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INNOVATIVE METHODS OF CHEMICAL SCIENCE COMMUNICATION: MAKING CHEMISTRY ACCESSIBLE TO ALL

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Research Paper

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ABSTRACT

Effective communication in chemical science is essential for enhancing public understanding and engagement with the subject, particularly given its significance in addressing contemporary global challenges. This study investigates innovative methods for communicating chemical science to diverse audiences, including students and the general public. By employing a mixed-methods approach that includes a literature review, bibliometric analysis, a survey, and expert interviews, the research identifies key challenges in chemistry education and communication. Findings indicate that the complexity of chemical concepts, insufficient hands-on experiences, and the abstract nature of the subject hinder comprehension. The study highlights the importance of using visual aids, real-world applications, and technology integration to make chemistry more accessible. Recommendations for improving communication strategies are provided, aiming to foster greater appreciation for chemistry and its relevance to everyday life.

No. of Pages: 9 **References: 10**

Keywords: Chemistry, biology, geology, education, communication, space.

INTRODUCTION

The need for effective science communication has never been more critical, especially as scientific literacy becomes increasingly important in addressing global challenges such as climate change, public health, and technological advancement[1]. In the common public opinion, Chemistry is often perceived as a complex and abstract subject matter leading to less engagement and understanding. However, the integral role Chemistry plays in our daily lives, influences everything from the food we eat to the clothes we wear. Perhaps the complexity lies more in the chemical concepts that often the general public can't relate to. In such a case, effective communication of chemical science is the key! It can help bridge this gap, fostering a greater appreciation for chemistry and its relevance to social issues. As science becomes increasingly integrated into policy decisions and mainstream public discourse, the ability to communicate scientific concepts clearly and effectively is essential.

This study aims to explore innovative methods of chemical science communication that can make chemistry and related topics more accessible to all audiences including students and the common people. The research focuses on identifying effective strategies for communicating chemistry, explore the challenges faced by chemistry educators and communicators and provide recommendations for improving chemical science communication. The study is based on a combination of scientific literature review, bibliometric

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analysis, and empirical data collection via surveys and expert interviews. By examining the current landscape of chemical science communication, the study aims to inform the development of new strategies and resources that can enhance public engagement with the central science i.e. Chemistry.

Methodology

The data has been collected using 4 main sources. They included:

1. **Scientific Literature Review:** To identify existing methods and strategies in chemistry education and science communication, a comprehensive review of peer-reviewed articles was conducted. This review focused on studies that highlighted innovative approaches to teaching and communicating chemistry[2].

2. **Bibliometric Analysis:** Using VOSviewer (version 1.16.19), a software tool for creating and visualizing bibliographic networks, a bibliometric analysis was performed on articles indexed in the PubMed database related to search keyword combination "Chemistry" AND "Science Communication" from 1980 to 2024. This analysis aimed to identify key themes, trends, and influential works in chemistry science communication.

3. **Survey:** A survey was designed to gather insights from students with chemistry and non-chemistry backgrounds and the general public. The survey collected inputsregarding their experiences and opinions on challenges they faced and improvements they can suggest in chemistry education and effective communication methods.

4. **Expert Interviews:** In-depth call interviews were conducted with Experts in Chemistry Education and Chemical Science Communication. Qualitative insights were gained from their experiences and best practices in chemistry communication. The interviews aimed to explore the nuances of effective communication strategies and the contextual factors that influence their implementation.

Participants of the Survey and Experts were approached through professional networks, social media platforms, and academic institutions. A total of 57 survey responses were collected, and 2 in-depth interviews were conducted.Quantitative data from the survey were analyzed and the most important and relevant ones have been listed in tabular form in this paper, while qualitative data from interviews were analyzed thematically. This mixed-methods approach allowed for a comprehensive understanding of the current landscape of chemical science communication.

RESULTS AND DISCUSSIONS

- **Results from Scientific Literature Review**

The literature review revealed several key themes in effective chemical science communication.

Methods in Chemical Science Communication	Brief description
1. Visual Aids and Hands-On Activities	Studies indicate that using visual aids, such as diagrams, videos, and interactive simulations, significantly enhances understanding of complex chemical concepts [2]. For example, Hofstein and Mamlok-Naaman (2007) highlighted the benefits of laboratory activities in enhancing students' understanding of chemistry and developing their scientific skills [3].
2. Relate to Real-World Scenarios	Research demonstrates that connecting chemistry to real-world issues, such as environmental sustainability and health, increases student motivation and interest [1]. Eilks and Hofstein (2015) found that using socio-scientific issues (SSIs) as a context for teaching chemistry can significantly enhance students' engagement and understanding of the subject [1]. Holman (1987) emphasized the importance of relating chemistry to everyday life and personal experiences to make it more meaningful and memorable for learners.

3. Technology Integration	Technology-enhanced teaching, including online resources and digital simulations, has been found to facilitate interactive learning experiences [4]. The use of social media and online platforms for science communication has also gained traction, allowing educators to reach wider audiences. Barak (2017) noted that technology can enhance collaborative learning environments and provide access to resources that may not be available in traditional classroom settings [4].

· **Results from the Bibliometric Analysis**

The bibliometric analysis conducted using VOSviewer software is as below and highlighted the following trends:

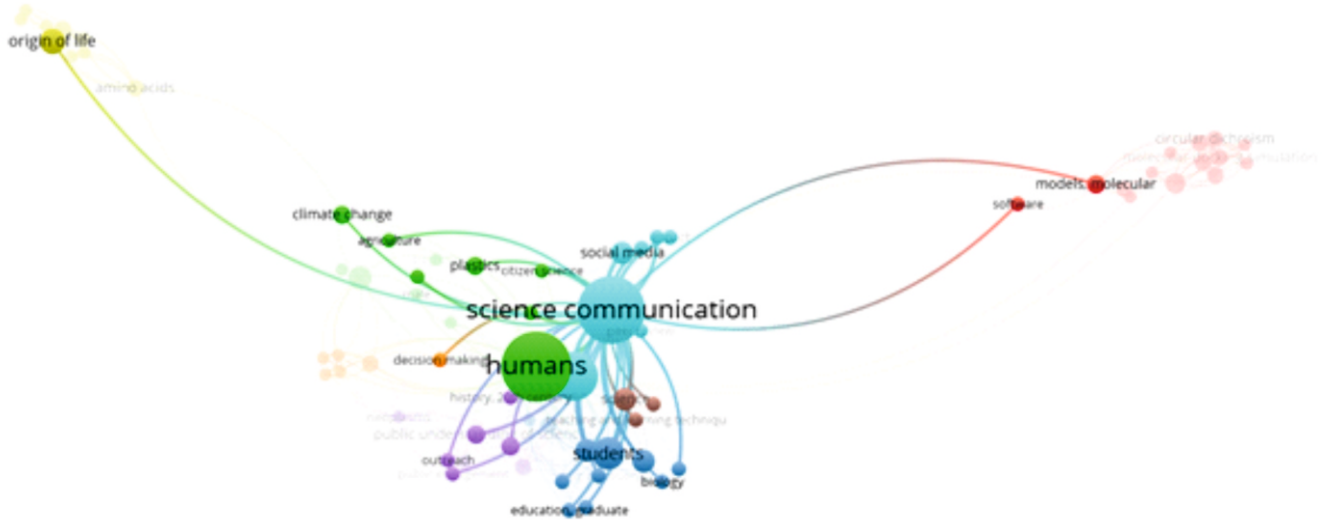

Figure 1: The figure shows the Bibliometric Network generated using VOSviewer- version 1.6.19 with the keyword combination "Chemistry" AND "Science Communication" based on the literature on the PubMed database published between 1980 and 2024 (Keyword Threshold count-2). This Bibliometric Network serves three purposes: 1) Validates the study showing the connections between "science communication" and popular topics related to chemistry like "models, molecular", "origin of life", "climate change", and more. 2) Reduces Bias during literature review (software generated). 3) Helps find loopholes directing future research based on connections in the Bibliometric Network.

NOTE: In a bibliometric network visualization, circle size denotes entity importance based on citation counts, while line thickness indicates connection strength. Colours differentiate clusters or categories, aiding in identifying research fields or collaboration groups within the network.

The Bibliographic Network generated, in Figure 1 implies that Chemical Science Communication is more often done citing concept examples or applications from physical or life sciences. Chemistry is a point of connection among various fields and finds more relevance to the readers and students through its role in physical or life science topics like the origin of life, climate change, plastics, thermodynamics, molecular models, DNA, spectrometry, biomedical research, and many more. Furthermore, this was even shared as an insight by an Expert Interviewee, Ms. Sanjukta Mondal, mentioned later in the paper. She thinks that sharing about Chemistry by connecting it to trending topics or daily-used objects or applications or through stories of inventions and stalwarts in the field is more appealing to her audience.

- **Survey Results**

The survey was able to collect a total of 57 responses. Please note that all the survey participants have provided us with their consent allowing us to use their survey data inputs for Research purposes only without revealing their identities. The following are the key findings:

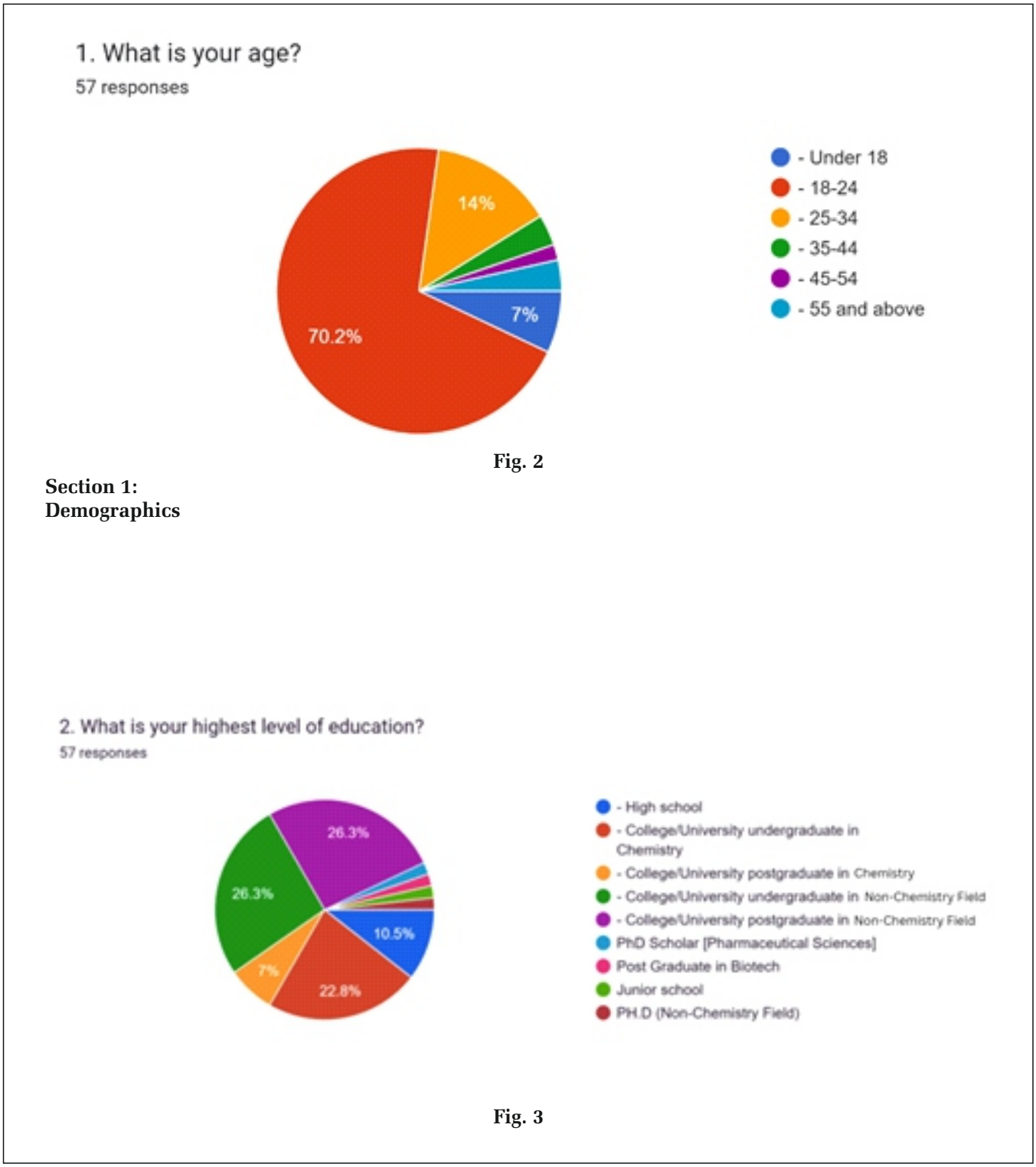

Fig. 2

Section 1:
Demographics

Fig. 3

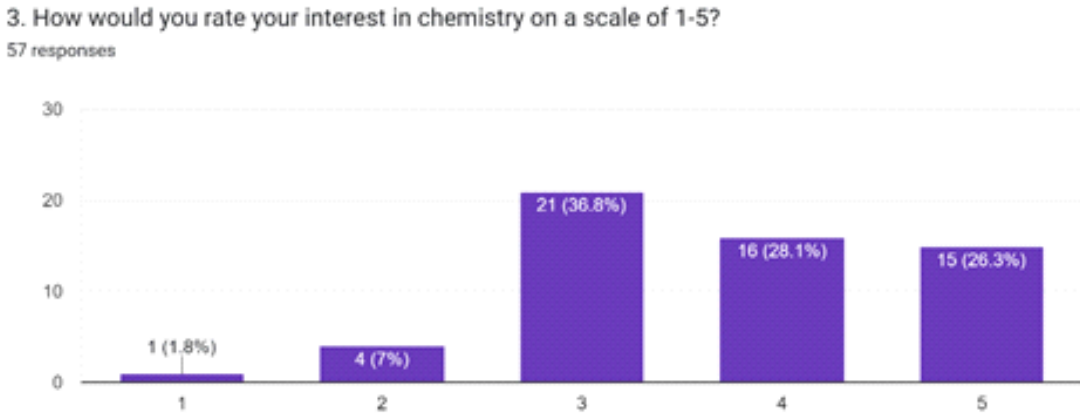

Fig. 4

Section 2: Interest in Chemistry

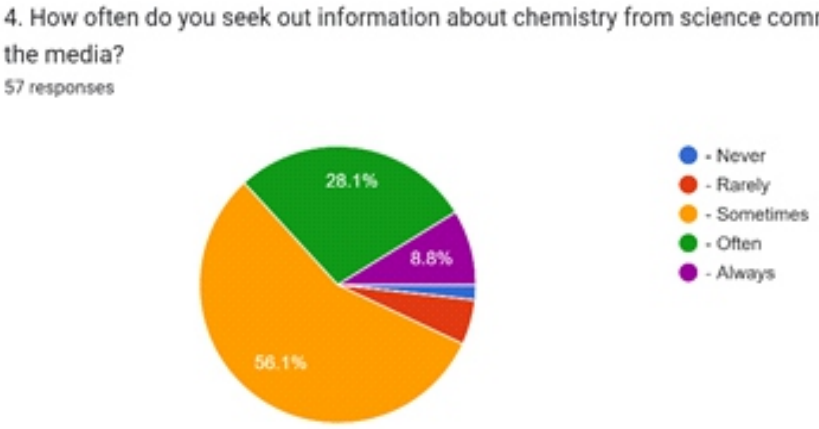

Fig. 5

Section 3: Learning Preferences

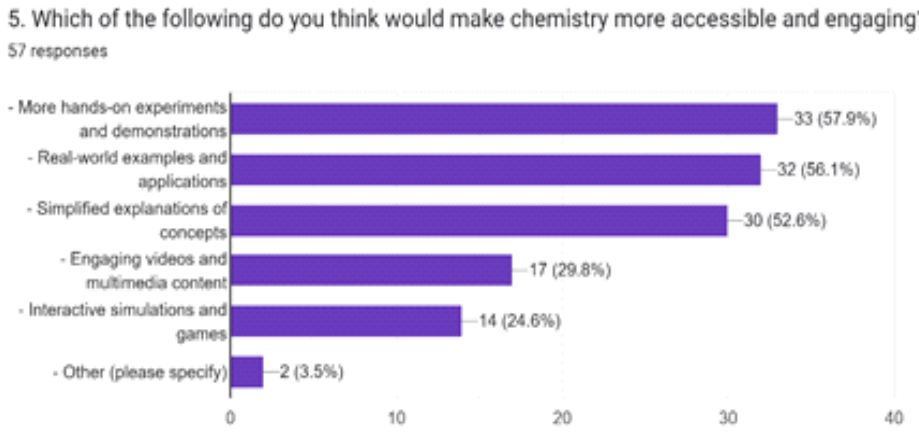

Fig. 6

6. What are some of the challenges you face in understanding chemistry concepts? *(Only the most important and relevant inputs have been considered)*

- Understanding Complex Chemical Reactions
- Difficulty in Remembering Formulas
- Lack of Hands-on Experiments
- Chiral Centers and Stereochemistry
- Poor Conceptual Understanding from Early Education
- Interconnected Nature of Concepts
- Visualization and Abstract
- Limited Multimedia Resources for Advanced Topics
- Mathematical Requirements
- Insufficient Practical Application

7. Do you have any suggestions for how chemistry can be made more accessible and engaging for students and the general public?

(Only the most important and relevant inputs have been considered)

- ✓ Real-World Applications
- ✓ Hands-On Experiments
- ✓ Interactive Learning Tools
- ✓ Simplified Explanations
- ✓ Use of Multimedia
- ✓ Focus on Experimental Learning
- ✓ Community Engagement
- ✓ Visual Representation
- ✓ Encouraging Curiosity
- ✓ Access to Resources

- ***Expert Interview Insights***

Two Chemical Science professionals were interviewed [5][6][7].A balance of inputs was ensured by interviewing [8][9][10] a Chemistry Researcher and Educator more relevant to student education and a Freelance Science Journalist involved with public understanding of chemical science. Dr. Maya Gupta (Teaching Faculty, Department of Education, Jadavpur University, Ph.D. and Post Doctorate in Chemistry) was interviewed as a Chemistry Researcher and Educator. Ms. Sanjukta Mondal (Freelance Science Writer, Journalist, and Consultant) was approached to receive inputs on Chemical Science Communication with relation to the general public. They provided additional insights into the challenges and best strategies in chemistry education and science communication:

1. *Personal inspiration pointers on taking up Chemistry as a field of study.*

   - o For Dr. Maya it was more the colourful chemical reactions, observation of nature, and her desperation to learn a subject generally considered hard by her peers that inspired her to take up Chemistry as a career path.

   - o For Sanjukta it was her School Chemistry Teacher who made the subject more fun and relatable to her. The hands-on laboratory work she was involved in high school also was a motivating factor behind going for further study in Chemistry.

2. *Effective methods of chemical science communication and tailoring it as per target audience.*

   - o Dr. Maya emphasized more on fostering observation of nature and its changes among the students like in leaf or flower (colour changes with chemical reactions, slow and fast with time). Hands-on activities and Application-based learning can help a student better understand the subject matter. The Five E-Model (Engage, Explore, Explain, Elaborate, and Evaluate) and Learning through collaboration, brainstorming, by-doing, project-based, group discussion, debate, wall magazines, etc. can be helpful on a case-to-case basis.

     She believes storytelling methods and traditional media like, nukkadnatak (a traditional Indian street play), and anti-superstitioncampaigns can be instrumental in making chemistry more relatable to the common people.

   - o Sanjukta believes in communicating about Chemistry with better storylines and visuals rather than just facts and figures. Connecting to popular Science shows or movies (like Breaking Bad) and the stories of people involved with the invention, discoveries, or historical context helps make the content more human and interesting for the people. She doesn't use chemical symbols or

reactions in her science communication works unless essential with supporting lucid explanation.

In Inreach, scientific communications can include a bit more jargon and facts given the target audience is more familiar with the fundamentals of the subject. However, for outreach science content storytelling and connecting to daily life activities can help gain a better appreciation for the topic. Being open to feedback from different kinds of audiences (without bias) and improving accordingly is the key!

3. Challenges in chemical science communication.

- A decline in the student interest in chemistry in recent times, corruption in the education system, lack of funds for fostering creative learning, and digital media addiction are some of the challenges faced by Dr. Maya in chemistry education.

- Sanjukta mentions that while simplification of facts is important, oversimplification which may lead to misinterpretation of the facts is not desirable. Over-explanation of a topic also stands out as a challenge at times.

4. Role of Chemistry educators and science communicators.

- Both Dr. Maya and Sanjukta agree that the role of a chemical science communicator lies in making the content more engaging and accessible to various kinds of audiences. This can foster an appreciation for the subject and most importantly promote ethics and scientific temperament.

Conclusion

The study validates the need for innovative communication strategies in chemical science to enhance student education, public understanding, and engagement. Key challenges identified include the complexity of chemical concepts, difficulties in memorization, and insufficient practical experiences, which affect effective learning. To address these issues, it is recommended to increase hands-on experiments, utilize technology for interactive learning, and connect chemistry to real-world applications. Additionally, employing visual aids and fostering community engagement can make chemistry more accessible. Future directions should focus on policy changes toward developing tailored communication strategies that resonate with diverse audiences, ultimately promoting a deeper appreciation for chemistry and its relevance in everyday life.

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Appendix A: Survey Questionnaire

The survey was collected using a Google Form. All questions marked with * were mandatory. The questions included.

Section 1: Demographics

1. What is your age?*
   - Under 18
   - 18-24
   - 25-34
   - 35-44
   - 45-54
   - 55 and above

2. What is your highest level of education?*
   - High school
   - College/University undergraduate in Chemistry
   - College/University postgraduate in Chemistry
   - College/University undergraduate in Non-Chemistry Field
   - College/University undergraduate in Non-Chemistry Field
   - Other

Section 2: Interest in Chemistry

3. How would you rate your interest in chemistry on a scale of 1-5?*

   (1 being not interested at all, 5 being extremely interested)

4. How often do you seek out information about chemistry from science communicators online or in the media?*
   - Never
   - Rarely
   - Sometimes
   - Often
   - Always

Section 3: Learning Preferences

5. Which of the following do you think would make chemistry more accessible and engaging?* (Multiple Choices)
   - More hands-on experiments and demonstrations
   - Real-world examples and applications
   - Simplified explanations of concepts
   - Engaging videos and multimedia content
   - Interactive simulations and games
   - Other (please specify)

Please specify here (if you have chosen others in the above question)

6. What are some of the challenges you face in understanding chemistry concepts?*(open-ended question)
7. Do you have any suggestions for how chemistry can be made more accessible and engaging for students and the general public?*(open-ended question)

Section 4: Final Thoughts and Consent

8. Any additional comments or feedback?
9. Please provide us your consent that you allow us to use your data provided in this survey for Research purposes only without revealing your identity.*
   - Yes sure!

Appendix B: Expert Interview Questions

Common questions:

1. What inspired you to become a science communicator and/or educator in the field of chemistry?
2. What are some of the most effective methods you have used to make chemistry accessible and engaging for your audience?
3. How do you tailor your communication style and content to different age groups and educational backgrounds?
4. What are some of the challenges you face in communicating complex chemistry concepts to a non-expert audience?
5. What message would you like to give to chemical science educators and science communicators in terms of making chemistry more accessible to all?

Miscellaneous (asked on case-to-case basis):

For Chemistry Educator: Name some organizations that help or can help cater to the greater audience in terms of chemical science education.

For Chemistry Science Communicator: How do you collect audience feedback based on your chemical science communication content?