a tendency to conceptualize it narrowly within classroom contexts. Most participants associated scientific communication with simplified language, visual aids, and one-way teacher-student interaction. These results reflect a limited understanding of the broader purposes of scientific communication, such as public engagement and policy influence, as emphasized by Burns et al. (2003) and Fischhoff (2013). While participants demonstrated basic awareness of communication strategies, their emphasis on visuals and clarity over critical engagement suggests an underdeveloped view of the multidimensional nature of scientific communication, which includes fostering public awareness, interest, and informed opinion .

This gap supports the argument by Baram-Tsabari and Lewenstein (2017) that current teacher training often neglects affective learning outcomes and identity development in communication. Furthermore, the limited recognition of communication as a two-way process aligns with findings by McCallie et al. (2009), who stress the importance of dialogue and audience-centered engagement. The conceptual framework developed in this study which includes understanding the meaning, significance, and effective strategies of scientific communication helps to interpret these perceptions and identify areas for development. Overall, the results underscore the need for teacher education programs to broaden their approach, integrating experiential learning, digital media tools, and interdisciplinary collaboration to build more comprehensive scientific communication competencies among future educators (Shivni et al., 2021). This will not only enhance science teaching but also contribute to improved and public understanding in broader societal contexts.

### 4.2 Recommendations

To foster pre-service science teachers' scientific communication skills, several targeted strategies should be implemented in teacher education programs.

**Expanding the scope of scientific communication beyond the classroom:** while pre-service science teachers generally understand scientific communication as a tool for classroom instruction, their knowledge remains limited to traditional teaching methods. Therefore, training programs should emphasize the broader role of scientific communication in public engagement and policymaking (Fischhoff, 2013; Jucan & Jucan, 2014; Rutt & Mumba, 2022). For example, pre-service teachers should be encouraged to participate in science outreach programs where they communicate scientific concepts to the public, such as community workshops on climate change or public health awareness campaigns. Such experiences will help them recognize the societal impact of scientific communication beyond school settings. The public understanding of science, scientific literacy, or science literacy varies across different communities. Despite the lack of a unified consensus on the definition of scientific literacy, it remains a crucial aspect of society (Ardyansyah

et al., 2025; Elmi et al., 2024). To support this, pre-service teachers must be trained to understand their audience. Training in communicating with diverse audiences with varying levels of scientific literacy is essential to equip future educators with effective science communication skills (Rutt & Mumba, 2022; Treise & Weigold, 2002).

**Promoting clarity and accessibility in scientific communication:** effective scientific communication requires clarity and accessibility. The study found that while pre-service teachers valued simplicity in communication, they often overlooked the importance of avoiding jargon (Goh et al., 2008). Training should focus on teaching future educators how to break down complex scientific concepts without oversimplifying or losing essential information (Shivni et al., 2021). For instance, when explaining genetics, instead of using technical terms like "homozygous recessive alleles," teachers could use analogies, such as comparing genes to a recipe that determines characteristics like eye color. Additionally, they could practice explaining scientific terms to non-experts and receive feedback to refine their communication skills.

**Integrating multimedia and digital tools for effective scientific communication:** given the increasing reliance on technology in education and public discourse, teacher training programs should incorporate multimedia tools such as infographics, videos, podcasts, and interactive applications to enhance scientific communication (Burns et al., 2003; Khaokhajorn & Srisawasdi, 2024). For example, pre-service teachers could be assigned projects where they create short explainer videos on topics like renewable energy or vaccine safety. Platforms such as TikTok, YouTube, or social media infographics can be used to present scientific concepts in an engaging and accessible manner. This approach would help pre-service teachers develop digital communication skills that are relevant in today's media landscape. However, in integrating technology into learning, pre-service teachers must also consider the type of technology being used. Each technology possesses distinct characteristics, which should be carefully taken into account in its implementation. For instance, augmented reality (AR) can visualize elements that are not directly observable to the naked eye by presenting them as digital objects (Ardyansyah & Rahayu, 2024; Khaokhajorn & Srisawasdi, 2024; Tyurina, 2021).

**Encouraging experiential learning through collaborative workshops:** experiential learning provides opportunities for pre-service teachers to apply scientific communication strategies in real-world contexts. Teacher education programs should include workshops, guest lectures, and collaborative projects with scientific communicators, journalists, or policymakers (Intemann, 2023; Iyengar & Massey, 2019; Rowe & Frewer, 2005). For example, pre-service teachers could work with science museums to develop interactive exhibits or partner with government agencies to create educational materials on environmental conservation. By engaging in hands-on activities, they can better understand how to communicate scientific ideas effectively to different audiences. Scientific communication also can be enhanced through scientific groups. These groups encourage individuals to engage more actively while also allowing them to recognize their strengths and weaknesses (Bautista et al., 2022).

**Conducting further research on the impact of science communication training:** future studies should explore how specific interventions, such as media training, interdisciplinary collaboration, and public engagement activities, affect the long-term development of scientific communication skills in pre-service teachers. Research could examine how these skills translate into their teaching practices and how effectively they communicate science to students and the general public. Longitudinal studies tracking the progress of trained teachers could provide valuable insights into the effectiveness of scientific communication education (Baram-Tsabari & Lewenstein, 2017; Committee on the Science of Science Communication, 2017). Researcher-trainer partnerships can help maximize the reach and positive impacts of these programs (Dudo et al., 2021).

By implementing these recommendations, teacher education programs can ensure that pre-service science teachers are well-equipped to communicate scientific knowledge effectively across various platforms and audiences, ultimately enhancing scientific literacy in society (Arochman & Fortinasari, 2024)..

## REFERENCES


Ardyansyah, A., & Rahayu, S. (2024). Technology-enhanced learning influence on chemical literacy: A systematic review. *Ecletica Quimica, 49*. https://doi.org/10.26850/1678-4618.eq.v49.2024.e1534

Ardyansyah, A., Rahayu, S., Munzil, M., Yahmin, Y., & Alsulami, N. M. (2025). Developing an instrument to assess chemical literacy for prospective chemistry teachers. *Jurnal Pendidikan Sains Indonesia, 13*(1), 36–52. https://doi.org/10.24815/jpsi.v13i1.42095

Arochman, T., & Fortinasari, P. B. (2024). Implementation of technology-based learning by pre-service teachers during teaching practice program. *Premise: Journal of English Education, 13*(1), 126. https://doi.org/10.24127/pj.v13i1.8988

Baram-Tsabari, A., & Lewenstein, B. V. (2017). Science communication training: What are we trying to teach? *International Journal of Science Education, Part B, 7*(3), 285–300. https://doi.org/10.1080/21548455.2017.1303756

Bautista, C., Alfuraiji, N., Drangowska-Way, A., Gangwani, K., de Flamingh, A., & Bourne, P. E. (2022). Ten simple rules for improving communication among scientists. *PLOS Computational Biology, 18*(6), e1010130. https://doi.org/10.1371/journal.pcbi.1010130

Burns, T. W., O'Connor, D. J., & Stocklmayer, S. M. (2003). Science communication: A contemporary definition. *Public Understanding of Science, 12*(2), 183–202. https://doi.org/10.1177/09636625030122004

Chinasa, P., Sohsomboon, P., & Yuenyong, C. (2021). Seeing and understanding new opportunities for developing educational research through research multi-paradigms. *Journal of Education Rajabhat Maha Sarakham University, 18*(2). https://so06.tci-thaijo.org/index.php/edu-rmu/article/view/252434/170409

Chummongkol, P., Sohsomboon, P., & Yuenyong, C. (2023). Building up trustworthiness in qualitative research to improve the quality of education. *Journal of Teacher Professional Learning Community (JTPLC), 3*(2), 107–120. https://so05.tci-thaijo.org/index.php/JTPLC/article/view/263096/179163

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education*. Routledge Falmer.

Committee on the Science of Science Communication. (2017). *Communicating science effectively*. National Academies Press. https://doi.org/10.17226/23674

Cormick, C. (2022). We need to do better: Five notable failings in science communication. *Sustainability, 14*(14). https://doi.org/10.3390/su14148393

Dudo, A., Besley, J. C., & Yuan, S. (2021). Science communication training in North America: Preparing whom to do what with what effect? *Science Communication, 43*(1), 33–63. https://doi.org/10.1177/1075547020960138

Edge, D. (1979). Quantitative measures of communication in science: A critical review. *History of Science, 17*(2), 102–134. https://doi.org/10.1177/007327537901700202

Elmi, H., Huda, Y., & Novaliendry, D. (2024). The role of information and communication technology in interactive learning. *Jurnal Ilmiah Sekolah, 23*(1), 193–203. https://ojs.trigunadharma.ac.id/index.php/jis/index

Faculty of Education. (2019). *Bachelor of Education Program Department of Chemistry and General Science*.

Fischhoff, B. (2013). The sciences of science communication. *Proceedings of the National Academy of Sciences, 110*(Suppl. 3), 14033–14039. https://doi.org/10.1073/pnas.1213273110

Gass, S. (2014). Transforming scientific communication for the 21st century. *Engineering Libraries: Building Collections and Delivering Services, 1109*, 3–18.

Goh, B., Pomsagun, A., Le Tissier, M., Dennison, W. C., Kremer, H. H., & Weichselgartner, J. (2008). *Science communication in theory and practice*.

Guidotti, T. L. (2016). Communication in science. *Journal of the Washington Academy of Sciences, 102*(3), 23–36.

Hurd, J. M. (2004). Scientific communication. *Science & Technology Libraries, 25*(1–2), 5–22. https://doi.org/10.1300/J122v25n01_02

Intemann, K. (2023). Science communication and public trust in science. *Interdisciplinary Science Reviews, 48*(2), 350–365. https://doi.org/10.1080/03080188.2022.2152244

Iyengar, S., & Massey, D. S. (2019). Scientific communication in a post-truth society. *Proceedings of the National Academy of Sciences, 116*(16), 7656–7661. https://doi.org/10.1073/pnas.1805868115

Jucan, M. S., & Jucan, C. N. (2014). The power of science communication. *Procedia - Social and Behavioral Sciences, 149*, 461–466. https://doi.org/10.1016/j.sbspro.2014.08.288

Khaokhajorn, W., & Srisawasdi, N. (2024). Assessing pre-service science teachers' understanding of the nature of scientific inquiry to develop a sustainable technology-infused pedagogical program in teacher education. *Cogent Education, 11*(1). https://doi.org/10.1080/2331186X.2024.2439160

Leach, J. (2013). The handbook of communication history. In P. Simonson, J. Peck, R. T. Craig, & J. Jackson (Eds.), *The handbook of communication history*. Routledge. https://doi.org/10.4324/9780203149119

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications. https://doi.org/10.1016/0147-1767(85)90062-8

Loo, D. B. (2017). Trust the researcher? Autoethnography as a tool to study English teaching professionals. *The English in Southeast Asia (ESEA)*, 45–58.

McCallie, E., Bell, L., Lohwater, T., Falk, J. H., Lehr, J. L., Lewenstein, B. V., Needham, C., & Wiehe, B. (2009). *Many experts, many audiences: Public engagement with science and informal science education*. Center for Advancement of Informal Science Education. https://digitalcommons.calpoly.edu/eth_fac/12/

O'Neill, D. K., & Holmes, P. E. (2022). The power of board games for multidomain learning in young children.

Rowe, G., & Frewer, L. J. (2005). A typology of public engagement mechanisms. *Science, Technology, & Human Values, 30*(2), 251–290. https://doi.org/10.1177/0162243904271724

Rutt, A. A., & Mumba, F. (2022). Pre-service teachers' enactment of language and literacy integrated science instruction in linguistically diverse science classrooms. *Journal of Research in Science Teaching, 59*(4), 619–655. https://doi.org/10.1002/tea.21739

Scheufele, D. A. (2013). Communicating science in social settings. *Proceedings of the National Academy of Sciences, 110*(Suppl. 3), 14040–14047. https://doi.org/10.1073/pnas.1213275110

Shivni, R., Cline, C., Newport, M., Yuan, S., & Bergan-Roller, H. E. (2021). Establishing a baseline of science communication skills in an undergraduate environmental science course. *International Journal of STEM Education, 8*(1), 47. https://doi.org/10.1186/s40594-021-00304-0

Suttiwan, W., Yuenyong, C., & Maneelam, P. (2022). Autoethnographic research grounded knowledge in school context. *Journal of Teacher Professional Learning Community (JTPLC), 2*(2), 33–60. https://so05.tci-thaijo.org/index.php/JTPLC/article/view/262247

Taylor, P. C., & Medina, M. N. D. (2013). Educational research paradigms: From positivism to multi-paradigmatic. *Journal for Meaning Centered Education, 1*. https://doi.org/10.13140/2.1.3542.0805

Treise, D., & Weigold, M. F. (2002). Advancing science communication. *Science Communication, 23*(3), 310–322. https://doi.org/10.1177/107554700202300306

Tyurina, A. (2021). Enhancing science communication through AR driven visual storytelling: Suggested approach and study. *10th International Conference on Digital and Interactive Arts*, 1–2. https://doi.org/10.1145/3483529.3483727