Title	Fostering science engagement and understanding among non-scientific audiences through communication strategies in art-based workshops
Sub Title	
Author	チョウ, ネイ琪(Zhang, Ningqi) 陳, 敦雅(Chen, Dunya Donna)
Publisher	慶應義塾大学大学院メディアデザイン研究科
Publication year	2025
Jtitle	
JaLC DOI	
Abstract	
Notes	修士学位論文. 2025年度メディアデザイン学 第1204号
Genre	Thesis or Dissertation
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO40001001-00002025-1204

Master's Thesis
Academic Year 2025

Fostering Science Engagement and Understanding among Non-scientific Audiences through Communication Strategies in Art-Based Workshops

Keio University
Graduate School of Media Design

Ningqi Zhang

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

Ningqi Zhang

Master's Thesis Advisory Committee:

Associate Professor Dunya Donna Chen	(Main Research Supervisor)
Professor Nanako Ishido	(Sub Research Supervisor)

Master's Thesis Review Committee:

Associate Professor Dunya Donna Chen	(Chair)
Professor Nanako Ishido	(Co-Reviewer)
Associate Professor Chihiro Sato	(Co-Reviewer)

Abstract of Master's Thesis of Academic Year 2025

Fostering Science Engagement and Understanding among Non-scientific Audiences through Communication Strategies in Art-Based Workshops

Category: Design

Summary

This research explores how art-based workshops can be designed as effective science communication tools to engage non-scientific audiences. In response to growing concerns over public disengagement with science—especially among younger generations—this study investigates the integration of creative practices and communication strategies to foster interest, understanding, and emotional connection. Drawing on experiential learning theory, encoding–decoding models, and informal science learning frameworks, four workshops were developed and implemented in collaboration with community partners. Each session incorporated hands-on art activities designed to convey scientific concepts through accessible and engaging formats.

Through a combination of participant questionnaires, observation, and communication strategy analysis, the findings reveal that such workshops can reduce cognitive barriers, enhance clarity, and encourage cross-generational engagement. Specific design elements, such as relatable analogies, interactive demonstrations, and collaborative installations, proved particularly effective in sparking curiosity and deepening understanding. This research contributes to the growing field of science communication by demonstrating the value of interdisciplinary, participatory approaches that connect science with everyday creativity and lived experience.

Keywords:

science communication, workshop, communication strategy, informal science education, public engagement, experiential learning

Keio University Graduate School of Media Design

Ningqi Zhang

Contents

List of Figures

List of Tables

Acknowledgements

I would like to express my heartfelt gratitude to my academic advisor, Professor Dunya Chen, for her invaluable guidance and for providing me with countless opportunities to engage with diverse partnerships. Her support enabled me to gain hands-on experience, and grow through every challenge. I am also sincerely thankful to my sub-supervisor, Professor Nanako Ishido, for her insightful perspectives on educational research, which greatly enriched my study.

My deepest appreciation goes to the collaborators who made this project possible. Special thanks to BnA_WALL—Yoko Yamaguchi and Anna Kuraya, for generously providing a vibrant venue, and to Pentel Corporation—Takeshi Saijo and Aya Otsubo for supplying materials and offering continuous support that was critical for iteration. I am also grateful to Shonan iPark—Naoko Sugita—for hosting an inspiring event and helping promote the project. Thank you all for believing in this initiative and contributing to its realization.

I would like to thank all members at Concordia who participated in my test runs and offered constructive feedback, which helped refine the workshop experience. I am thankful to everyone who served as facilitators and supporters during the iPark Fiesta on May 24, 2025. your dedication and teamwork made it all possible. A special thanks to Maki Maede, my kouhai from Concordia, who supported my first workshop from beginning, till the final workshop in Shonan iPark with incredible generosity.

To Yumi Komoriya, thank you for being the perfect partner during the iPark Fiesta, we made a great team! My sincere thanks to Yutong Luo senpai, a researcher from Concordia, for being my constant source of clarity. Every time I felt lost, she was there with guidance and reassurance.

To March Hernes Hebæk, thank you for always being by my side, as a friend who always share your thoughts with me. And to Xuanye Zhu, Shuqin Chen, and Qi Li, thank you for the everyday chats that kept me emotionally grounded and up-

lifted. To Riseki Qianrong Fu, thank you for introducing me to KMD and giving me the opportunity to embark on this incredible journey.
Lastly, I am forever grateful to my parents and my family for their unwavering financial and emotional support. Your presence, advice, and belief in me gave me the strength and energy to continue growing throughout this journey.

Chapter 1
Introduction

1.1. Research Context

While many urban Asian societies still maintain their influence in finance and business, the development of science and technology-related industries is facing a stagnant status. Hong Kong, used to be known as the “Asian Four Tigers”,illustrates this issue. According to the HKTDC 2023 Hong Kong Economic Report, the major sectors are retail and finance, with information technology services accounting for only 5.3% [1]. The economy’s dominance by certain industries leads investors to favor established sectors over high-tech ventures [2]. Although this approach has provided significant benefits in economic prosperity, this imbalance threatens to hinder future growth and innovation, especially in the young generation.
Recent data shows a consistent decrease in the number of students enrolling in science, technology, and innovation-related university programs across East Asia [3]. This decline raises important questions about what is preventing the younger generation from entering science-related fields—questions that must be addressed in order to ensure the development of the industry in the future.
Two major factors are driving this trend: strong parental influence and low engagement with science among youth.

1.1.1 Parental Influence

In most Asian countries, students heavily rely on family advice for major educational and career decisions. As Leung et al. [4] found, in collectivist cultures like China, values such as filial piety and submission to authority strengthen parental influence, often leading students to choose careers based on family expectations. Meanwhile, as Chen et al. [5] note, parents often encourage children to pursue careers deemed honorable, such as public service, in order to secure economic and social advancement for the family, which leads to a lack of emphasis on science learning.

However, this generational influence is becoming less aligned with current economic trends. For example, many Gen Z individuals now gravitate toward emerging fields that didn't exist when their parents were making career decisions. This gap in generational understanding creates tension and missed opportunities.

1.1.2 Low Interests

Second, given the societal emphasis on industries that require less scientific knowledge, East Asian students often exhibit below-average attitudes toward science. As Wan and Lee [6]observed in Hong Kong, youth showed only a moderate interest in science—especially in activities outside of class and in choosing science-related jobs. This is closely related to the exam-driven education system, where academic success under parental expectations is prioritized over cultivating personal interest. Consequently, they tend to pursue degrees from reputable universities in non- science fields to secure socially prestigious jobs [7], which causes a loss in professional high-tech human resources.

1.2. Opportunity

As society undergoes rapid digital transformation, the demand for professionals equipped with scientific literacy and technical skills is rising. Innovations in AI, biotechnology, and climate tech are reshaping nearly every industry, from manufacturing to public health. However, there is a significant gap between the industry's demand and the younger generation's attention in these fields [8].The global shift in STEM education patterns and declining international student mobility has created significant challenges for universities worldwide, with international science and engineering student enrollment in the United States alone declining by approximately 20% (80,000 students) from 2019 to 2020 [9]. Without attracting and nurturing talent in science and technology, the potential for growth and development in this critical sector remains limited.

The two major factors discussed above—parental influence and lack of engagement—are not fixed conditions; they are shaped by cultural norms and societal conditions that evolve over time.

1.2.1 Generational Shift

Many East Asian parents still believe that choosing an educational and career path in traditional industries will ensure their children a better quality of life with a higher salary. However, there is a disconnect between the perspectives of parents shaped by past experiences and the current job market [10]. Research suggests that the science and technology industry salary has grown significantly, reflecting the growing demand for skilled professionals in these fields [11]. Despite this upward trend, many parents remain unaware of the evolving opportunities and continue to push their children toward traditional careers. This gap in awareness contributes to the low participation of youth in high-tech industries and keeps old career ideas that no longer match the current market.

1.2.2 Interest-Driven Choices

Further, today's youth are increasingly prioritizing personal interests when choosing their professional paths. This shift is especially happening in digital societies, where social media strongly impacts their perceptions. Report highlights young people's career aspirations are shaped less by traditional prestige and more by personal passion and media influence, with platforms like social media, TV shows, and online influencers playing a key role in how they imagine "ideal jobs" [12].
As a result, personal interest has become an increasingly important factor in shaping students' educational choices. Studies suggest that intrinsic interest in a subject not only improves academic performance but also increases the likelihood of pursuing related professions [13].Unfortunately, in many East Asian societies, such interest is rarely encouraged due to rigid academic structures. As Byun et al. [14]point out, South Korea's exam-oriented education system places academic achievement, measured primarily through standardized tests, as the sole criterion for success, leaving little room for the development of students' personal interests.

1.3. Rethinking Communication Strategies in Science Education

To bridge these gaps, science education must evolve beyond traditional methods and speak directly to the interests and values of young people. Communication strategies need to highlight the relevance of science to everyday life, showcase diverse career pathways. This includes creating participatory experiences that resonate with the realities and aspirations of today's learners. Without such strategies, the disconnect between talent and opportunity in science and technology will only widen.

1.4. Research Target

This research focuses on a specific target audience: individuals without a background in science, with the aim of shifting their perception of the field. Within this group, particular emphasis is placed on younger generations—specifically Gen Z and Gen Alpha. As future decision-makers, educators, and parents, their attitudes toward science will significantly influence in the future. By initiating interest and positive engagement with science at an early stage, we can foster a more informed, curious, and innovation-driven society.

1.5. Research Goal

To ultimately increase participation in the science and technology sector, people must first recognize the value and relevance of the industry. But before this shift in perception can occur, they need to develop a sense of interest, engagement, and connection with the field. These elements form the foundation for any meaningful change in attitude or behavior. Therefore, this research focuses on the initial and essential step: raising awareness, fostering engagement, and sparking interest in science and technology through more inclusive, accessible, and engaging forms of communication. It aims to serve as an entry point in that process by designing strategies that spark initial curiosity as the groundwork for future growth and wider involvement in the industry.

1.6. Research Overview

This study explores how art-based workshops can enhance awareness, engagement, and interest in science among individuals without a formal science background. Grounded in experiential and constructivist learning theories, the research investigates how scientific concepts can be effectively communicated through creative, hands-on activities in informal settings such as galleries and public workshops. The project adopts a design-led, iterative approach, emphasizing context-sensitive methods and participant-centered communication strategies. Through a series of real-world workshops involving diverse audiences, including parent–child participants, this study examines how encoding scientific ideas into visual and interactive formats can foster more inclusive and emotionally resonant learning experiences. The findings aim to contribute to both science communication practices and interdisciplinary education design.

1.7. Research Question

Based on the challenges and opportunities outlined above, this study seeks to answer the following research questions to better understand how art-based communication strategies can support science engagement among non-scientific audiences:

- **RQ1**: How can art-based workshops be designed to enhance science engagement among non-scientific audiences?
- **RQ2**: How can science communication strategies, particularly encoding techniques, be tailored within art-based workshops to support clearer understanding and reduce communicative "noise"?
- **RQ3**: How do art-based activities influence participants' ability to become more aware of, engaged with, and interested in science topics?

Chapter 2
Literature Review

2.1. The Challenge of Science Engagement in Public Settings

In recent decades, science communication has evolved far beyond academic publishing, extending into exhibitions, media, and community engagement initiatives, reflecting a global shift toward more participatory and socially embedded practices [15]. Yet despite this growing visibility, science remains widely perceived by the public as difficult, disconnected, or inaccessible. Many individuals—especially those without formal scientific training—report feeling intimidated by scientific content or uncertain about their ability to understand it [16]. These perceptions pose a critical barrier to broader science engagement, particularly in public settings where diverse participants bring varied expectations, prior knowledge, and emotional associations with science.

Two recurring challenges in public perception are deep-rooted stereotypes about what science is and who it is for, and the frustration or anxiety many people experience when engaging with scientific topics. These challenges often discourage curiosity and participation, especially among young audiences, or those with negative experiences in school science environments. The following subsections explore these two barriers in more detail.

2.1.1 Stereotype

Public perceptions of science are strongly shaped by enduring stereotypes that have been reinforced over generations through cultural narratives, media portrayals, and limited firsthand experience. These stereotypes often present scientists as intellectually brilliant but socially awkward, emotionally detached, or morally ambiguous individuals. As Tintori [17] notes, such images portray scientists as “clever, bright, reserved, socially clumsy people, devoted only to their work”—figures who are fundamentally “different” from ordinary citizens. While these portrayals may seem kind, they contribute to a rigid and biased mental model that distances science from everyday life and discourages engagement. Stereotypes simplify complex realities to make them cognitively manageable, but in doing so, they often distort. Based on Social Identity Theory [18], stereotypes help define in-groups and out-groups, which can result in exaggerated perceptions of difference, such as those often seen between scientists and the general public. This leads to the perception that scientists belong to an elite, isolated world, an ”ivory tower” inhabited by intellectuals.

Gender

One of the most persistent stereotypes is that science is a male-dominated field, rooted in centuries of gender bias. Tintori [17] emphasizes that from childhood, individuals absorb messages that depict science as inherently masculine and incompatible with traditional female roles. Media portrayals often reflect this imbalance, female scientists—if present at all—are shown as minor characters or unrealistic versions of male scientists. As Steinke [19] notes, popular media often portrays female scientists as exceptions to the norm, frequently emphasizing their physical appearance, emotional conflicts, or relational roles over their scientific competence, reinforcing traditional gender stereotypes and limiting diverse representations. Research has shown that media images can significantly shape the perceptions of women [20], where this perception can possibly influence women’s career choices because of the public assumptions about who can ’do science’.

However, in recent years, public figures and popular media have begun to challenge outdated gender stereotypes in science. Role models such as Nobel laureate Dr. Jennifer Doudna, co-recipient of the Nobel Prize in Chemistry for CRISPR gene-editing technology, have gained widespread recognition for their scientific achievements[1], helping to normalize the presence of women in high-profile STEM

1 The Nobel Prize, “Jennifer A. Doudna – Biographical,” https://www.nobelprize.org/prizes/chemistry/2020/doudna/biographical/. Accessed June 18, 2025.

roles. These shifts indicate progress in public perception, but continued efforts are needed to further broaden and normalize diverse representations in science and technology.

Media

In addition to gender bias, the portrayal of scientists as 'mad geniuses' or even morally irresponsible figures - originating from cultural references such as Frankenstein - adds another layer of suspicion. Research shows that television portrayals frequently present scientists as 'geniuses, villains, or eccentric figures', contributing to distorted public perceptions of science and scientists. [21] As a result, many members of the public—especially those outside the STEM pipeline—struggle to see themselves related to science or to view scientific knowledge as personally meaningful.

2.1.2 Frustration

In addition to persistent stereotypes, individuals who perceive themselves as excluded from scientific communities often experience frustration when engaging with science. This frustration is frequently rooted in how science is communicated and taught. Intemann [22] argues that the use of technical jargon can undermine key goals of science communication—namely, fostering understanding, accessibility, and engagement. Similarly, Vedder-Weiss and Fortus [23] found that science learning environments that prioritize control, performance, and rote knowledge over autonomy and curiosity contribute to student disengagement. When learners feel pressured or incapable, their emotional connection to science weakens, reinforcing the perception that science is inaccessible. These limitations in formal science education highlight the need for alternative learning environments that can reframe science as approachable, relevant, and emotionally engaging.

2.2. Creative Approach in Science Education

2.2.1 Informal Science Learning

Given the persistence of stereotypes and the frustration many people experience with formal science education, informal science learning (ISL) environments have emerged as important alternatives for engaging the public. Hofstein and Rosenfeld [24] describe informal science learning refers to learning experiences that occur outside formal school settings, such as in museums, zoos, media, and community programs. These experiences are typically voluntary, unstructured, and not tied to a formal curriculum. They further discussed informal learning as "not developed primarily for school use" and "characterized by voluntary as opposed to mandatory participation." However, they also acknowledge a "hybrid approach," where informal learning can supplement or even occur within formal settings, as long as it retains its out-of-school learning design and learner-centered qualities.
A key distinction between informal and formal science learning lies in their structure and intent. Informal learning is often learner-led, open-ended, and social, while formal learning is teacher-directed, sequenced, and assessed. This distinction is important for designing science activities that prioritize engagement and curiosity over prescribed outcomes [24].
As McCallie et al. [25] emphasize, ISL environments foster more interactive, dialogic forms of engagement, encouraging mutual learning between scientists and the public. Anderson and Lucas [26] highlight that informal settings often foster stronger emotional engagement and motivation, particularly through hands-on and social experiences. Rather than replacing formal education, ISL serves as a valuable complement, offering accessible pathways into science that are more inclusive and meaningful.
Emerging technologies such as augmented reality (AR) are further transforming informal science learning environments. For example, at Miraikan, the National Museum of Emerging Science and Innovation in Tokyo, visitors engage with exhibits like Geo-Prism, which overlays live video from the iconic Geo-Cosmos globe

with layered AR data[2]. This allows users to visualize not only the Earth's surface but also surrounding environmental data in real time, deepening their understanding through an interactive, sensorimotor experience. These innovations demonstrate how technology can enhance curiosity-driven learning and offer more personalized, engaging pathways into science.

2.2.2 STEAM Education

STEAM education—an expanded form of STEM that includes the arts—has gained global attention as a trans-disciplinary model designed to cultivate creativity, critical thinking, and real-world problem-solving [27]. By incorporating artistic and humanistic perspectives, STEAM supports experiential, inquiry-based learning that prepares students for future challenges while promoting innovation, collaboration, and ethical awareness [28]. Compared to traditional STEM education, STEAM fosters deeper engagement, improved content retention, and greater emotional involvement by integrating the arts into the learning process [29]. Furthermore, it not only broadens access to science but also supports different modes of thinking. As Land [30] explains, the arts foster both divergent thinking, which encourages creativity and exploration, and convergent thinking, which focuses on problem-solving and synthesis. These cognitive processes are essential for innovation and allow learners to approach scientific content from multiple angles.

2.2.3 Citizen Science

Citizen science refers to the active involvement of the public in scientific research—often through data collection, observation, or analysis—in fields ranging from ecology to astronomy. The practice has expanded significantly through the use of digital tools, allowing large-scale data collection and enhancing public involvement in scientific inquiry [31]. Projects such as eBird, Zooniverse, and COASST demonstrate how non-scientists can meaningfully contribute to research on biodiversity, climate change, and conservation. Beyond its scientific contribu-

2 Miraikan, "Geo-Prism / Geo-Cosmos Exhibit Description," `https://www.miraikan.jst.go.jp/en/exhibitions/tsunagari/geo-prism/`. Accessed June 18, 2025.

tions, citizen science also fosters public understanding and engagement, offering meaningful learning experiences and promoting environmental stewardship [32].

2.3. Gaps in Current Approaches

2.3.1 Lack of Structured Learning Outcomes

While informal science learning (ISL), STEAM education, and citizen science each promote engagement, creativity, and public participation, a common limitation lies in the absence of structured content and clear learning outcomes. Informal science learning environments—such as museums or community programs—are often unstructured and learner-directed, which, while beneficial for curiosity-driven exploration, can lead to fragmented understanding and limited long-term knowledge retention [33]. Similarly, STEAM education faces criticism for lacking a unified conceptual framework. Studies caution that without clear integration between disciplines, especially between STEM subjects and the arts, learning can become superficial or inconsistent [28]. In the context of citizen science, while participants may contribute meaningfully to scientific data collection, many projects lack formalized educational goals or assessment mechanisms to evaluate what participants actually learn. These challenges highlight a broader issue across all three approaches: the difficulty of balancing open-ended, participatory learning with the need for depth, coherence, and measurable outcomes.

2.3.2 Limited Educator or Facilitator Preparedness

Another shared challenge across current approaches to informal and interdisciplinary science learning is the lack of trained facilitators capable of implementing these models effectively. In informal learning settings, facilitators may not have formal training in science communication or education, resulting in missed opportunities for deeper engagement or conceptual clarity [33]. In STEAM education, teacher preparedness remains a persistent issue. Belbase et al. [28] point out that many educators feel unprepared to integrate arts with STEM content meaningfully, often resulting in tokenistic applications of creativity rather than true interdisciplinary learning. Likewise, citizen science projects frequently rely on community leaders, scientists, or volunteers without educational training to design and deliver experiences. Without guidance rooted in learning theory or science communication strategies, facilitators may struggle to sustain participant engagement or adapt to diverse learning needs [34]. Addressing this gap requires intentional investment in educator training and cross-disciplinary collaboration.

2.3.3 Access and Motivation Issues

Despite their inclusive intentions, there are challenges related to accessibility, participant motivation, and long-term sustainability. Informal learning spaces are often available primarily in urban, well-funded areas, leaving rural or under-resourced communities underserved [33]. In citizen science, motivation and retention remain ongoing concerns. Research shows that many participants engage only once, and projects often struggle to retain contributors over time [35]. Moreover, external incentives may create unrealistic expectations and threaten the authenticity or sustainability of engagement. As Geoghegan et al. [34] note, a better understanding of what drives participation—and how to support it over time—is needed to ensure citizen science reaches its full potential. Across these approaches, more inclusive communication strategies and sustained involvement are needed to ensure equitable and lasting impact.

2.4. Theoretical Frameworks Guiding the Design

2.4.1 Experiential Learning Theory

This research adopts Kolb's Experiential Learning Theory (1984) to structure informal science learning through hands-on art-based activities. Unlike traditional teaching methods that focus on abstract instruction, Kolb's model emphasizes learning as a process through four interconnected stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation [36]. This framework supports a learner-centered, participatory approach—well-suited to workshops where participants engage with scientific concepts through creative exploration.

Kolb's model is particularly relevant in informal or diverse learning settings, as it accommodates different entry points and learning styles. It offers a clear structure to design learning experiences where participants can discover, reflect, and internalize knowledge at their own pace. Abdulwahed and Nagy [37] demonstrated the value of this approach in a university engineering lab context. They found that activating all four stages of Kolb's cycle, especially the often overlooked dimension of 'prehension' (ex. concrete experience and abstract conceptualization) led to deeper learning results, improved knowledge retention and more meaningful engagement. This helps ensure that participants are moving through a full learning cycle, leading to more coherent, consistent, and measurable outcomes, even in informal or creative settings.

Constructivist Learning Theory

Constructivist learning theory views knowledge as actively constructed by learners through their interactions with the world, rather than passively absorbed from external sources [38]. This perspective informs the design of this study's workshops, where participants engage with scientific ideas by creating and reflecting through art making. Rather than presenting fixed content, the learning environment encourages open-ended exploration, interpretation, and personal meaning making.

Hein [39] emphasizes that learning is both a personal and social process, rooted in active engagement, language, and shared experience. In informal learning settings such as workshops, hands-on activities must also be "minds-on"—providing opportunities not just to manipulate materials, but to think critically and construct meaning. This approach values the learner's perspective, recognizing that understanding is shaped by prior knowledge, cultural background, and the context of the learning experience.

In line with this theory, it allows even non-expert facilitators to guide learning through open-ended exploration, discussion, and learner driven meaning making. This reduces the pressure on facilitators to deliver content and instead emphasizes creating supportive environments for co-learning.

Narrative Theory

In addition to experiential and constructivist approaches, narrative theory offers a valuable perspective for understanding how participants make sense of science. As Bruner [40] argues, narrative is a fundamental mode of human thought, helping individuals make sense of the world by organizing experiences into meaningful sequences or stories. In informal learning settings, narratives can serve as cognitive and emotional bridges—connecting abstract scientific concepts to everyday experiences, prior knowledge, and personal relevance.
This perspective is especially valuable when considering communication strategies for non-scientific audiences. Rather than relying solely on explanatory or factual content, narrative framing can help make scientific information more engaging, memorable, and accessible. By structuring content in story-like ways—through scenarios, metaphors, or sequences—educators and facilitators can support deeper comprehension and emotional connection, even before formal teaching or design methods are introduced.

Multimodal Communication

Multimodal communication uses multiple modes—such as visuals, text, and sound—to convey meaning more effectively than language alone [41]. In informal science learning, it supports accessibility, engagement, and comprehension, especially for audiences without a science background.
Research finds that meaning-making in multimodal communication is shaped by the interaction of cognitive, perceptual, and contextual factors [42]. This supports the design of an educational workshops that go beyond verbal explanation to engage learners visually, emotionally, and experientially. This diversity supports varied learning preferences, cultural contexts, and cognitive needs—broadening reach, maintaining interest, and enhancing participant motivation.

2.4.2 Communication Models

Effective communication plays a central role in informal science learning, especially in workshops where participants vary in age, background, and familiarity with scientific content. Traditional models, such as the Shannon and Weaver

Model of Communication [43], conceptualize communication as a linear process—where a sender transmits a message to a receiver through a channel, potentially disrupted by "noise." This study focuses on designing effective encoding strategies that convey scientific knowledge clearly, reduce potential "noise," and ensure the message can be accurately interpreted by the target audience.

This study also draws on interactive models of communication, which emphasize two-way exchanges and the importance of feedback loops [44]. In this model, both sender and receiver alternate roles and influence each other's understanding through mutual interaction. This is especially relevant in family-based workshops where communication is fluid, and meaning is shaped collaboratively. Conversations between children, parents, and facilitators become dynamic learning processes in themselves, not just a means of delivering information.

Applying these principles, the workshop design incorporates structured opportunities for dialogue,such as open-ended questions, shared reflection moments, and collaborative problem solving. By creating an environment that values both verbal and non-verbal exchanges, the workshops support a participatory form of communication that reinforces understanding, builds trust, and encourages curiosity. This aligns with broader constructivist and experiential frameworks, where learning is seen not as a passive intake of content, but as a relational and negotiated process.

2.4.3 Parent-Child Learning

Parent–child interaction is a key factor in science learning. When parents engage in science activities with their children, they help foster curiosity, understanding, and a positive attitude toward science. These shared experiences encourage open dialogue and exploration. Research highlights that such interactions significantly increase children's time spent with scientific content and deepen the quality of their exploration. In particular, when parents ask open-ended questions, connect to prior knowledge, and allow children to take the lead, children exhibit greater persistence and use more scientific reasoning. These behaviors are most effective when they are autonomy-supportive, when parents encourage self-direction rather than giving direct instructions [45]. Importantly, when parents develop an interest in the subject, they are more likely to positively influence their children's attitudes and engagement. Research finds that parents who view science as useful in everyday life and feel confident in their ability to support their child's learning are more likely to engage in frequent and meaningful science conversations at home [46]. This leads to richer scientific reasoning, questioning, and explanation from the child. Therefore, when designing programs for child participants, it is essential to actively involve their parents, as their engagement can help sustain the child's motivation and support continued learning beyond the activity itself.

Chapter 3
Methodology

3.1. Research Approach

3.1.1 Methodological Orientation

This study adopts Research Through Design (RtD) and Design-Based Research (DBR) approaches, focusing on the iterative development and evaluation of public-facing creative workshops. RtD, provides a framework for generating new knowledge through the creation and study of designed artifacts and experiences [47]. DBR offers a systematic approach to understand the learning processes through iterative cycles of design, implementation, and refinement in real-world contexts [48]. These frameworks are suitable for exploring how designed experiences can generate new understandings about science engagement among participants who do not identify with science learning in formal contexts, as both methodologies emphasize the development of practical interventions that produce theoretical insights about learning and engagement processes.

3.1.2 Research Goals and Questions

The aim of this research is to investigate how workshop-based experiences that focus on designated communication strategies can raise awareness, foster engagement, and spark interest in science and technology.
The research questions are:

- **RQ1**: How can art-based workshops be designed to enhance science engagement among non-scientific audiences?
- **RQ2**: How can science communication strategies, particularly encoding

techniques, be tailored within art-based workshops to support clearer understanding and reduce communicative "noise"?

- **RQ3**: How do art-based activities influence participants' ability to become more aware of, engaged with, and interested in science topics?

This is explored through the iterative development and testing of a novel design concept, introduced in detail in Section 3.3.

3.1.3 Justification for Practice-Based Approach

A practice-based approach is justified because science engagement is inherently experiential and context-dependent [49]. Conducting workshops in real-life contexts – gallery spaces, public venues, with diverse audiences – through an iterative, design-led process allows for context-sensitive insights that emerge from actual practice, enabling the refinement of encoding strategies based on observed participant engagement rather than theoretical assumptions alone.

3.2. Design Overview

3.2.1 Design Concept: Sci-Art

This design project, titled "Sci-Art", explores how art can serve as a communication medium to promote interest in science. "Sci-Art" consists of a series of themed workshops that incorporates underlying scientific knowledge—such as light, color, or chemical reactions— into the making of visually appealing artworks. The name "Sci-Art" reflects the central concept of combining science and art to create an interdisciplinary learning experience.
This integration is intended to lower psychological barriers to science, as research demonstrates that arts-based approaches can effectively convey scientific concepts to diverse audiences [50], especially for individuals who may view scientific concepts as difficult, inaccessible, or irrelevant to their lives. Aiming at those audiences, "Sci-Art" uses creative, hands-on activities to make scientific concepts more approachable and engaging.

3.2.2 Theoretical Frameworks

STEAM Education

The concept of integrating science with art is inspired by STEAM education [51]. The integration of art, visuals, storytelling, and tactile exploration embodies principles of multimodal communication [52], allowing participants to engage with scientific ideas through multiple sensory and cognitive channels.

Kolb's Experiential Learning Cycle

Each "Sci-Art" workshop follows a structured yet flexible format, using Kolb's experiential learning cycle as its foundational framework [36]. Workshops begin with a hands-on art activity that introduces a scientific phenomenon in a tangible, engaging way. Participants then reflect on what they observed or felt, often through guided discussion, before connecting their experiences to scientific concepts. Finally, they are encouraged to explore further through iteration or variation of the activity, reinforcing their understanding through action. This pedagogical approach aligns with broader principles of constructivist learning theory, which holds that learners construct knowledge through experience and reflection, rather than passively receiving information [38].

While this structure provides a consistent foundation, it is adapted according to the context of each session. Variables such as the participants' age, time constraints, group size, and specific testing goals influence how the workshop is conducted. For instance, sessions with younger children may place greater emphasis on play and exploration, while workshops targeting teens or adults might include more structured reflection or discussion. This adaptability ensures that the workshops remain inclusive, relevant, and effective across different learning environments.

In addition to contextual considerations, each session is designed around a unique theme that integrates relevant scientific principles with seasonal or cultural elements to sustain participant engagement [53]. For example, workshops held in December may incorporate a Christmas theme, while others might align with natural phenomena or holidays throughout the year. This thematic variation not only helps illustrate a wide range of activities, but also keeps the experience timely, relevant, and engaging for participants. By connecting science to familiar events or seasons, the project encourages participants to see science as part of their everyday lives [54].

Communication Models

A key component of this design is the development of communication strategies—referred to here as encoding strategies that conduct how scientific content is embedded within the art-based activities. These strategies are grounded in communication theory, particularly Shannon and Weaver's Model of Communication and the Interactive Model [43], which conceptualize communication as the transmission of a message from sender to receiver, often disrupted by various forms of noise. In the context of "Sci-Art", noise may arise from unfamiliar scientific terminology, abstract explanations, or mismatched learning styles. To address this, "Sci-Art" uses multimodal encoding to reduce cognitive barriers and improve message clarity.

These encoding strategies serve as the project's primary communication mechanism, determining how science is introduced, represented, and experienced by participants. Rather than delivering scientific content through direct instruction, the workshops aim to embed or "encode" science within multimodal forms—including materials, visuals, and interactive actions. According to multimodal communication theory, meaning-making emerges from the integration of multiple sensory channels [42], and effective communication depends on the participant's ability to decode these messages across different modes [55]. By leveraging this approach, the project allows participants to encounter and interpret scientific ideas through experience, emotion, and interaction, not just verbal explanation. This increases the likelihood that the intended message will be successfully decoded, even by audiences with diverse backgrounds and varying levels of scientific literacy.

Each strategy is designed with a specific purpose, tailored to the context of the session, such as the participant demographics, the workshop theme, or the intended focus of the user test. While each session may emphasize different aspects, the main goal remains consistent: to enhance participants' awareness, engagement, and interest in science.

For each strategy, the design includes three core elements following Hall's [56] encoding/decoding framework. First is the encoding, where scientific messages are intentionally embedded into the activity through visual, tactile, or thematic cues. Second is the expected decoding, which anticipates how participants might interpret or respond to the design based on theoretical predictions. Finally, during and after the session, participant reactions are observed and collected as actual reception, which reveals how the message was genuinely received and interpreted. This framework allows for systematic comparison between intended and actual meaning-making, providing empirical evidence for refining encoding strategies in creative science communication settings.

3.2.3 Workshop Structure and Timeline

To evaluate the effectiveness of the design and explore the role of encoding strategies in enhancing science engagement, a series of four workshops were conducted across different public venues between August 2024 and May 2025. These workshops were organized in gallery spaces, academic forums, and public innovation hubs, allowing the research to capture responses from diverse audience groups, including the general public and university students.

Across the four sessions, three distinct activities were designed, each integrating

Activity	Science	Art Output
Activity 1	Capillary action, Paper chromatography	Coffee Filter Art
Activity 2	UV light, Neon color	Neon Color Butterfly
Activity 3	Immiscibility, Acid and base reaction	Christmas Decoration Jar

Figure 3.1 Activity Overview

two core scientific principles and translated into hands-on art making experiences. One of these activities—"Coffee Filter Art," which focuses on capillary action and paper chromatography—was conducted in three separate workshops (WS1, WS2 and WS4), with revisions made to its format and facilitation based on prior findings. The other two workshops introduced "Neon Color Butterfly" (UV light and neon color) and "Christmas Decoration Jar" (acid–base reaction and immiscibility), respectively. All activities were structured to embed scientific content within the creative process, encouraging participants to engage with science through observation, exploration, creation, and reflection. An overview of the four workshops and their corresponding activities is presented in Figure3.2, which summarizes the date, location. Figure3.1 shows details of each activity with its scientific focus and creative output.

Workshop	Date	Location	Activity
WS1	2024.08.04	BnA_WALL	Activity 1
WS2	2024.10.12 - 10.13	KMD Forum	Day 1: Activity 1 / Day 2:Activity 2
WS3	2024.12.08	BnA_WALL	Activity 3
WS4	2025.05.24	Shonan iPark	Activity 1

Figure 3.2 Workshop Overview

Each workshop employed the same high-level structure aligned with Kolb's experiential learning cycle, while adjusting session pacing, tone, and facilitation style according to contextual factors such as audience age, setting, and workshop goals.
These workshops not only served as iterative design tests, but also as opportunities to gather insights into participant engagement, assess how well scientific ideas were communicated, and understand how art-based, multimodal approaches shape the learning experience for non-science audiences.

3.2.4 Design Iteration Plan

Iterative design played an essential role in the development of "Sci-Art", enabling each workshop to evolve through cycles of testing and refinement. As in Research-through-Design approaches, iteration plays a central role in refining materials and strategies based on contextual feedback and experiential insight [47].For every session, the design process began with internal prototyping—conducting trial runs with graduate school peers and collaboration companies' representatives to test early-stage concepts, materials, pacing, and communication strategies. These internal tests allowed for rapid feedback and adjustment, helping to refine the structure and enhance clarity before public implementation. Once finalized, each

session will be implemented in real-world settings, with participants recruited through public channels such as websites and social media, or public outreach events where collected data were used to demonstrate how well the scientific content was communicated and received. This two-phase process ensured that each workshop was grounded in participant experience and continuously improved to better support engagement, understanding, and interest in science.
Each iterative development of Sci-Art follows the principles of Design-Based Research (DBR) [57]. DBR emphasizes designing in real-world contexts, testing interventions with users, evaluating outcomes, and reflecting to inform further refinement. As illustrated in Figure3.3, the DBR cycle consists of four iterative phases: design, test, evaluate, and reflect, each contributing to continuous refinement of instructional tools [57].

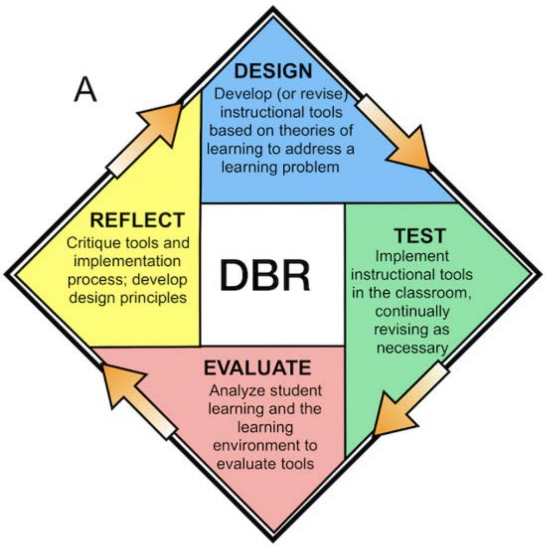


Figure 3.3 The iterative cycle of Design-Based Research (DBR).Adopted from Scott et al.2020,19:es11, p.2.

3.3. Research Context

While the overall structure and objectives of the workshops remained consistent, each session was slightly different in terms of its context, setting, and participant composition. These variations were intentional, allowing the research to explore how different audiences engage with science communication across formats. Factors such as the venue, participant demographics, and facilitation style influenced how each workshop unfolded. An overview of the four workshop sessions, including participant type, recruitment method, number of participants, entry fee, and provided gift, is summarized in Figure3.4. A more detailed description of each session will be provided in Chapter 4, where individual workshops are discussed in relation to their specific design focus and user testing outcomes.

Workshop	Participants	Recruitment	Number	Entry Fee	Gift
WS1	Parent-child	Peatix	10 pairs	Paid	Pentel Sign Pen (set)
WS2	Gen-Z	Free entry	14	Free	N/A
WS3	Gen-Z	Peatix	7	Paid	Acrylic Gouache(set)
WS4	Parent-child	Free entry	41 groups	Free	Workshop Kit

Figure 3.4 Workshop Participants Overview

3.3.1 Partnership

Three main partners supported the realization of this project:

- BnA_WALL – an art hotel and gallery based in Nihonbashi, Tokyo
- Shonan Health Innovation Park (Shonan iPark) – Japan's first pharmaceutical-initiated science park
- Pentel Corporation – a Japanese stationery company

BnA_WALL and Shonan iPark each served as physical venues for the workshops, contributing distinct thematic environments. BnA_WALL offered a creative, art-centered atmosphere ideal for testing science engagement through visual expression. In contrast, Shonan iPark provided a science-forward setting aligned with innovation and research, attracting a more STEM-oriented audience.
Pentel played a key role in material support, supplying essential art tools such

as water-based sign pens, acrylic paints, and neon-colored Art Brushes. These materials were not only functional but conceptually integrated into the workshop experience, acting as mediums through which scientific principles were encoded and explored visually.

In addition to logistical and material support, all three partners contributed to the iteration process of the workshop design, offering feedback and facilitating real-world implementation. Their involvement was instrumental in grounding the research within authentic, community-engaged environments. Further details on their specific contributions are discussed in the corresponding workshop sections in Chapter 4.

3.3.2 Research Setting

To reach diverse audience segments, workshops were conducted in three distinct settings, each selected for its alignment with the project's goals of inclusive, informal science engagement:

BnA_WALL

Located in Nihonbashi, Tokyo, BnA_WALL's basement space functions as a flexible event venue and regularly hosts creative programs, such as "PLAY ART" for young children. This venue was selected for its alignment with the project's aim to integrate science into public, art-focused environments. Its naturally art-interested audience offered an ideal context to explore how science could be embedded into visual and creative practices.

KMD Forum

KMD Forum is an annual public exhibition organized by the Graduate School of Media Design at Keio University. It showcases student-led "Real Projects" through interactive booths and installations. The event is held at Tokyo Port City Takeshiba, 3rd Floor, providing a spacious and accessible environment for public interaction. This setting allowed the workshop to be tested in a university-driven, walk-in format, attracting a wide demographic—from students to external visitors—and promoting spontaneous participation. The forum provided a valuable opportunity to observe engagement in a dynamic, interdisciplinary academic environment.

Shonan iPark

As a national hub for science and innovation, Shonan iPark organizes an annual event called “iPark Fiesta”, featuring public-facing science activities hosted by companies and research institutions. The venue drew participants with a predisposition toward science and an interest in hands-on learning. This setting was especially valuable for evaluating how science-themed activities were interpreted by science-oriented audiences and for testing how the encoding strategies functioned in a more technically informed context.

3.3.3 Participants

Parent-child

Among the workshops, WS1 and WS4 were designed for parent–child pairs. In WS1, parents primarily took on an observational role, allowing their children to lead the activity and express themselves independently. In contrast, WS4 involved both parent and child actively participating together, emphasizing shared exploration and co-creation. These different formats enabled an examination of varying parent–child interaction styles and their influence on engagement.

Gen Z

In addition to parent–child pairs, WS2 and WS3 attracted young adult participants from Generation Z (born between 1997 and 2012). These individuals, often university students or early-career professionals, represent a demographic known for growing up with digital technology, short attention spans, and a preference for interactive and visually engaging experiences. Their participation provided valuable insights into how younger audiences respond to informal, art-based science learning outside of traditional educational settings.

3.3.4 Recruitment

Participant recruitment strategies varied depending on the venue and format of each activity.

Peatix

For the workshop held at BnA_WALL, participants were recruited through a ticketed registration system using the platform Peatix. Each ticket was priced at 1,500 yen, as required by the venue. The research team did not receive any financial benefit from these fees. However, it is acknowledged that this cost may have unintentionally excluded individuals who could not afford to pay, potentially limiting the accessibility and diversity of participants.

Free Entry Public Events

Workshops held as part of the KMD Forum and at Shonan iPark were free and open to the public, with no advance registration required. These events attracted spontaneous participation from visitors already attending the venues, enabling a diverse and organically formed participant group. However, it is acknowledged that participants were likely already interested in the hosting organizations or event themes, which may have influenced their motivation and openness to engage with the workshop content.

3.3.5 Promotion

To show appreciation and also attract more potential participants, gift items provided by Pentel were distributed to participants after selected workshops. These gifts also served as a subtle reinforcement of the collaborative and supportive atmosphere of the event, while enhancing Pentel Corporation's branding communication.

To reach a broader audience, we conducted social media-based promotion in collaboration with project partners. Promotional content was disseminated through multiple channels to recruit, including both online and offline. Online channels include BnA_WALL's official Instagram account, Pentel's official X (formerly Twitter), and Shonan iPark's event website. These channels were selected to leverage existing follower networks and reach art and science-interested communities. Offline channels consisted primarily of physical posters and flyers, which were displayed at the venue and in nearby community spaces to attract local visitors and passersby who might not be reached through digital platforms. The design of the workshop poster for WS1, which is used for participant recruitment, is shown in Figure3.5 as an example.

Figure 3.5 Poster and flyer design for Workshop 1

3.4. Methods of Data Collection

To evaluate the effectiveness of the design and understand participant responses, a mixed-methods approach was adopted following established principles of methodological triangulation [58]. Multiple forms of data were collected across the four workshops to capture both observable behaviors and self-reported perceptions, allowing for a richer understanding of how participants engaged with the activities and how the encoding strategies influenced their awareness, interest, and understanding of science.

3.4.1 Observation

Each workshop was video-recorded to capture participant interactions, engagement levels, and facilitator behavior. These recordings served as the primary tool for documenting behavioral responses to the embedded scientific content, enabling post-session analysis of verbal and non-verbal cues through systematic video analysis techniques [59].

3.4.2 Participants' Artworks

The artworks produced by participants served as tangible outputs for assessing engagement and science interpretation. These artifacts were analyzed to explore how participants visually represented scientific concepts, how they interacted with the materials, and how they applied their understanding through creative choices [50]. In addition to evaluating the clarity and accessibility of the encoded scientific content, attention was given to participants' behavioral responses toward their creations—such as their inclination to continue working, take their artwork home, or express interest in sharing it on social media. These observations were used to gauge the emotional connection, personal investment, and perceived value of the activity, offering deeper insight into participant engagement across different workshop formats and age groups.

3.4.3 Questionnaire

All four workshops employed structured questionnaires to systematically evaluate participants' responses to the science-art integration experience. The questionnaire design followed established principles for educational research surveys, incorporating Likert-type response scales for their demonstrated effectiveness in measuring attitudinal and perceptual constructs [60].

Post-Workshop

Post-workshop questionnaires were distributed across all four workshops to capture participants' immediate reflections on the experience. Following practices in educational survey design [60], questions were structured to address four key domains:

- **Perceived enjoyment and engagement with the workshop activities** - recognizing that emotional responses, particularly enjoyment, are fundamental to sustained science engagement [61].
- **Clarity of the activity and comprehension of scientific concepts** - addressing Kirkpatrick's Level 2 learning outcomes focused on knowledge acquisition and understanding [62].
- **Interest in the scientific topic following the hands-on experience** - following the hands-on experience - as increased interest correlates with greater knowledge gains and positive activity evaluation [61]

Questions utilized 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree) to capture nuanced responses while maintaining sufficient granularity for analysis [63]. The selection of a 5-point scale aligns with recommendations by Artino Jr et al. [60] for educational research contexts, as it provides adequate response differentiation without overwhelming participants with excessive choice complexity.
Questions were adjusted for each workshop depending on the different audience and the specific purpose of the workshop, also incorporating experience from the previous workshop as iteration. This iterative approach to questionnaire refinement ensures that instruments remain relevant and effective across diverse educational contexts [60]. Further details will be discussed in Chapter 4 within the questionnaire sections of each workshop.

Parent-child

In WS1 and WS4, where participants included parent-child pairs, differentiated questionnaires were provided for children and their guardians to capture both direct and reflective perspectives. As demonstrated by recent research on parent-child educational dynamics, multi-informant studies using differentiated assessment tools can reveal important discrepancies and complementary insights that single-perspective approaches might miss [64].

Children aged 4 to 7 received simplified questionnaires incorporating the Smileyometer—a validated child-friendly visual analogue scale using facial expressions to represent levels of enjoyment [65]. The Smileyometer, described as part of the "Fun Toolkit," has been specifically developed and validated for measuring children's subjective experiences with technology and activities. This instrument assessed children's fun, curiosity, and engagement with the activity.

Parents completed more detailed questionnaires designed to evaluate their perceptions of their child's learning, emotional involvement, and the overall effectiveness of the workshop. This dual approach was particularly valuable, as research demonstrates that young children may not yet have the ability to articulate complex thoughts or accurately assess their own learning [66]. Research on informal science learning sites emphasizes the critical role parents play in children's learning experiences, noting that parental involvement and perception significantly influence children's engagement with scientific content outside traditional classroom settings [67]. This body of research supports the methodological decision to include parental perspectives as a primary data source, particularly given their privileged position to observe children's behavior across multiple contexts and over extended periods.

3.5. Method of Data Analysis

3.5.1 Observation Analysis

Observational data, including video recordings and facilitator notes, were analyzed to assess real-time indicators of engagement and interaction. Behaviors such as body language, eye contact, verbal expressions of curiosity or confusion, and time spent on tasks were used to infer levels of interest and focus. A thematic analysis approach was applied to categorize participant behaviors into recurring themes such as exploration, hesitation, social engagement, and delight. Braun and Clarke [68] define thematic analysis as a research method used to identify and interpret patterns or themes in a dataset, providing a systematic framework for analyzing qualitative data. These themes were identified through repeated viewing of video footage and review of field notes, using a process of coding and pattern recognition for thematic analysis [68]. This methodological approach enabled the identification of meaningful patterns across participant responses while maintaining analytical rigor. The analysis helped evaluate how participants responded to the embedded scientific content and the workshop format.

3.5.2 Artwork Analysis

Participant-created artworks were examined as tangible outputs that reflected participants' understanding, interpretation, and engagement with scientific principles. Additional attention was given to how participants interacted with their own creations—for example, whether they showed pride in their work, asked to take it home, or discussed it with others. These interactions were treated as secondary indicators of engagement and emotional connection.

3.5.3 Questionnaire Analysis

Questionnaire data were analyzed using both quantitative and qualitative methods. Likert-scale responses were aggregated to determine overall trends in enjoyment, interest, and perceived learning. In WS4, pre- and post-questionnaire comparisons were used to detect changes in participant attitudes. Open-ended responses, where applicable, were thematically coded following the same analytical framework applied to observational data [68] to supplement quantitative findings with participant perspectives on their experience.

3.5.4 Triangulation and Synthesis

Triangulation is the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena [69]. For example, instances of observed engagement were cross-referenced with participant feedback and corresponding artwork outputs. This integrative process enabled a more nuanced understanding of each workshop's impact and the effectiveness of specific communication strategies.

3.6. Validity, Reliability and Researcher Reflexivity

To ensure the trustworthiness of this research, particular attention was given to the concepts of validity, reliability, and researcher reflexivity throughout the study design and execution.

3.6.1 Validity

Validity in this study was addressed through triangulation across multiple data sources, including observations, questionnaires, and participants' artworks—to capture a holistic view of engagement and learning. The communication strategies were tested across varied workshop settings (child, Gen Z, and parent–child formats), which strengthened ecological validity by situating the activities in real-world, public contexts. Furthermore, efforts were made to align questionnaire content with specific learning and engagement goals, including the use of pre-post formats and simplified tools like the Smileyometer for younger participants.

3.6.2 Reliability

To enhance reliability, consistent facilitation protocols were maintained across workshops, including clear instructional materials and structured session flows. For WS4, a detailed facilitator training session was conducted to ensure consistent delivery of the activity and explanation of scientific content. Data collection procedures, such as standardized video recordings, consistent questionnaire distribution, and coded responses, supported the systematic handling of data. Internal pilot tests also helped refine workshop materials and session timing, reducing variability in participant experience across sessions.
In addition to these technical measures, this study also considered communication reliability: how effectively scientific ideas were conveyed and understood by

participants. Miscommunication is a common challenge in public science education, where unfamiliar terminology, abstract content, and passive teaching formats can hinder comprehension. Drawing from communication studies, this research views interactive workshops as a form of mediated communication. By allowing participants to engage directly with scientific content through hands-on activities and dialogue, the workshops provided opportunities for real-time clarification and personal interpretation. This approach reduces the risk of misunderstanding and encourages co-construction of meaning, aligning with research that highlights the effectiveness of learner-centered, participatory models in informal science learning.

3.6.3 Research Reflexivity

Given the participatory and iterative nature of this research, the role of the researcher was both as designer and primary facilitator in most workshops. This dual role introduced the possibility of researcher bias, particularly in interpreting participant reactions or guiding discussions. To mitigate this, detailed field notes and video recordings were used to reflect more objectively on participant behavior. In WS4, facilitators other than the researcher were trained and observed, allowing for greater neutrality in implementation and providing insight into how the workshop performed when led by others.

3.7. Ethical Considerations

3.7.1 Ethical Approval

The research was reviewed and approved under the ethical guidelines of Keio University Graduate School of Media Design. It followed institutional standards for research involving human subjects, particularly in educational and public engagement settings.

3.7.2 Informed Consent

All participants were informed of the research purpose, data collection methods, and their rights before participating. A formal video recording consent form was distributed, outlining that participants' actions during the workshops would be recorded for research purposes. For participants under 18 years of age, signed consent was obtained from their parent or legal guardian, as required. The form was available in Japanese to ensure clarity and accessibility for all participants. The consent form explained that recorded data may be used for academic analysis, presentation, and outreach activities in collaboration with the partner institutions. Participants were required to sign the document only after confirming their full understanding and agreement with the stated conditions.

3.7.3 Confidentiality and Anonymity

To protect participant privacy, all personal data were anonymized. Video recordings were stored securely on password-protected, access-restricted drives managed by the Keio University Graduate School of Media Design. Any data used for publication or presentation was processed to ensure that individuals' identities could not be discerned. Video and audio data will be retained for a maximum of five years (from August 4, 2024, to August 5, 2029), after which they will be securely deleted.

3.7.4 Voluntary Participation

Participation in the research was strictly voluntary. All individuals were informed that they could withdraw their consent at any time without explanation and with no negative consequences. Participants were also reassured that their decision to withdraw would not affect their ability to take part in the workshop or any related activities.

3.8. Facilitation

3.8.1 Facilitator Roles

Facilitation played a critical role in shaping the participant experience and ensuring that each workshop was conducted in a safe, engaging, and inclusive environment. In this study, the facilitator's role extended beyond logistical coordination

to include guiding participant interaction, framing the activity, and supporting science communication through creative engagement.
W1,WS2 and WS3 were led by the primary researcher, while WS3 supported by assistants for translation. WS4 was led by a facilitators team and they got proper training session to understand the workshop content and proper behavior.
At the beginning of each session, facilitators provided a simple, welcoming introduction, explaining the structure of the workshop and the materials involved. Scientific concepts were not presented as formal instruction, but rather embedded within the creative process, with facilitators offering gentle prompts, asking open-ended questions, and encouraging participants to explore, reflect, and make personal connections with the materials.

3.8.2 Adaptive Support

For parent–child workshops, facilitators were especially attentive to the interpersonal dynamic, inviting parents to either observe or co-create, depending on the workshop format. This flexibility ensured that both children and adults felt comfortable participating at their own pace.
Facilitation also required real-time adaptation to participants' needs, energy levels, and reactions. The facilitator observed carefully and adjusted the tempo, level of guidance, or framing of science concepts accordingly. This responsive approach ensured that scientific ideas were accessible without being prescriptive, aligned with the project's broader goal of fostering intrinsic interest in science through multimodal, experience-based learning.

3.8.3 Ethical Responsibilities

Throughout the workshops, facilitators also supported the implementation of ethical protocols, including confirming consent, managing video documentation, and offering assistance when participants needed help or clarification. Their role was integral to creating an environment that was both educational and respectful.

3.9. Summary

Together, these methodological choices laid the foundation for interpreting how adaptive workshop design can foster accessible and engaging science learning experiences across age groups and learning environments. In the following chapter, each workshop is examined in detail, highlighting how the design was implemented in context, how participants responded to the communication strategies, and what insights were gained from the iterative development process.

Chapter 4
Validation

4.1. Overview

This chapter is structured around the four workshops, as shown in Figure4.1, while each serving as a user test. For each session, the research will detail the specific context, outline the iterative design process, describe the final workshop flow, and evaluate the effectiveness of the intended communication strategies. This structure allows for a contextualized analysis of how the design evolved and how participants responded across different settings.
The analysis follows a three-part structure:

1. A breakdown of the communication approach and its intended and actual effects

2. Questionnaire-based evaluation of participant engagement and conceptual understanding

3. Workshop-specific insights and future implementations

Following these individual analyses, a cross-workshop synthesis is provided to identify overarching communication patterns, effectiveness of strategy design, and emerging implications for informal science communication in Chapter 5. This framing allows the workshops to be understood not only as educational experiences but also as mediated communication experiments that reflect on clarity, framing, and audience interpretation.

Workshop	Activity	Focus
Workshop 1	Activity1	*Hands-on Engagement for Children*
Workshop 2	Activity1+Activity2	*Emotional Connection for Gen Z*
Workshop 3	Activity3	*Simplifying Abstract Science*
Workshop 4	Activity1	*Family Learning and Collaboration*

Figure 4.1 Workshop Overview

4.2. Workshop 1:Hands-on Engagement for Children

4.2.1 Context

Workshop 1 served as a pilot session, involving multiple iterations to refine the activity concept, workshop flow, and expected art outcomes. The first official user test was conducted on August 4, 2024, in the basement event space of BnA_WALL in Nihonbashi, Tokyo. This workshop was specifically designed for children around the age of 10, with a total of 9 child participants and 8 accompanying guardians. The format focused on observing how young children engage with hands-on science–art activities, while guardians primarily took on an observational role. Insights from this pilot session helped shape the structure and facilitation of subsequent workshops. Iteration process is shown in Figure4.2

Design Iteration	Participants	Purpose
Iteration 1	Graduate School Peers	Activity, theme
Iteration 2	Representatives from Partnerships	Structure, feasibility
Iteration 3	Graduate School Peers	Rehearsal

Figure 4.2 Activity 1 Iteration Overview

4.2.2 Iteration Process

Iteration 1

- Design
  In the early development phase of Sci-Art, a wide range of existing science and art-based activities were reviewed and tested independently by the designer to assess their feasibility, accessibility, and creative potential. Among them, "fizzy art" , uses baking soda and vinegar to paint, and paper chromatography activity that uses coffee filter and water-base pen to make patterns were identified as particularly promising due to their vivid visual results and connection to core scientific principles. The initial session was designed to include both activities within a single workshop. The intention was to offer participants a diverse and stimulating experience, maximizing engagement through variety.

- Test
  To explore the feasibility and overall appeal of combining two activities into a single session, an internal pilot was conducted with graduate school peers, who served as stand-in participants for adult audiences. At this stage, the goal was not to measure effectiveness in detail, but rather to gain a broad understanding of the session's flow, balance, and potential impact. Participants engaged with both activities, and the test was used to observe which elements naturally attracted attention, where confusion or disinterest occurred, and how participants responded emotionally and intellectually. Feedback was collected on participants' overall impressions, emotional engagement, and which activity felt more compelling or enjoyable. This exploratory session functioned as an early brainstorming tool to help determine which direction had stronger potential for refinement.

- Evaluate
  The feedback from the pilot indicated that while each activity was enjoyable on its own, combining them into one session introduced cognitive and logistical challenges. Participants reported feeling overwhelmed by the quantity of materials and the mental shift required to transition between distinct activities. Further, participants found the paper chromatography activity more

Figure 4.3 Iteration 1 test phrase

appealing than the "fizzy art" activity, as the unexpected visual outcome of the color separation evoked a stronger sense of surprise, while the final output needs to be reconsidered to make it more compelling for the target research audience.

- Reflect
  This evaluation revealed that combining multiple activities in one session overwhelmed participants and reduced the overall learning impact. It highlighted the importance of clear pacing and thematic focus in building engaging learning experiences. As a result, the format was revised to include only one core activity per session. The paper chromatography activity was selected due to the feedback and further developed into a flower and butterfly making format to enhance visual appeal. This refinement simplified the structure and allowed participants to both observe a scientific phenomenon and create a meaningful, take-home artwork, deepening the connection between creative expression and scientific exploration.

Iteration 2

- Design
  Following the initial pilot session, the paper chromatography activity was

further developed into a 90-minute workshop structured around Kolb's experiential learning cycle. A presentation slide deck was created to guide participants through each phase of the activity, including step-by-step instructions for the experiment, a basic explanation of the science behind paper chromatography, and directions for completing the final handcraft. At this stage, the instructional materials were still relatively formal and text-heavy, with the primary aim being to test the feasibility of the workshop structure and assess whether participants could follow the instructions effectively.

- Test
  This version of the workshop was tested with representatives from the collaborating organizations—BnA_WALL and Pentel. As project supporters, their perspective was especially valuable in assessing both the scientific accessibility and material practicality of the activity. Their approval was also a key factor in deciding whether the activity was ready to move forward for public implementation. The session functioned both as a design test and a rehearsal for future facilitation, helping all parties become familiar with the flow and logistics of conducting the workshop.

- Evaluate
  The feedback from this session focused on two key aspects: the presentation materials and the activity flow. Participants noted that the slides, while informative, contained too much text and abstract explanations, which could be difficult for younger Japanese children to follow. They recommended the inclusion of more visual aids—such as diagrams, videos, or live demonstrations—to enhance clarity and maintain attention. In terms of activity flow, the current format felt overly instructional, resembling a manual rather than an engaging, hands-on experience. Suggestions included adding interactive elements, such as short quizzes or mini-demonstrations, to re-capture attention at various points in the session. There were also minor comments on content: for example, limiting the craft output to only flowers (instead of both flowers and butterflies) could improve visual focus and encourage practical use as a decorative object at home.

- Reflect
  This session revealed the importance of designing not just for clarity, but also for sustained engagement, especially with younger participants. While the instructional content served its basic function, the delivery format needed to evolve from a static, text-based guide to a more dynamic, experience-driven process. The inclusion of interactive cues and sensory elements emerged as crucial for maintaining attention and enhancing comprehension. Additionally, the feedback highlighted the value of designing with a clear aesthetic and functional purpose, such as creating decorative flowers, to increase emotional attachment to the outcome. These insights informed the next iteration of the workshop, which incorporated more visual storytelling, simplified language, and strategically placed engagement moments to transform the experience from instructional to immersive.

Iteration 3

- Design
  Building on feedback from the previous session, this iteration focused on improving the flow and engagement level of the workshop by incorporating interactive elements throughout the session. A color quiz was added at the beginning as an icebreaker and a thematic introduction to the concept of color. To support understanding of paper chromatography, a demonstration called the "chromatography race" was introduced. Participants were asked to predict which color would travel the fastest up a strip of paper placed in water—stimulating curiosity before observing the actual outcome. This created a shared moment of excitement while providing a visual and tangible demonstration of the scientific principle.
  To deepen conceptual understanding, capillary action was introduced before chromatography as a foundational concept. Everyday examples such as using cotton swabs or observing water movement in plants were used to help participants connect abstract scientific phenomena to familiar, lived experiences. These changes were designed to shift the workshop from a passive instructional format to an active and emotionally engaging experience.
- Test

This version was tested in a rehearsal session with graduate school peers, serving both as a detailed walkthrough of each step and a facilitator practice run. The test allowed for timing adjustments, identification of unclear transitions, and fine-tuning of instructions for the interactive segments.

- Evaluate
  Overall, the feedback was positive. Participants noted that the added interactive elements helped maintain attention and made the science content feel more approachable. The chromatography race, in particular, was effective in sparking energy and curiosity. However, while the demonstration was visually engaging, some participants found the scientific explanation lacking in depth. The mechanism behind why certain pigments travel faster remained unclear to many. It was suggested that additional explanatory materials—such as simplified diagrams or analogies—could be prepared in advance to support comprehension during the demonstration. A minor suggestion was also made to include example patterns for decorating the coffee filters, to help participants begin their artwork without limiting creative freedom.

- Reflect
  This iteration highlighted the importance of balancing excitement with conceptual clarity. While the activity successfully engaged participants, the underlying science needed to be communicated in a more accessible way. To address this, a new visual aid was developed using anthropomorphized diagrams—portraying pigment molecules as characters with different "personalities," such as liking water or sticking to paper. This metaphorical approach aimed to make the mechanism of chromatography easier to grasp, especially for younger participants. With this adjustment, the workshop was considered nearly complete, with only minor refinements remaining before public implementation.

4.2.3 Structure and Flow

As shown in Figure4.4, the workshop followed the structure of Kolb's Experiential Learning Cycle:

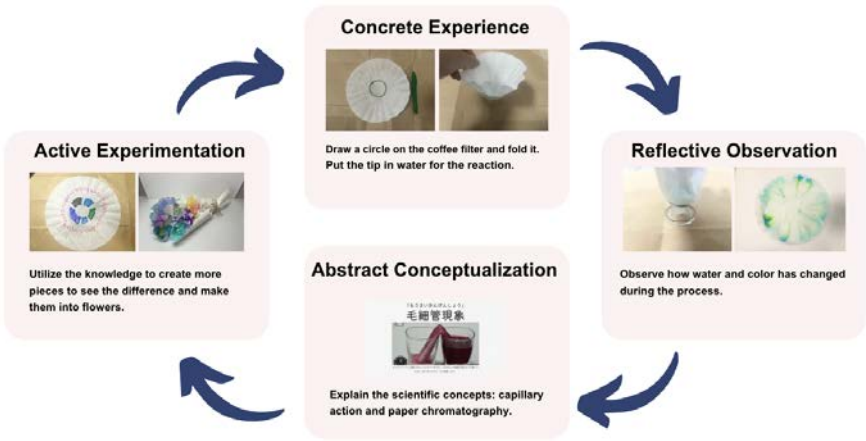


Figure 4.4 Workshop 1 Framework

- **Concrete Experience**: Participants began by selecting a color and drawing on a coffee filter using water-based Pentel Sign Pens. They folded the filter and placed its tip in a cup of water, initiating capillary action.
- **Reflective Observation**: As the water rose through the paper, participants were prompted to observe the movement and describe what they saw. The facilitator guided a group discussion, encouraging children to voice their observations.
- **Abstract Conceptualization**: The facilitator introduced the term "capillary action" and explained the scientific mechanism using familiar analogies, such as how plants absorb water through roots or how cotton swabs absorb liquid. The concept of "paper chromatography" was then introduced through a second experiment: the Chromatography Race, in which participants compared how eight different ink colors separated and moved on the filter paper.
- **Active Experimentation**: Participants used the colored filter papers to create paper flowers. Encouraged to try different patterns, they explored how scientific outcomes could be creatively repurposed. The session con-

cluded with assembling the flowers into personal bouquets using additional craft materials.

Usage	Item	Quantity	Purpose
Individual	Flat Bottom Coffee Filter	3	Main material
	Sign Pen (8 colors set)	1	For drawing and coloring
	Disposable Cup	2	For holding water
	Watercolor Paper (A4)	1	To absorb water and ink
	Tray	1	To prevent spills and contain the work area
Shared	Scissors (Kids-friendly)	5	To cut the edges of flower petals
	Clear Tape	5	To assemble or attach parts
	Paper Straw	1 pack	Used as flower stems
	Paper Towel	2 packs	To absorb excess water and keep area clean

Figure 4.5 Workshop 1 Material List

4.2.4 Material

The full list of materials used in Workshop 1 is summarized in Figure4.5. The use of everyday materials (water, coffee filters, water) reinforced the idea that science is accessible and observable in daily life. The hands-on, creative process enabled participants to internalize scientific ideas without needing prior knowledge.

4.2.5 Workshop Environment and Attendance

The workshop venue was arranged with a long table, accommodating five participant seats on each side. Adjacent to the activity area, a designated seating area was prepared for parents, allowing them to observe the session comfortably. While parental observation was encouraged, it remained entirely voluntary. A total of 10 participants registered for the workshop; however, one withdrew during the session, resulting in 9 valid participants for the study. Among the accompanying guardians, one parent chose not to observe, while the remaining 8 parents attended and observed the workshop. The workshop layout is shown in Figure4.6, which illustrates the seating arrangement for participants, facilitators, and parents.

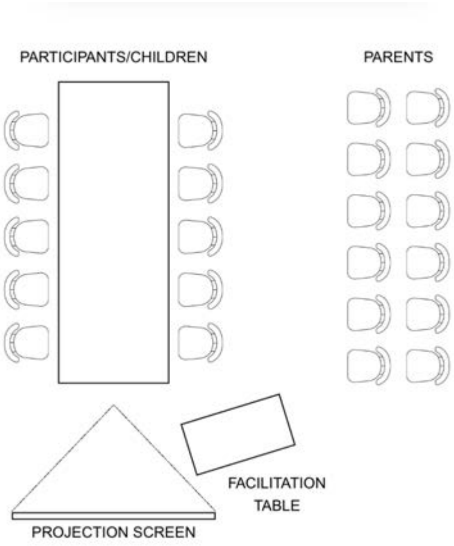


Figure 4.6 Workshop 1 Venue Layout Plan

4.2.6 Communication Strategy

Because the participants were children, this workshop prioritized active engagement to address their shorter attention spans and tendency to become distracted in learning environments. To sustain their interest and ensure consistent participation, the communication strategy focused on hands-on, interactive elements that encouraged immediate involvement. Specifically, the strategy emphasized two key techniques: the use of questions and interactive demonstrations. These methods were designed to invite participation, maintain attention, and prompt reflection throughout the session. By embedding scientific explanations within a creative, sensory-based activity, the workshop sought to make science more accessible and emotionally resonant for young learners.

Questioning and Guided Observation

- **Encoding**
  The session began with a simple color-mixing quiz projected at the front of the room. This served as an icebreaker and a gentle introduction to the day's scientific theme. Participants were invited to guess which two primary colors combine to make green, sparking discussion and anticipation. As the workshop progressed, the facilitator continued using targeted questions to guide participant observation—such as, "What do you notice about the water?" and "How is the color changing?" These prompts encouraged children to verbalize their observations and reflect on the unfolding process.

- **Expected Decoding**
  It was expected that starting with an interactive question would help activate prior knowledge and curiosity, making participants more mentally and emotionally prepared for the activity. This approach aligns with research that reflects "the quality of the questions that teachers ask plays an important role in promoting or hindering students' curiosity, thinking, and, consequently, their learning [70]."Continued questioning during the experiment was intended to keep their focus on key scientific phenomena and support deeper cognitive engagement.

- **Actual Reception**
  As Figure4.7, participants showed strong willingness to answer the opening quiz, with many raising their hands and sharing their thoughts out loud. During the observation phase, several children described the changes they were seeing, indicating active reflection. The questions effectively anchored their attention and supported understanding by linking abstract science to immediate sensory experiences.

Interactive Demonstration

- **Encoding**
  As part of the workshop, a group-based demonstration called the Chromatography Race was introduced to visually communicate how different ink pigments separate at different speeds. A prepared piece of filter paper with

Figure 4.7 Participants actively answering the question.

eight colored dots aligned at the same height was shown to participants. Before initiating the experiment, the facilitator invited the children to guess which color would travel the fastest to the top when the paper was placed in water. The filter paper was then positioned with its lower edge submerged, allowing participants to observe the movement and separation of each color in real time.

- **Expected Decoding**
  This approach follows Predict-Observe-Explain (POE) framework [71], which "prompts students to predict the outcome of an experiment, then do the experiment and, finally, to explain their reasons for the prediction and the outcome." It was anticipated that combining prediction with visual observation would heighten participants' engagement and curiosity. Encouraging children to form hypotheses before seeing the results was expected to deepen their investment in the activity and facilitate a more meaningful understanding of chromatography through active cognitive engagement.

- **Actual Reception**
  Participants responded with enthusiasm, offering predictions aloud and closely tracking the progress of each color. Many leaned in to follow the movement, while others expressed surprise as the results unfolded. Notably, several parents also became actively engaged—photographing the demonstration, discussing the outcome with their children, and even expressing their own

curiosity. Figure 4.8captures a moment during the demonstration, illustrating the high level of engagement across generations. This unexpected level of adult involvement revealed the broader appeal of the activity and inspired future consideration of expanding the target audience to include inter-generational participants. The success of this demonstration highlighted the value of incorporating playful prediction and visual impact into science communication.

Figure 4.8 Parents filming the demonstration.

4.2.7 Questionnaire

To evaluate participant experience and learning outcomes, both children and their guardians completed post-workshop questionnaires tailored to their roles and comprehension levels, as shown in Figure4.9.

Participant Engagement

Children responded using a Smileyometer with five facial icons. 88.9% of the children selected the happiest face when asked if the event was fun, indicating high emotional engagement. Similarly, 88.9% reported they would like to try the activity again at home, and 92.9% expressed strong interest in joining similar events in the future. These results suggest that the workshop succeeded in delivering a positive, enjoyable experience that sparked lasting interest.

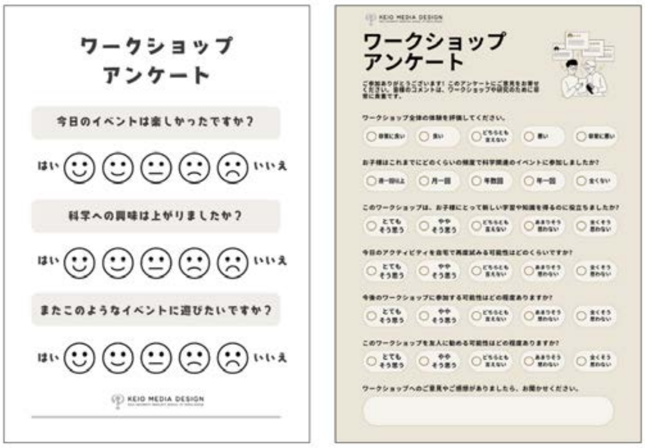


Figure 4.9 Questionnaire design for children (Left) and Questionnaire design for parents (right)

Guardians' responses echoed these trends. 85.2% rated their overall satisfaction as "good" or "very good" (4 or 5 on a 5-point scale), and 81.5% said they were likely to participate in similar workshops again. 66.7% indicated that they were interested in trying the activity again at home. This shows that engagement extended beyond the workshop setting, influencing intentions to continue science-art activities in everyday contexts.

Knowledge Acquisition

In terms of learning outcomes, 85.2% of the parents agreed that the workshop helped their child gain new knowledge or understanding.
Together, the feedback suggests that Workshop 1 was highly effective in engaging participants through creative and accessible formats, successfully combining emotional enjoyment with elements of science communication. While the results highlight the potential of this approach to foster lasting interest in science among children and families, it should be noted that the current questionnaire placed greater emphasis on affective engagement than on measurable learning outcomes. To better assess the depth and nature of science understanding, future iterations of the questionnaire should include more targeted items that evaluate conceptual grasp and knowledge retention.

4.2.8 Workshop Insights

Cross-Age Engagement

Both communication strategies were successful in engaging the target audience by achieving the expected decoding. Notably, the interactive demonstration attracted not only children but also unexpected interest from adult participants, suggesting that such activities can appeal across age groups. This insight influenced the direction of future workshop designs to more intentionally include adult engagement opportunities.
Additionally, some children demonstrated a strong understanding of the scientific concepts and terminology introduced during the workshop. One particularly enthusiastic participant even approached the Pentel representative after the session to ask further questions, indicating a high level of interest and curiosity beyond the activity itself. These responses highlight the potential of the workshop format to spark deeper engagement and learning across both children and adults.

Future Implementation

For future iterations, it is important to move beyond surface-level engagement and assess whether participants have actually improved their understanding of the scientific concepts introduced. While behavioral cues and expressions of curiosity suggest emotional involvement, they do not necessarily indicate conceptual learning. Incorporating more structured assessments, such as brief reflective prompts, could help evaluate knowledge gain more effectively. This would provide clearer evidence of cognitive impact and support a more robust evaluation of how well the encoded science content was received and internalized by the audience.

4.3. Workshop 2:Emotional Connection for Gen Z

4.3.1 Context

Workshop 2 was initially planned to test Activity 2 at BnA_WALL, targeting the same demographic as Workshop 1. However, due to challenges in participant recruitment during the end of the summer vacation period, the session was relocated to the KMD Forum, a public exhibition hosted by the Graduate School of Media Design at Keio University. This shift provided an opportunity to test the activity in a more spontaneous, walk-in environment while still reaching a diverse audience.

The workshop was conducted over two consecutive days. On Day 1, Activity 1 was offered, and on Day 2, the originally intended Activity 2 was implemented. While both activities were designed according to the structure outlined in the previous section, they were adapted to fit the constraints of the booth format at the KMD Forum. Specifically, the typical 90-minute session was shortened to 45 minutes to accommodate higher turnover and the informal nature of the event. This setting allowed for observation of how shorter, booth-based formats influenced engagement and comprehension, and offered valuable insights into the flexibility of the design for different public settings.

Due to space limitations at the exhibition booth, a maximum of two participants were allowed per round, each paired with the main researcher as the facilitator to ensure guided interaction. The activities were not targeted specifically at children or parent–child pairs, allowing for greater flexibility in age and background. In total, seven participants took part each day, resulting in 14 valid participant data sets. This workshop provided valuable insights into how the activities performed in a compact, public-facing format and how the design adapted to varied participant demographics.

4.3.2 Iteration 1

- Design

  The concept for Activity 2 emerged from Pentel's neon marker installation

at a past exhibition, where participants drew on stickers using fluorescent pens, then observed their artwork under UV light in a dark room. Inspired by this interactive setup, the workshop design sought to blend artistic creation with a scientific phenomenon—fluorescence under ultraviolet light.
To build on this concept within the framework of Sci-Art, the activity was further developed by researching suitable handcraft structures that could support both aesthetic expression and basic science explanation. A flapping butterfly mechanism was selected: participants would color butterfly cards using neon sign pens, assemble them with paper straws of varying diameters, and activate the wings using a simple push-pull motion. This tactile structure provided an opportunity to connect color, light, and motion into a cohesive science-art experience. The design also drew from the successful workshop structure of Activity 1, incorporating encoding strategies such as material-based storytelling and interactive demonstration.

- Test
  A prototype session was conducted with representatives from Pentel and BnA_WALL to evaluate both the scientific framing and the clarity of the activity flow. This internal trial allowed the research team to observe whether the science of fluorescence and ultraviolet light could be effectively communicated through creative engagement. It also served as a dry run to test the logistics, pacing, and instruction delivery.

- Evaluate
  The feedback from the session was mainly positive, particularly regarding the artifact design. The visual appeal and interactive nature of the butterfly craft were well received. However, two key improvements were identified:

  - It was suggested that using only neon colors made it harder to demonstrate contrast, especially to younger participants. Incorporating regular colors alongside neon markers would create a more dramatic "before and after" effect under UV light.
  - The presentation materials were found to be too text-heavy. While the slides conveyed correct scientific information, they lacked the visual simplicity needed for accessibility.

- Reflect
  This iteration confirmed the strength of the activity concept while emphasizing the need for clearer visual communication. In response, the final workshop design introduced side-by-side examples using both normal and neon colors to visually reinforce the science behind UV light. Slide content was revised to replace lengthy text blocks with photo-based illustrations and step-by-step visual guides. These refinements aimed to lower cognitive load, enhance attention, and maintain the experiential integrity of the workshop—aligning with the broader design goal of integrating science into art-based activities through intuitive, multimodal communication.

4.3.3 Structure and Flow

Day 1: Activity 1

Due to the booth format and time constraints, the standard 90-minute workshop was condensed into a 45-minute session. While the activity remained grounded in Kolb's Experiential Learning Cycle, several adjustments were made to fit the setting.

- **Concrete Experience**: Participants began by drawing freely on coffee filters using multiple colors of Pentel Sign Pens. The filters were then folded and placed in water to trigger capillary action. Compared to the original session, this version placed greater emphasis on creative expression during the initial drawing phase, with more color variation encouraged.

- **Reflective Observation**: As the ink dispersed, facilitators prompted participants to describe what they saw, helping them notice how the water affected different pigments.

- **Abstract Conceptualization**: A simplified explanation of "capillary action" was provided using everyday analogies (e.g., how plants absorb water). Paper chromatography was explained through diagrams, but the Chromatography Race component was omitted due to time constraints.

- **Active Experimentation**: Each participant created a single paper flower from the filter, while there was no time to complete a bouquet.

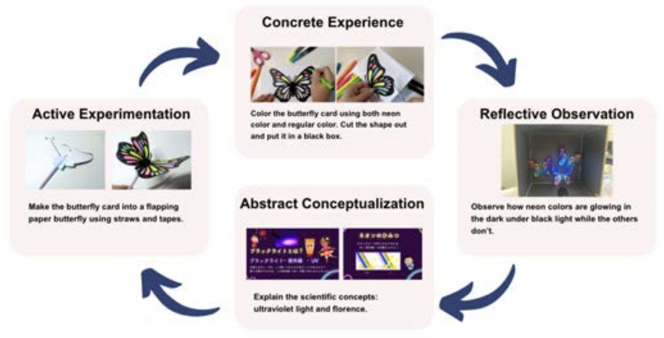


Figure 4.10 Activity 2 Framework

Day 2: Activity 2

This activity introduced a new scientific concept—fluorescence under ultraviolet (UV) light—through art creation and hands-on experimentation, as shown in Figure4.10:

- **Concrete Experience**: Participants began by picking and coloring a butterfly coloring card using both regular and neon Pentel Sign Pens. After coloring, they cut out the shape in preparation for the next phase.
- **Reflective Observation**: Participants placed their colored butterfly into a black box and illuminated it using a UV torch to observe how the neon colors glowed compared to the regular inks. This direct visual comparison emphasized the unique brightness of fluorescent materials.
- **Abstract Conceptualization**: Facilitator explained the concept of ultraviolet light using everyday analogies like sun exposure and sunscreen, then clarified how neon colors absorb UV light and reflect more visible light, creating a glowing effect. All six neon pen colors were compared for brightness for participants to see the difference.
- **Active Experimentation**: Participants used thin and thick plastic straws to assemble a simple flapping mechanism, bringing the butterfly to life. The UV light was then used again to view the final moving artwork under fluorescent conditions, reinforcing both the scientific and creative components.

Usage	Item	Quantity	Purpose
Individual	Butterfly Coloring Card	4 patterns	For coloring and assembling the flapping butterfly
	Scissors (Kids-friendly)	1	To cut out the butterfly shape
	Paper strip	1	To create the base flap mechanism that connects the butterfly wings to the straw and allows movement
	Thick Straw	1	Outer structure for the flapping mechanism
	Thin Straw	1	Inner sliding piece to create the flapping motion
	Clear Tape	1	To attach parts securely and support the structure
	Double-sided Tape	1	To attach the folded paper strip securely to the butterfly wings
Shared	Pentel Sign Pen (8 colors set)	1	For coloring the butterfly card
	Pentel Art Brush		For coloring the butterfly card
	Pentel Touch Brush Sign Pen (6 colors set)	1	For coloring the butterfly card
	UV light torch	1	To observe the glowing effect of neon colors under UV light
	Black box	1	To provide a dark environment
	Presentation Slide	N/A	Workshop instruction

Figure 4.11 Activity 2 Material List

4.3.4 Material

The materials for Day 1, which is Activity 1, kept t shown in the earlier Figure4.5. For Activity 2, illustrated in Figure4.11, participants used Pentel neon color brush pens, black construction paper, and UV flashlights to create glowing butterfly artworks that introduced principles of UV light and fluorescence in an engaging, visually impactful way.

4.3.5 Workshop Environment

The workshop was conducted in a compact booth setting at the KMD Forum, with a long table setup accommodating two participants per session, seated along one long side. A facilitator sat opposite the participants to guide the activity. This format allowed for focused, one-on-one or one-on-two interaction while maintaining an efficient flow for walk-in visitors. As shown in Figure 4.12, both days shared the same layout, with different materials on the table.
A total of eight sessions were held over two days—four sessions each day. While 16

participants in total took part in the workshop, only 14 completed questionnaires, resulting in 14 valid participant data sets (seven per day). This setup allowed each participant to receive individualized support while enabling facilitators to observe reactions closely within the limited booth space.

Figure 4.12 Workshop 2 venue setup: Day 1 (left) , Day 2 (right), seminar-style setting.

4.3.6 Communication Strategies

Unlike Workshop 1, which focused on maintaining engagement among young children through interactivity and guided explanation, Workshop 2 targeted a Gen Z audience within the context of a bustling public exhibition. Given the booth-based format and the high volume of competing stimuli at the KMD Forum, this session prioritized emotional connection and memorable experience to stand out and resonate with participants.

The primary challenge was to create a sense of fulfillment and personal meaning in an activity often perceived as child-oriented. To address this, the communication strategy centered on two key techniques: Interactive Discovery and Art Appreciation. Together, these strategies aimed to activate emotional resonance and personal investment, increasing the likelihood that Gen Z participants would connect with the workshop content and remember the experience as both surprising and fulfilling.

Self-Discovery

Figure 4.13 Participants used ultraviolet torch by themselves to see the neon colors glowing.

- **Encoding**
  Participants were asked to uncover the science behind the visual effects, the neon fluorescence under ultraviolet (UV) light, through hands-on experimentation, as depicted in Figure4.13 Instead of providing a scientific explanation at the outset, facilitators allowed participants to first experience the glow effect themselves. This discovery-first approach aimed to generate curiosity, emotional engagement, and a sense of wonder by allowing participants to encounter the unexpected through direct interaction.

- **Expected Decoding**
  The strategy anticipated that self-directed discovery would create stronger emotional and cognitive impact than direct instruction. The surprise from the UV glow effect was expected to trigger an AHA experience—a moment of sudden insight and reward.

Recent research links AHA moments to meta-cognitive prediction errors, where outcomes exceed initial expectations [72]. Participants likely approach everyday objects with conventional assumptions, making the fluorescent transformation an unexpected revelation that shifts their perception of hidden scientific properties. By having participants physically activate the UV light before explanations, this approach aimed to maximize surprise-driven memory encoding.

Figure 4.14 Participants capturing the glowing effect of their artwork with surprise and curiosity, using their phones to document the moment.

- **Actual Reception**
  Participants expressed visible surprise through their facial expressions and gestures. As can be seen in Figure 4.14, some of them used their smartphones to photograph or record the glowing effect. Their enthusiastic reactions suggest that the surprise-based discovery approach effectively captured attention and created a memorable, emotionally resonant learning experience—even for an adult audience. This suggests the potential to expand the target audience of such activities beyond children.

Art Appreciation

- **Encoding**
  The workshop design intentionally encouraged participants to recognize the value of their creations by framing them as art pieces rather than simple crafts. Each activity was structured so that the final artifact—whether a neon butterfly or chromatography flower—was visually appealing, complete, and easy to preserve or display. Participants were given the option to take their creations home, reinforcing a sense of ownership and pride. This strategy was applied across both activities, aiming to elevate the perceived value of the scientific experience through artistic expression.

- **Expected Decoding**
  It was expected that participants would take pride in their work and feel emotionally connected to the outcome. Research demonstrates that the act of creating art serves as a source of pride and enhances self-concept development [73], while learning artifacts that make knowledge visible provide opportunities for engagement and reflection. This sense of accomplishment was anticipated to motivate them to keep the artifact, take it home, and possibly share it with others. The act of preserving or displaying the creation would serve as a continued point of reflection on the experience and the science embedded in the activity.

- **Actual Reception**
  Many participants expressed enthusiasm and pride in their creations. Several chose to take their work home, describing it as "cool" or "worth keeping." Notably, Figure 4.15 shared photos of their creations on social media, suggesting personal investment and a desire to show others. However, not all participants chose to take their artifacts home—indicating varied levels of emotional connection or practical considerations—but the option itself added a meaningful layer of self-reflection and appreciation to the workshop experience.

Figure 4.15 Participant shared the artwork from Day 1 to their social media platform, showing their enthusiasm to their own work.

4.3.7 Questionnaire

In this session, participants only completed a post-questionnaire, as their age group (Gen Z) was considered capable of providing independent and reliable feedback on both engagement and learning outcomes.

Participant Engagement

Workshop 2 demonstrated strong participant engagement through both behavioral intentions and reflective feedback. Most participants expressed interest in attending similar sessions, with many also indicating a desire to purchase the materials used. While fewer showed strong interest in repeating the activity at home, moderate interest was still present, suggesting the activity sparked broader curiosity rather than simple repetition.
Reflective statements further confirmed positive engagement:

- 71.4% agreed or strongly agreed that they would join another session in the future.
- 64.3% said they would recommend the workshop to others.
- 64.3% also reported that their interest in science had increased.

Together, these findings indicate that Workshop 2 effectively captured participants' interest and motivated continued exploration of science through creative experiences.

Knowledge Acquisition

To evaluate actual knowledge gain, participants were asked to reflect on their understanding of the scientific principles both before and after the workshop within a single post-workshop questionnaire. This retrospective approach allowed participants to self-assess changes in their understanding of neon color and ultraviolet light, as well as paper chromatography. As a reflection from the first workshop, this questionnaire placed greater emphasis on learning inquiry to better assess participants' scientific understanding. As illustrated in Figure4.16, although the participants were adults—assumed to have more baseline science knowledge than children—many indicated limited familiarity with the concepts prior to the workshop. Their responses showed a clear shift toward greater understanding after the activity, suggesting that the workshop effectively conveyed new scientific knowledge.

In addition to the learning outcomes, participants also shared positive comments about the final artifact, expressing satisfaction with the visual and creative aspects of their work. This indicates that the activity not only supported conceptual learning but also provided a meaningful and enjoyable experience.

4.3.8 Workshop Insights

Emotional Engagement

Both communication strategies implemented in Workshop 2 successfully facilitated emotional engagement, particularly among adult participants. The Self-

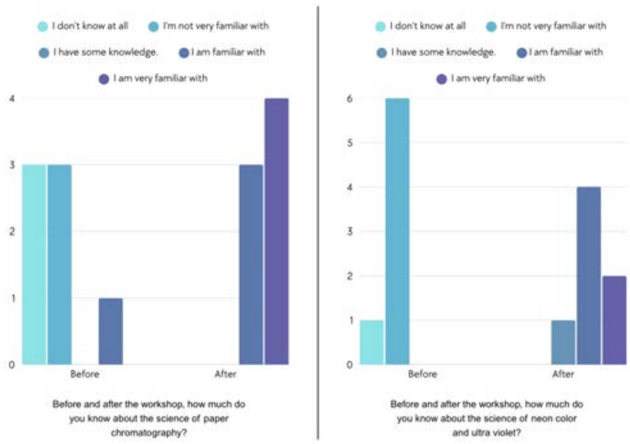


Figure 4.16 Self-reported understanding of the science concepts before and after the workshop. The left chart shows increased familiarity with paper chromatography, while the right chart indicates a similar shift in understanding of neon color and ultraviolet light.

Discovery approach proved especially effective, as many participants expressed surprise and delight when observing the neon fluorescence under UV light. This reaction demonstrated that the activity resonated beyond the intended childlike aesthetic and could also captivate a Gen Z audience. The sense of wonder sparked by the hands-on discovery suggested that such playful formats hold strong potential for engaging adult learners in informal science contexts.
In contrast, the Art Appreciation strategy yielded more varied responses. While some participants eagerly took their creations home or photographed them for social media, others left their work behind. This variability appeared to stem more from personal taste or the specific theme—such as a disinterest in butterflies or flowers—rather than the effectiveness of the communication design itself. This highlights the importance of offering theme flexibility in future iterations to better align with diverse participant preferences. Providing an optional display space in future workshops may also offer participants more choices in how they value and share their artifacts, accommodating both those who wish to take their creations home and those who prefer contributing to a collective presentation.

Adult Learning

Post-workshop questionnaires also revealed that several adult participants had limited prior understanding of the scientific concepts, yet reported learning something new through the activities. This feedback underscores the untapped potential of art-based workshops to serve as informal science learning tools for adult audiences.

Future Implementation

Moving forward, the workshop will be further developed with a stronger emphasis on adult engagement. Adapting themes, incorporating deeper reflective elements, and designing more conceptually flexible activities may enhance relevance and cognitive impact. These refinements aim to not only sustain emotional connection but also foster a clearer understanding of the scientific principles at play.

4.4. Workshop 3: Simplifying Abstract Science

4.4.1 Context

Workshop 3 was held on December 8, 2024, in the same basement event space at BnA_WALL in Nihonbashi, Tokyo. This session targeted Gen Z participants and featured a Christmas-themed activity centered on a more complex scientific concept—acid-base reactions—designed to engage adult learners. As shown in Figure4.17, two iterative test sessions were conducted to refine both the materials and the clarity of the science explanation, ensuring the concept could be effectively communicated to a non-expert audience. The festive theme and hands-on format aimed to create a balance between seasonal creativity and deeper scientific learning. Insights from this session provided valuable feedback on how to present more advanced content in an accessible and engaging way for adult participants.

Design Iteration	Participants	Purpose
Iteration 1	Graduate School Peers	Activity, theme, artifact
Iteration 2	Representatives from Partnerships	Science explanation

Figure 4.17 Activity 3 Iteration Overview

4.4.2 Iteration

Iteration 1

- Design
  The concept for Activity 3 was inspired by a combination of a homemade lava lamp experiment and the aesthetics of a Christmas snow globe. The activity was designed to explore the scientific principles of immiscibility and acid-base reactions, blending science with a festive, visual theme. As with previous sessions, the structure followed Kolb's experiential learning cycle, beginning with a small trial jar to introduce the science and followed by creating a larger, Christmas-themed jar after participants gained basic understanding. The goal was to maintain both visual appeal and scientific clarity while encouraging seasonal creativity.

- Test
  An internal trial was conducted with graduate school peers serving as stand-in participants for the target Gen Z audience. This pilot aimed to test the engagement level, clarity of the scientific content, and the appeal of the final artifact. Additionally, it allowed the research team to experiment with material selection, ensuring the components were both functional and visually compelling.

- Evaluate
  Feedback from the pilot indicated that the overall workshop structure was effective, and the final artifact was well-received. Participants responded positively to the hands-on process and the holiday theme. However, suggestions were made to increase the range of decorative materials to enhance creativity. It was also noted that the instructional slides could benefit from additional visuals to clarify each step. In terms of material, It was also

reported that the primary materials, baking soda and citric acid, were not familiar terms to some participants. Therefore, it is important to provide clear explanations of how these substances are commonly used in everyday life to enhance relevance and understanding. Clearer guidance on the scientific role of each material was also requested. Additionally, for the initial small jar, participants emphasized the need to precisely control the amount of liquid to avoid spills and improve the success rate.

- Reflect
  This iteration highlighted the importance of visual clarity, material control, and participant freedom in shaping an enjoyable learning experience. For future versions, more visual aids will be integrated into the instruction to reduce ambiguity, and specific guidelines on liquid measurements will be included to improve consistency. Additionally, more attention will be given to curating a wider variety of decorative options to enhance participant ownership and engagement with the final artifact. Furthermore, greater emphasis will be placed on contextualizing the scientific materials by explaining their common uses in everyday life, thereby making the science more relatable and accessible to participants.

Iteration 2

- Design
  In response to feedback from the first iteration, the second round of development focused on enhancing the clarity of science explanations through the addition of visual aids and the use of everyday analogies. The revised slides incorporated diagrams to explain the concepts of acid-base reactions and immiscibility more clearly. Everyday materials like baking soda and citric acid were introduced as examples, aiming to make the concepts more accessible. While the original examples were general, care was taken to avoid overly abstract language and provide concrete, relatable visuals to support participants' understanding.

- Test
  This iteration was tested with representatives from the project's partner

organizations, including BnA_WALL and Pentel. The focus was to verify the clarity and flow of the updated content, particularly the revised science explanations, and to observe whether the changes made the concepts easier to grasp for a general audience.

- Evaluate
  Feedback indicated that while the overall structure was effective, the science explanations remained somewhat weak. Participants found the diagrams helpful but suggested that the visuals needed to be further developed to better illustrate the chemical reaction process. Additionally, it was recommended to replace the generic examples with culturally familiar references—for instance, substituting the oil-and-water example with oil floating on ramen soup to enhance relatability for a Japanese audience. Reviewers also recommended adding a small interactive demonstration to accompany the explanation for better clarity and engagement.

- Reflect
  This iteration underscored the importance of cultural context, visual communication, and layered explanation strategies when introducing scientific concepts to non-expert audiences. Moving forward, the workshop content will be further refined to incorporate metaphors and real-life imagery grounded in Japanese daily life. Diagrams will be made more lively and narrative-driven, and abstract terms will be introduced only with clear analogies or demonstrations to ensure the science remains approachable and meaningful.

4.4.3 Structure and Flow

The session was designed around Kolb's Experiential Learning Cycle, as shown in Figure4.18 to guide participants through a hands-on exploration of immiscibility and acid-base reactions, integrated with a Christmas-themed crafting experience:

- **Concrete Experience**: Participants began by selecting a color and mixing it with water, then pouring the colored water into a small transparent jar. Baby oil was added on top, and the jar was shaken to initiate the visual effect of oil and water separation.

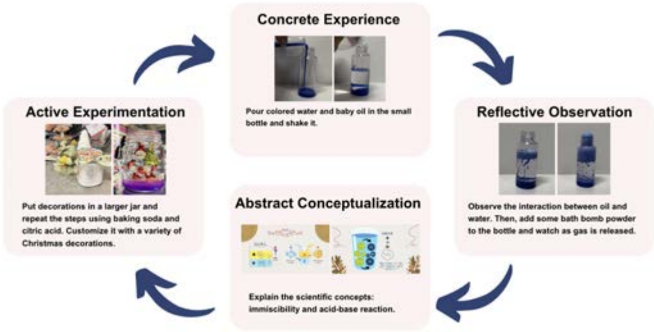


Figure 4.18 Activity 3 Framework

- **Reflective Observation**: Participants observed that the two liquids did not mix and discussed what they noticed. The facilitator guided their observations by prompting them to describe the interaction between oil and water. Bath bomb powder was then added, and participants watched the effervescent reaction as bubbles formed in the jar.

- **Abstract Conceptualization**: The facilitator introduced the concept of immiscibility, supported by visual diagrams and relatable examples (e.g., oil floating on ramen). The chemical components of bath bombs—baking soda and citric acid—were explained, including where these materials are found in daily life. The facilitator elaborated that the observed bubbling results from an acid-base reaction, producing carbon dioxide gas when both substances interact with water. This explanation was reinforced through a second guided mini-demonstration with a balloon.

- **Active Experimentation**: After understanding the science, participants created their own Christmas-themed lava jars. They selected holiday decorations to attach to the exterior of the jar and then repeated the initial experiment—this time replacing the bath bomb with individually measured baking soda and citric acid. Participants also had access to a broader selection of decorative materials, including glitter, bows, and stickers, allowing them to personalize their creations and reinforce the science concept through creative expression.

4.4.4 Material

Usage	Item	Quantity	Purpose
Individual	Plastic Bottle Small	1	For the initial experiment
	Plastic Jar	1	For the final Christmas-themed artifact
	Baking Soda (Cleaning)	1 cup	Main chemical used for acid-base reaction
	Citric Acid (Cleaning)	1 cup	Main chemical used for acid-base reaction
	Bath bomb powder	Portioned	For the initial experiment
	Tray	1	To prevent spills and contain the work area
	Baby oil	1	To enhance the visual effect of gas formation during the reaction
	Pentel Acrylic Gouache	1	For coloring water
	Paint brush	1	To apply gouache into water
	Disposable cup	2	To obtain water and mix it with color
Shared	Paper Towel	2 packs	To absorb excess water and keep area clean
	Stickers	Assorted	To decorate the jar
	Ribbons	Assorted	To decorate the jar
	Decoration items	Assorted	To decorate the jar
	Hot Glue Gun	1	To attach decorative elements to the jar
	Presentation Slide	1	Workshop Instruction
Facilitator	Pet Bottle with water	1	Used as the container for the demonstration
	Balloon	1	To capture gas produced from the acid–base reaction
	Baking soda	1 spoon	Reactant for the balloon experiment
	Citric Acid (Powder)	1 spoon	Reactant for the balloon experiment

Figure 4.19 Workshop 3 Table Setup

The material list is shown in Figure4.19. Figure4.20 shows how the materials were setup on the day. The use of familiar materials such as baby oil, baking soda and bath bomb ingredients emphasized that science can be explored through simple, everyday items. To enhance the sensory experience while maintaining practicality, edible substances like vinegar and cooking oil were intentionally avoided due to their strong odor and perishability. Instead, non-edible alternatives such as cosmetic-grade baby oil and craft-use citric acid were selected to preserve the visual appeal and longevity of the final artifact. This hands-on, creative process allowed participants to intuitively grasp abstract concepts like immiscibility and chemical reactions, reinforcing the idea that science is both accessible and embedded in everyday experiences—even for those without prior scientific knowledge.

Figure 4.20 Activity 3 Material List

4.4.5 Workshop Environment and Attendance

Figure 4.21 shows the the setup for Workshop 3, which mirrored Workshop 1, taking place in the same basement event space at BnA_WALL and utilizing a similar venue arrangement. A long table was prepared, with four participant seats on each side to accommodate the activity. One extra table was used for participants to use glue gun. However, unlike Workshop 1, this session targeted Gen Z participants and did not include parental observation. All seven registered participants attended, resulting in seven valid data points for the study.

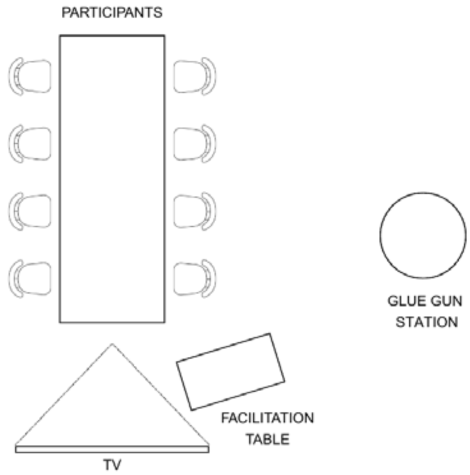


Figure 4.21 Workshop 3 Layout Plan

4.4.6 Communication Strategy

Because Workshop 3 targeted Gen Z participants and introduced a more complex scientific concept—immiscibility and acid-base reactions—the communication strategy prioritized clarity and relatability. The primary objective was to make abstract concepts easier to grasp and to shift participants' perception of science from being distant or difficult to something observable and relevant in everyday life.

To achieve this, the workshop incorporated visually engaging diagrams and infographics that broke down the scientific process into accessible steps. Additionally, everyday examples—such as oil floating on ramen or the fizzing effect in bath products—were used to contextualize the science, making it more memorable and culturally resonant. These strategies helped translate abstract ideas into tangible understanding, allowing participants to connect with the content both intellectually and emotionally.

Infographic

- **Encoding**
  To support comprehension of complex scientific concepts, two key infograph-

ics, referring Figure4.22, were used—each illustrating one of the workshop's main scientific principles: immiscibility and acid-base reactions. The infographics incorporated personification to simplify abstract ideas, such as portraying oil and water as characters that refuse to mix, or acid and base as playful opposites that react when combined. These visual tools were designed to make invisible scientific processes more relatable and easier to visualize.

Figure 4.22 Infographic A illustrates immiscibility of oil and water; Infographic B shows an acid-base reaction producing CO.

- **Expected Decoding**
  It was expected that the use of infographics would help participants build clearer mental models of the underlying science, as research demonstrates that presenting information in a visual manner decreases the cognitive load, or "mental energy," required to interpret information [74]. By representing abstract phenomena through storytelling and familiar imagery, the infographics aimed to reduce cognitive load and make learning more intuitive—especially for those without a strong science background.

- **Actual Reception**
  According to the post-workshop questionnaire, 6 out of 7 of the participants identified the infographics as the most effective element for learning, ranking them above both the hands-on experiments and verbal explanations. This response suggests that the visual aids successfully enhanced understanding, particularly by translating technical concepts into accessible, engaging narratives.

Relatability

- **Encoding**
  To make the scientific principles more approachable, the workshop integrated culturally relevant and everyday examples into the explanation of each concept. For immiscibility, salad oil and ramen soup were used as familiar references to illustrate how oil separates from water. For the acid-base reaction, participants learned that baking soda is commonly used in making muffins, and citric acid is present in many drinks found in Japanese convenience stores. Both are shown in Figure 4.23 The reaction was also linked to household uses like cleaning and creating carbonated drinks. These examples helped anchor abstract concepts in participants' daily experiences.

Figure 4.23 Real-life examples of immiscibility (left) and acid-base use in cleaning and food (right).

- **Expected Decoding**
  The strategy aimed to shift participants' perception of science from something distant and academic to something present in their everyday lives. . By connecting scientific ideas to ordinary items and activities like ramen soup and convenience store drinks, the workshop intended to foster a sense of relevance and accessibility, as culturally responsive science curriculum allows students to connect the material to their own lives and experiences, which facilitates deeper learning [75].

- **Actual Reception**
  Post-workshop feedback revealed that participants gained a clearer understanding of the science behind bath bombs—specifically the roles of baking

soda and citric acid in producing the fizzing reaction. This concrete example helped demystify abstract chemical concepts. As a result, participants reported that science felt more relatable and embedded in their everyday lives, enhancing their appreciation for how basic scientific principles are present in common household products.

4.4.7 Questionnaire

In Workshop 4, the questionnaire focused more on identifying which components of the workshop participants found most memorable and effective, while also gauging their perceived learning before and after the session. This shift was intended to assess not only emotional engagement but also cognitive gain and comprehension.

Participants Engagement

Participants reported high levels of emotional and motivational engagement. A majority expressed strong agreement that they would recommend the workshop to others and attend a similar session in the future. Additionally, several respondents indicated that their interest in science had increased after the session. Notably, over half of the participants showed enthusiasm for purchasing the materials used in the workshop, suggesting that their engagement extended beyond the session itself and translated into tangible follow-up interest.

Knowledge Acquisition

As illustrated in Figure4.24,the infographic explanation of oil and water was selected by the majority of respondents as the most helpful learning aid. This contrasts with findings from Workshop 1, where live demonstrations were more commonly cited as impactful. This shift suggests that as the scientific content becomes more complex—or the participant group more mature—visual aids may better support conceptual understanding than verbal explanation alone.

Post-workshop reflection questions further supported this. Participants showed clear gains in their reported understanding of immiscibility, acid-base reactions,

and ingredient functions, with before-and-after self-assessments shifting noticeably toward "I have some knowledge." These gains reflect the importance of pairing clear visual explanations with hands-on experience, especially when dealing with abstract or layered scientific concepts.
Together, these findings suggest that for middle or older audiences, visual clarity plays an increasingly central role in facilitating learning. Future workshops should consider prioritizing infographic or diagram-based materials alongside interactive components to optimize both understanding and sustained engagement.

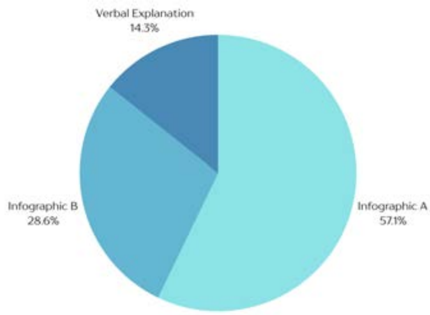


Figure 4.24 Pie chart of the question: Which part of the workshop do you feel was the most effective for your learning?

4.4.8 Workshop Insights

Accessible Science Communication

Workshop 3 reinforced that sci-art activities can effectively engage adult audiences. Infographics proved highly effective, even more than demonstrations, in helping participants understand complex science concepts. Everyday examples, such as ramen oil or convenience store drinks, successfully connected abstract ideas to familiar contexts, making science feel more approachable.

Future Implementation

However, feedback also revealed a limitation in the artifact design. While participants enjoyed the hands-on process of making the Christmas-themed lava lamp, some noted that the visual effect faded quickly after the workshop, making it difficult to preserve as a lasting memento. This points to a trade-off between experiential impact and artifact sustainability—an important consideration for future iterations. Future designs may explore ways to extend the life of the outcome or offer a takeaway element that retains emotional value and scientific meaning over time.

4.5. Workshop 4: Family Learning and Collaboration

4.5.1 Context

Workshop 4 marked the most significant shift in format compared to previous sessions. Unlike earlier workshops, which were all facilitated directly by the primary researcher, this session adopted a decentralized facilitation model to accommodate a larger audience and test the scalability of the design. The workshop took place on October 14, 2024, during iPark Fiesta—an annual public event hosted by Shonan iPark that attracts a diverse range of visitors from families to science enthusiasts.

To manage the increased capacity and broaden the facilitation approach, the session was divided into five rounds, each featuring three simultaneous participant groups. Poster was created to inform the visitors about the schedule, shown in Figure4.25. Participants who wished to join the workshop were given a numbered ticket upon sign-up, which corresponded to their assigned group and round. Each group was led by a trained facilitator supported by at least one supporter. All facilitators and supporters received a dedicated training session conducted by the primary researcher to ensure consistent delivery and adherence to the core communication strategies of the project.

This workshop reused Activity 1, the coffee filter art session, which had already undergone multiple rounds of iteration and refinement. Therefore, no further iteration was conducted this time. However, a key modification was introduced: instead of taking their creations home, participants were invited to contribute their artwork to a large-scale collaborative installation. This shift aimed to explore new dimensions of collective engagement and foster a shared sense of accomplishment among participants. The resulting installation became a visual representation of the event's community-driven spirit and offered a different form of post-workshop impact—one centered on collective identity and contribution rather than individual takeaway.

Through this evolved format, Workshop 4 tested the adaptability of the Sci-Art activity in a high-traffic, public setting while introducing collaborative creation as a new outcome model. Insights from this session contributed to evaluating the reproducibility of the workshop design and the effectiveness of delegated facilitation.

Figure 4.25 Poster for Workshop 4, showing the 5 rounds of workshop.

4.5.2 Facilitator Training

To ensure that participants can engage with the activity smoothly and fully understand the materials, it is essential for facilitators to have a thorough grasp of both the workshop content and the scientific concepts involved. To support this, a detailed training session was conducted prior to the event. The session was designed to familiarize facilitators with the workshop flow, materials, and key communication strategies through clear explanations and hands-on demonstration. This preparation helped ensure consistency in facilitation quality and allowed facilitators to guide participants confidently and effectively throughout the session.

- **Research and Design Background**
  Introduced the purpose of the workshop as part of a design research project. Emphasized the importance of communicating not just activity steps, but also the underlying scientific and engagement goals.

- **Activity Overview**
  Explained the workshop content, materials, and objectives, including how the activity promotes collaborative participation and informal science learning.

- **Shift Scheduling**
  Provided an overview of the event schedule. Facilitators could select their preferred shift (morning or afternoon) based on availability.

- **Visitor Flow and Onsite Roles**
  Briefed on expected visitor flow during the public event and outlined responsibilities beyond facilitation, such as welcoming participants and managing transitions.

- **Session Structure**
  Walked through the full flow of a single session—from participant arrival and consent form handling to pre- and post-activity tasks like distributing and collecting questionnaires.

- **Step-by-Step Demonstration**
  Conducted a live walkthrough using actual materials. One facilitator acted as a mock participant while others observed. Included detailed explanations of the scientific principles to ensure all facilitators could confidently explain the content.

- **Key Reminders from Past Iterations**
  Shared essential facilitation tips based on prior iterations—what works, what to avoid, and how to maintain an engaging and effective experience.

- **QA and Individual Support**
  Concluded with a QA session. Facilitators with additional questions received one-on-one clarification as needed.

4.5.3 Structure and Flow

Workshop 4 followed a similar structure to Workshop 2, Day 1, adapting the original 90-minute coffee filter art activity into a 45-minute booth-style session. Grounded in Kolb's Experiential Learning Cycle, the format was modified to fit the flow of the public event while emphasizing collective engagement.

- **Concrete Experience**: Participants began by freely drawing on coffee filters using a variety of Pentel Sign Pen colors. The filters were folded and placed in water, initiating capillary action. This stage encouraged individual expression and exploration of color mixing.

- **Reflective Observation**: As the colors spread, facilitators prompted participants to observe and describe the changes, helping them focus on how different pigments reacted to water.

- **Abstract Conceptualization**: A simplified explanation of "capillary action" was provided using everyday analogies (e.g., how plants absorb water). Paper chromatography was explained through diagrams, but the Chromatography Race component was omitted due to time constraints.

- **Active Experimentation**:Instead of taking their creations home, participants contributed their paper flowers to a large shared canvas, creating a collaborative art piece that visually represented the event's collective spirit.

4.5.4 Material

The main materials used in the workshop are shown in Figure 4.5. As a token of appreciation for their contribution to the collaborative artwork, all participants

Item	Quantity	Purpose
Pentel Sign Pen (Random Color)	1	For drawing designs
Flat bottom coffee filter	1	Main material
Sketch paper	1	To protect the table from ink leakage
Paper straw	1	Used as a flower stem
Pamphlet	1	Workshop instructions and key takeaways

Figure 4.26 Material list of the take-away for participants from Workshop 4.

received a take-home workshop kit (Figure 4.26). In addition to essential materials such as coffee filters, the kit included a specially designed pamphlet that provided step-by-step instructions shown in Figure4.27 and reinforced the scientific concepts introduced during the session, extending the educational impact beyond the workshop itself.

4.5.5 Workshop Environment and Attendance

Workshop 4 was conducted in a meeting room within the Shonan iPark venue as part of the annual iPark Fiesta. The room was arranged with three long tables, each designed to accommodate up to six participants. The layout was optimized for a parent–child format, with each table intended to host three parent–child pairs. However, the setup allowed for flexible groupings based on family structure. For example, in cases where a family had two children, both children could participate while the parent observed, adapting the session to meet the needs of diverse family dynamics. As shown in Figure4.28,each group was assigned a number, and participants were seated according to the number on their ticket.
Facilitators and supporters were assigned to each table, ensuring that every group received sufficient guidance and assistance throughout the session. This arrangement allowed for collaborative learning and ensured the environment remained supportive, interactive, and family-friendly.
A total of 41 groups participated in the workshop across five rounds, enabling broad engagement while preserving the intimate, hands-on nature of the activity.

Figure 4.27 Workshop 4 pamphlet design, including the steps of the activity and the science knowledge from the activity.

4.5.6 Communication Strategy

Because Workshop 4 was conducted as part of a large public event, the communication strategies were designed to maximize accessibility and collective engagement. The first strategy, Multimodal Instructional Materials, provided facilitators with illustrated manuals that combined visual diagrams, simple language, and step-by-step guidance. This ensured consistent and understandable science explanations across a broad audience, including children and adults unfamiliar with scientific concepts.

The second strategy focused on Collaborative Framing—shifting from an individ-

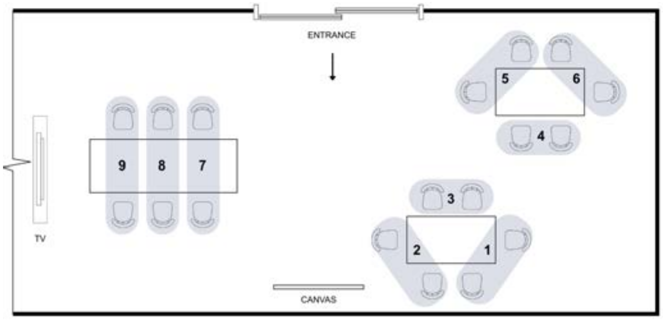


Figure 4.28 Workshop 4 Layout Plan

ual take-home activity to a shared art installation. This approach encouraged participants to view their creations as part of a larger collective work, reinforcing a sense of contribution and community. It also allowed public visitors to see the cumulative impact of the workshop, expanding its influence beyond individual participation. Together, these strategies aimed not only to make science more approachable, but also to showcase the potential of integrating art and science in a public, socially meaningful context.

Multimodal Instructional Materials

- **Encoding**

  To support facilitators and ensure participants could clearly understand both the activity process and the underlying science, a set of printed manuals was developed. These materials were designed with a multimodal approach, combining text, diagrams, and step-by-step photos to accommodate a range of learning preferences and facilitate consistent explanation across all sessions.

  The manual consisted of three double-sided sheets, each serving a specific purpose aligned with Kolb's Experiential Learning Cycle:

  - **Sheet 1: Workshop Steps**

    This sheet shown in Figure4.29 focused on the hands-on activity and was divided into two parts. Front side illustrated the Concrete Experience phase—drawing on the coffee filter and initiating capillary action and paper chromatography—while the back side guided the Active Experimentation phase, showing how to transform the colored filters into paper flowers. Clear visuals and numbered steps supported participants and facilitators alike in navigating the process smoothly.

Figure 4.29 Sheet 1: Front (left) and back (right).

– **Sheet 2: Water (Capillary Action)**
  This sheet shown in Figure4.30 corresponded to the Reflective Observation and Abstract Conceptualization phases. One side featured the keyword "Water" along with guiding answer to prompt participant observation. When flipped, the reverse provided a simple explanation of capillary action, using daily life analogies (e.g., water rising in plant stems, cotton pads absorbing liquid) to help participants connect the scientific term to familiar experiences.

– **Sheet 3: Color (Paper Chromatography)**
  Similarly structured, this sheet shown in Figure4.31 supported observation and explanation around color separation. One side labeled "Color" invited participants to observe how pigments moved and changed, while the reverse explained the concept of paper chromatography. Again, relatable examples and visual metaphors were used to clarify the mechanism in an approachable way.

These instructional materials were carefully iterated based on insights from

Figure 4.30 Sheet 2: Front (left) and back (right).

Figure 4.31 Sheet 3: Front (left) and back (right).

previous workshops, where visual aids and familiar contexts were found to significantly enhance understanding. By providing facilitators with structured yet flexible teaching tools, the workshop ensured that both scientific content and creative engagement could be delivered effectively, even in a fast-paced, public-facing environment.

- **Expected Decoding**
  It was anticipated that facilitators would actively refer to the manual throughout the session—pointing to specific images or diagrams to explain scientific concepts in a consistent and accessible way. Participants, including children and their caregivers, were expected to engage with the manual visually, using it to support their understanding of both the creative process and the

underlying science.

- **Actual Reception**
  The manual was widely used by facilitators during the session as shown in Figure4.32, especially during the explanation phases, where it helped structure their narration and provided helpful visual cues. Facilitators reflected that it was particularly effective in guiding them to use appropriate analogies and maintain consistency in scientific explanation. However, post-workshop questionnaire responses from parents indicated that many still found facilitators' verbal explanations to be more effective than the manual alone. This suggests that while the manual was a helpful tool, its impact was greatest when integrated with live facilitation, highlighting the importance of combining material support with interactive communication.

  Beyond its in-session function, the manual was also utilized by visitors

Figure 4.32 Facilitator using the manual to explain capiliary action to the paritcipants.

who passed by the workshop space and expressed curiosity about the activity. It provided them with a quick overview, helping them understand what was happening inside. Some visitors even took photos of the manual and inquired whether the activity could be replicated at home using the guide—demonstrating its effectiveness as a communication tool that extended the workshop's reach beyond direct participants.

Collaborative Framing

- **Encoding**
  Instead of allowing participants to take their flowers home—as done in previous workshops—they were invited to contribute their creations to a large, shared canvas placed prominently at the center of the room. This canvas was positioned to face the entrance and could be seen by people passing by through the glass doors, making it both a focal point and an evolving public installation. Facilitators framed this final step of the workshop as an opportunity to "leave a trace" in a collective science-art piece, symbolizing shared memory, community engagement, and the integration of creativity with scientific exploration.

- **Expected Decoding**
  It was expected that participants would feel a sense of pride and belonging by adding their work to a visible, collective creation. Additionally, the public visibility of the canvas was designed to attract interest from other visitors, potentially encouraging spontaneous engagement and curiosity from those who had not initially planned to participate.

- **Actual Reception**
  Most participants expressed excitement and pride in contributing to the collaborative canvas, captured by Figure4.33 The growing artwork drew attention from passersby, some of whom inquired about the activity and how to join—demonstrating its success in attracting new interest. However, a few participants showed a strong preference to bring their creations home instead, which was accommodated by providing a take-home workshop kit containing materials and instructions.
  Furthermore, a notable pattern emerged: participants who joined later in the day, when the canvas was already partially filled, appeared more enthusiastic about contributing, suggesting that the visual impact of others' contributions positively influenced willingness to engage in the communal format. This highlights the value of visible social proof in promoting collective participation, while also acknowledging the need to balance personal ownership with shared experience.

Figure 4.33 Participants contributing their own work to the big canvas, making it a collaborative installation.

4.5.7 Questionnaire

Questionnaire	Form	Target	Purpose
Pre-workshop	Online	Parent-child	Establish baseline: prior science interest, self-perception, expectations
Post-workshop (Children)	Online	Children above 7	Measure enjoyment, feasibility, and preferred learning methods
Post-workshop children (Children 4–7)	Physical	Children 4-7	Assess enjoyment and basic feasibility using Smileyometer
Post-workshop (Guardians)	Online	Parent	Gauge perceptions of child's learning and engagement

Figure 4.34 Workshop 4 Questionnaire Overview

As depict in Figure 4.34, four different questionnaires were distributed across pre- and post-workshop stages to accommodate a variety of family dynamics and participant age groups. Parents were encouraged to assist their children in completing the forms when needed, particularly for younger participants. The aim was to gather a comprehensive understanding of which aspects of the activity were most effective—both in terms of engagement and learning outcomes. Each questionnaire was labeled using a coded system based on time slots and numbered tickets to ensure accurate tracking and analysis.

Participant Engagement

The questionnaire results demonstrate a high level of engagement and satisfaction among participants. When asked if they would like to participate in a similar "Sci-Art" event in the future, 92.9% answered "definitely yes," indicating a strong desire for continued involvement. Similarly, 88.9% of participants expressed interest in recreating the activity at home, suggesting that the workshop successfully sparked long-term interest beyond the session itself.
Participants also felt a personal connection to the activity. Open-ended responses highlighted repeated use of positive terms such as "It was fun“, "I want to do it again", and "It was fun to make something“. One parent mentioned “Although my child is six years old, they seemed to really enjoy it. The mysterious experience made them curious about why it worked". This qualitative feedback supports the quantitative findings and illustrates the emotional and motivational impact of the workshop.

Knowledge Acquisition

The workshop also proved effective in fostering science-related learning. In response to whether participants felt they had learned something new through the workshop, 74.1% answered "learned a lot" and 18.5% said "learned somewhat." Additionally, 74.1% of respondents agreed that the activity increased their interest in science, demonstrating the workshop's potential to enhance scientific curiosity.
When asked what contributed most to understanding the scientific concepts, the majority (64.3%) selected “actually doing the activity,” followed by “explanations from staff” (25%). This underscores the effectiveness of hands-on, inquiry-based learning in informal education settings.
Furthermore, 64.3% reported that the mechanisms and reasoning behind the activity were “very easy to understand.” Supporting this, another multiple-choice question revealed that participants found the following aspects helpful for understanding:

- Avoiding difficult terminology (75%)
- Visualizing changes with their own eyes (57.1%)
- Connecting explanations with hands-on actions (42.9%)

These findings suggest that the workshop successfully communicated complex scientific principles in an age-appropriate and accessible manner. The use of visual aids, interaction, and simple language contributed to making abstract ideas more tangible for the participants.

4.5.8 Workshop Insights

Parent-child

Workshop 4 revealed the unexpected strength of the parent–child collaboration model. Many parents naturally took on a facilitator-like role, helping their children understand instructions, refocus their attention when distracted, and even explain some of the scientific content using everyday language. This organic support proved especially effective with younger children, some of whom struggled to remain engaged throughout the session but benefited from their guardian's involvement.
The findings suggest strong potential for further developing the workshop into a home-based parent–child activity, where parents could be equipped with a facilitator kit to guide their children independently. While the printed manual was helpful for structuring the session, observations and feedback indicated that verbal guidance from facilitators remained essential, especially when interpreting the science behind the activity. This underscores the importance of integrating instructional materials with active human facilitation.

Collaboration

The collaborative art installation at the end of the session was also well received, successfully fostering a sense of shared accomplishment. However, some participants were unsure how or where to contribute their work. This points to an opportunity for improvement—such as incorporating more interactive elements like color-coded areas or fill-in zones—to encourage fuller participation and enhance motivation to engage with the final artwork.

Conclusion

Overall, Workshop 4 demonstrated that combining family interaction, hands-on creativity, and guided explanation can create a rich and flexible science learning experience. Future work can focus on strengthening this dynamic, enhancing facilitator support tools, and designing more participatory elements for collaborative art outcomes.

4.6. Summary

Chapter 4 presented a detailed account of four workshops conducted as part of the Sci-Art project, each serving as a user test to evaluate the effectiveness of different communication strategies, activity structures, and participant experiences in informal science learning environments.

Workshop 1 served as the initial pilot session, focusing on young children and observational facilitation by guardians. It went through several iterations to refine the workshop flow and confirm the accessibility of scientific content through hands-on art activities. This session provided foundational insights into participant behavior, facilitator roles, and age-appropriate engagement strategies.

Workshop 2 , held at KMD Forum, introduced two different activities across two days under a walk-in booth format. Aimed at Gen Z participants, this setting tested how "Sci-Art" activities perform in short-format public exhibitions. The workshop emphasized emotional engagement through strategies such as Interactive Discovery and Art Appreciation. Insights revealed that while surprise-driven discovery was effective in capturing attention, art-related themes needed flexibility to appeal to diverse preferences.

Workshop 3 targeted adult learners and introduced a more conceptually complex science theme using Christmas-themed lava lamp experiments. The communication strategy focused on visual infographics and relatable daily-life examples to simplify abstract scientific concepts. Iterative testing revealed the importance of cultural context, clarity of material use, and visual instruction in promoting understanding and retention.

Workshop 4, the final session, was held at a large public science event and adapted the previously refined Activity 1 for a collaborative parent–child format. It introduced a collective art-making element and distributed printed manuals to support both facilitators and families. This session highlighted the value of parental involvement in guiding children's learning and showed potential for developing the activity into an at-home science education kit. Feedback also underscored the importance of facilitation in complementing instructional materials and the opportunity to improve participation in collaborative installations.

Across all four workshops, key strategies such as multimodal communication, experiential learning, guided facilitation, and social framing were tested and refined. These findings collectively inform how science-art activities can be designed to engage diverse audiences, from children to adults, in meaningful, inclusive, and enjoyable learning experiences. These findings set the foundation for Chapter 5, where they are discussed in relation to prior research and future applications.

Chapter 5
Discussion and Future Works

5.1. Overview of the Evaluation

The research goal of this project is to foster awareness, engagement and interest of science among young generation especially people without science background. The three main research questions are:

- **RQ1**: How can art-based workshops be designed to enhance science engagement among non-scientific audiences?
- **RQ2**: How can science communication strategies, particularly encoding techniques, be tailored within art-based workshops to support clearer understanding and reduce communicative "noise"?
- **RQ3**: How do art-based activities influence participants' ability to become more aware of, engaged with, and interested in science topics?

5.2. Individual Workshop Findings

The following section synthesizes key findings from all four workshops, examining how different communication strategies influenced participant engagement, learning outcomes, and overall reception. A summary of the communication approaches, questionnaire insights, and reflective takeaways for each workshop is presented in Figure 5.1.
In Workshop 1, the combination of questioning and guided observation with interactive demonstrations effectively engaged young participants, while also revealing the potential for adult involvement through observation-based learning. Workshop

2 utilized a self-discovery approach paired with art appreciation to foster emotional connection and conceptual understanding among adults, highlighting the potential of art-based formats for informal adult science learning. In Workshop 3, infographic-based explanations and culturally relatable examples supported conceptual clarity and prompted a noticeable shift in participant perception, emphasizing the value of multimodal materials in communicating abstract scientific ideas. Finally, Workshop 4 employed multimodal instructional materials and collaborative framing to enhance accessibility and understanding of scientific content, particularly through dialogic exchanges between parents and children, suggesting a promising model for intergenerational science communication.

Workshop	Communication Strategy		Questionnaire	Reflection
WS1	Questions and guided observation	Interactive Demonstration	Engagement of young participants	Potential for adult engagement through observational formats
WS2	Self-Discovery	Art Appreciation	Learning outcomes among adult participants	Potential of art-based formats for adult science learning
WS3	Infographic	Relatability	Effective learning methods and perception shift	Impact of multimodal materials in clarifying abstract concepts
WS4	Multimodal Instructional Materials	Collaborative Framing	Accessible science communication and learning effectiveness	Emergence of parent–child interaction as a co-learning model

Figure 5.1 Summary of each workshop's communication strategy, questionnaire, and insights

5.3. Cross-Workshop Synthesis

5.3.1 Communication Strategy Effectiveness

Across the four workshops, diverse communication strategies were tested to improve scientific understanding and engagement among non-scientific audiences. Strategies such as guided questioning (WS1), self-discovery (WS2), relatable infographics (WS3), and multimodal instructional materials (WS4) all aimed to reduce communicative "noise" and support clearer decoding of scientific content. Infographics paired with culturally familiar visuals in WS3 were particularly effective in improving conceptual clarity, especially for abstract topics like immiscibility and acid–base reactions. In contrast, guided demonstrations in WS1 helped sustain curiosity and participation among children, while WS4's combination of visuals, language, and hands-on interaction fostered accessibility across age groups. These findings suggest that encoding strategies grounded in interactivity, cultural familiarity, and visual clarity consistently enhanced communication outcomes across the workshops.

5.3.2 Multigenerational Engagement

While the workshops were initially designed with children in mind, feedback and observations revealed strong engagement from adult participants as well. In WS2 and WS3, adults expressed curiosity, asked questions, and reflected on their own learning—particularly when the content was framed through sensory or familiar contexts. This highlights the untapped potential of science-art activities to engage older audiences through informal learning. These observations support the need for more adult-inclusive formats that encourage lifelong learning and make science approachable beyond childhood education settings. Designing workshops with flexibility in content delivery and activity framing may help ensure relevance and accessibility for a wider demographic.

5.3.3 Symbolic and Cultural Framing

Many of the science communication strategies employed drew from participants' everyday cultural experiences. In WS3, for example, ingredients like ramen soup and convenience store drinks were used to illustrate scientific principles, anchoring abstract concepts in familiar and culturally meaningful symbols. This approach aligns with the theory of symbolic interactionism, which suggests that people construct meaning through shared symbols and social context. By using culturally resonant examples, the workshops helped participants relate science to their own lives, thereby increasing interest and understanding. These results suggest that culturally contextualized framing is not only effective in enhancing clarity but also in generating a sense of relevance and personal connection to science.

5.3.4 Dialogic Learning and Interpersonal Meaning-Making

Participant observations, particularly in WS4, demonstrated the importance of interpersonal communication in facilitating learning. In several cases, parents engaged in dialog with their children to co-interpret scientific phenomena, using their own language and examples to reinforce understanding. This reflects the principles of dialogic communication, where learning is a mutual and evolving process shaped by interaction rather than one-way transmission. These moments of conversation and shared discovery enabled participants to build meaning collaboratively, reinforcing key concepts and expanding their comprehension. Such interactions reveal the potential of science workshops not only as individual learning experiences but also as relational spaces that foster co-learning and emotional engagement through dialogue.

5.4. Reframing Workshops as Science Communication Media

While the workshops in this study were originally designed as informal learning experiences, their outcomes suggest a broader function: they operate as participatory media formats that frame, repackage, and communicate scientific knowledge to non-scientific audiences. Rather than delivering fixed content in a traditional pedagogical structure, these workshops created spaces for collaborative meaning-making, cultural relevance, and sensory engagement. Through this lens, each workshop functioned as a communication experiment, testing how science can be emotionally, visually, and socially decoded by diverse participants.

This reframing aligns directly with the study's research questions. First, in terms of RQ1:how art-based workshops can be designed to enhance science engagement, the findings show that incorporating elements such as everyday materials, hands-on activities, and relatable visuals increases accessibility and interest. Participants across age groups, particularly adults, expressed emotional resonance and curiosity when engaging with creative, science-infused tasks. This shift demonstrates that design decisions rooted in participatory interaction and symbolic familiarity can foster deeper engagement with science beyond formal educational settings.

Secondly, in relation to RQ2, the workshops illustrate how communication strategies, especially encoding techniques, can be tailored to reduce “noise” and clarify scientific meaning. The strategic use of infographics, culturally familiar examples (e.g., ramen broth, convenience store drinks), and storytelling helped clarify complex concepts like immiscibility and acid–base reactions. These methods worked not only to simplify content but also to reinforce participants’ confidence in interpreting it. The encoding was intentionally designed to align with the audience’s lived experiences, ensuring that the message reached its target more effectively and with minimal loss.

Lastly, regarding RQ3, the workshops revealed that art-based activities significantly influenced participants’ awareness, curiosity, and perception of science. Many participants reported learning something new, experiencing a shift in how they viewed science—from something abstract and academic to something approachable, artistic, and emotionally resonant. These shifts were particularly evident in spontaneous comments, visual outputs, and follow-up conversations. The workshops reframed science not only as knowledge, but as an experience: something felt, co-created, and socially understood.

In sum, by functioning as communication experiments rather than simply educational interventions, these workshops demonstrated the power of art-based formats to act as inclusive, emotionally engaging, and culturally situated media. This perspective positions design not just as a method of instruction, but as a strategy for shaping public understanding of science in more diverse, human-centered ways.

5.5. Limitations

While the findings of this study offer valuable insights into the potential of art-based workshops as science communication media, several limitations must be acknowledged. These limitations relate to methodological design, participant diversity, interpretive scope, and the inability to assess long-term impact.

5.5.1 Methodological Limitations

As a design-based research project situated in real-world environments, the workshops were subject to contextual variables that affected consistency. Although standardized facilitation protocols and materials were implemented across workshops, minor differences in facilitator tone, group size, and environmental conditions may have influenced participant engagement and outcomes. Additionally, due to the exploratory and practice-oriented nature of the study, most of the data was qualitative or self-reported, which limits the ability to draw firm causal conclusions. While questionnaires and observations provided rich insight into engagement and understanding, they were not triangulated with more rigorous assessment tools, such as pre/post testing or cognitive interviews, which could have further strengthened the evaluation.

5.5.2 Participant Diversity and Representativeness

The participant pool was limited in size and demographic diversity, primarily involving families with young children or local community members already inclined to attend public workshops. Adult participants, though present in each session, were fewer in number and often secondary to the children they accompanied. As a result, findings about adult engagement and learning—though promising—remain preliminary. In addition, cultural context (urban Japan) played a significant role in framing content and participant response. Therefore, the insights drawn from this group may not be broadly representative of other populations with different cultural, linguistic, or educational backgrounds.

5.5.3 Longitudinal Impact and Interest Retention

One significant limitation was the inability to track participants' long-term interest in science following the workshops. While many participants expressed enjoyment and curiosity during the sessions, there was no structured mechanism to assess whether these experiences translated into sustained interest, further exploration, or educational choices. The workshops offered an initial spark of engagement, but without follow-up contact, the extent to which this spark persisted remains unknown. Future research could incorporate longitudinal methods, such as post-event surveys or interviews, to better understand the lasting impact of informal science-art interventions.

5.6. Future Work

5.6.1 Expansion of Audience and Format

Future iterations of the workshops could be extended to reach more diverse demographics, including inter-generational audiences, rural communities, and students in formal educational settings. Adapting delivery formats to suit different age groups, learning environments, and accessibility needs, while preserving the workshops' creative, participatory core, would allow the model to be scaled and adapted across a wider range of contexts.
Additionally, collaborative installations such as the one piloted in WS4 demonstrate potential for transforming short-term workshops into sustained, community-driven science engagement platforms. These large-scale, co-created artifacts invite broader participation and foster a sense of shared ownership, making science more visible and integrated into everyday public life.

5.6.2 Improvement in Evaluation Methods

To better understand the long-term impact of the workshops, future research should incorporate longitudinal methods to track shifts in participants' interest, attitudes, and behavior over time. Follow-up surveys, interviews, or related activities conducted weeks or months after the initial session could offer deeper insights into how informal experiences shape ongoing science engagement.
Moreover, broadening the evaluation strategy to include facilitator perspectives and systematic artifact analysis would provide a richer, more triangulated understanding of workshop effectiveness. By connecting participants' visible outputs with both their self-reported experiences and facilitator observations, future studies can more comprehensively assess the educational and communicative outcomes of the workshops.

5.6.3 Refining Science-Art Integration

While the workshops effectively communicated scientific concepts through creative methods, future work could explore how to deepen and diversify this integration. For instance, incorporating narrative storytelling, digital media, or interactive

technologies may enhance immersion and allow participants to engage with more complex or cross-disciplinary topics.
Expanding the thematic scope of the workshops, such as addressing global issues like sustainability, climate change, or space exploration, could further increase their relevance and appeal to a broader audience. These timely themes would not only enhance content diversity but also connect science learning with current societal challenges.
These findings also point to the broader potential of interdisciplinary science-art workshops to function not only as educational tools but also as platforms for cross-sector collaboration—connecting schools, local governments, businesses, and cultural institutions. With further development, this approach could inform regional education policy and serve as a scalable, community-centered model for inclusive STEAM outreach.

5.7. Conclusion

This study examined how art-based workshops can enhance science engagement among non-scientific audiences through thoughtfully designed communication strategies. By applying models like experiential learning and encoding–decoding theory, four workshops were developed and evaluated to explore how interactive formats and visual tools can clarify complex topics, reduce communication "noise," and spark curiosity.
Findings showed that creative activities, such as surprise-based self-discovery, relatable analogies, and collaborative displays,successfully engaged both children and adults. Participants demonstrated increased interest and understanding, indicating that such workshops can effectively serve as informal science communication tools.
Overall, this research highlights the potential of science-art integration as a new form of science communication to create accessible, emotionally engaging learning environments. It offers a flexible model for inclusive science outreach, with implications for educational programming, public engagement, and future interdisciplinary initiatives.

References

[1] Cherry Yeung. Economic and trade information on hong kong, 2024. https://research.hktdc.com/en/article/MzIwNjkzNTY5.

[2] Joseph YS Cheng and Zheng Peiyu. Hi-tech industries in hong kong and the pearl river delta. *Asian Survey*, 41(4):584–610, 2001.

[3] Zehui Zhan, Wenyao Shen, Zhichao Xu, Shijing Niu, and Ge You. A bibliometric analysis of the global landscape on stem education (2004-2021): towards global distribution, subject integration, and research trends. *Asia Pacific Journal of Innovation and Entrepreneurship*, 16(2):171–203, 2022.

[4] S Alvin Leung, Zhi-Jin Hou, Itamar Gati, and Xixi Li. Effects of parental expectations and cultural-values orientation on career decision-making difficulties of chinese university students. *Journal of Vocational Behavior*, 78(1):11–20, 2011.

[5] Chung-an Chen, Chengwei Xu, and Don-Yun Chen. "expecting children to be dragons" in an east asian context: Parental expectations of children choosing a career in the public sector. *Asia Pacific Journal of Public Administration*, 45(2):118–138, 2023.

[6] Zhi Hong Wan and John Chi Kin Lee. Hong kong secondary school students' attitudes towards science: A study of structural models and gender differences. *International Journal of Science Education*, 39(5):507–527, 2017.

[7] Xiang Hu, Frederick KS Leung, and Gaowei Chen. School, family, and student factors behind student attitudes towards science: The case of hong kong fourth-graders. *International Journal of Educational Research*, 92:135–144, 2018.

[8] Vera G Goulart, Lara Bartocci Liboni, and Luciana Oranges Cezarino. Balancing skills in the digital transformation era: The future of jobs and the role of higher education. *Industry and Higher Education*, 36(2):118–127, 2022.

[9] National Science Foundation. U.s. and global stem education and labor force, 2022. URL: `https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force`.

[10] Kee-Cheok Cheong, Christopher Hill, Yin-Ching Leong, Chen Zhang, and Zheng Zhang. "parents just don't understand"–generational perceptions of education and work. *Higher Education Evaluation and Development*, 12(2):85–98, 2019.

[11] John F Sargent Jr. The us science and engineering workforce: Recent, current, and projected employment, wages, and unemployment. 2017.

[12] OECD. Dream jobs? teenagers' career aspirations and the future of work, 2020. URL: `https://jacobsfoundation.org/wp-content/uploads/2020/02/OECD_Dream-Jobs-Teenagers-Career-Aspirations-and-the-Future-of-Work.pdf`.

[13] Kathleen M Quinlan and K Ann Renninger. Rethinking employability: how students build on interest in a subject to plan a career. *Higher Education*, 84(4):863–883, 2022.

[14] Soo-yong Byun, Evan Schofer, and Kyung-keun Kim. Revisiting the role of cultural capital in east asian educational systems: The case of south korea. *Sociology of education*, 85(3):219–239, 2012.

[15] Peter Weingart, Marina Joubert, and Karien Connoway. Public engagement with science—origins, motives and impact in academic literature and science policy. *PloS one*, 16(7):e0254201, 2021.

[16] Christian Humm, Philipp Schrögel, and Annette Leßmöllmann. Feeling left out: Underserved audiences in science communication. *Media and Communication*, 8(1):164–176, 2020.

[17] Antonio Tintori and R Palomba. The most common stereotypes about science and scientists: What scholars know. *Turn on the light on science*, pages 1–18, 2017.

[18] Henri Tajfel, John C Turner, William G Austin, and Stephen Worchel. An integrative theory of intergroup conflict. *Organizational identity: A reader*, 56(65):9780203505984–16, 1979.

[19] Jocelyn Steinke. Cultural representations of gender and science: Portrayals of female scientists and engineers in popular films. *Science communication*, 27(1):27–63, 2005.

[20] Michael Morgan. Television and adolescents' sex role stereotypes: A longitudinal study. *Journal of Personality and Social Psychology*, 43(5):947, 1982.

[21] Anthony Dudo, Dominique Brossard, James Shanahan, Dietram A Scheufele, Michael Morgan, and Nancy Signorielli. Science on television in the 21st century: Recent trends in portrayals and their contributions to public attitudes toward science. *Communication Research*, 38(6):754–777, 2011.

[22] Kristen Intemann. Science communication and public trust in science. *Interdisciplinary Science Reviews*, 48(2):350–365, 2023.

[23] Dana Vedder-Weiss and David Fortus. Adolescents' declining motivation to learn science: A follow-up study. *Journal of research in science teaching*, 49(9):1057–1095, 2012.

[24] Avi Hofstein and Sherman Rosenfeld. Bridging the gap between formal and informal science learning. 1996.

[25] Ellen McCallie, Larry Bell, Tiffany Lohwater, John H Falk, Jane L Lehr, Brice V Lewenstein, Cynthia Needham, and Ben Wiehe. Many experts, many audiences: Public engagement with science and informal science education. *A CAISE Inquiry Group Report*, page 1, 2009.

[26] David Anderson and Keith B Lucas. The effectiveness of orienting students to the physical features of a science museum prior to visitation. *Research in Science Education*, 27(4):485–495, 1997.

[27] David A Sousa and Thomas Pilecki. *From STEM to STEAM: Using brain-compatible strategies to integrate the arts.* Corwin Press, 2013.

[28] Shashidhar Belbase, Bhesh Raj Mainali, Wandee Kasemsukpipat, Hassan Tairab, Munkhjargal Gochoo, and Adeeb Jarrah. At the dawn of science, technology, engineering, arts, and mathematics (steam) education: prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*, 53(11):2919–2955, 2022.

[29] Robert L Long II, Stephen S Davis, et al. Using steam to increase engagement and literacy across disciplines. *The STEAM Journal*, 3(1):7, 2017.

[30] Michelle H Land. Full steam ahead: The benefits of integrating the arts into stem. *Procedia computer science*, 20:547–552, 2013.

[31] Rick Bonney, Jennifer L Shirk, Tina B Phillips, Andrea Wiggins, Heidi L Ballard, Abraham J Miller-Rushing, and Julia K Parrish. Next steps for citizen science. *Science*, 343(6178):1436–1437, 2014.

[32] Janis L Dickinson, Jennifer Shirk, David Bonter, Rick Bonney, Rhiannon L Crain, Jason Martin, Tina Phillips, and Karen Purcell. The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, 10(6):291–297, 2012.

[33] Susan M Stocklmayer, Léonie J Rennie, and John K Gilbert. The roles of the formal and informal sectors in the provision of effective science education. *Studies in science education*, 46(1):1–44, 2010.

[34] Hilary Geoghegan, Alison Dyke, Rachel Pateman, Sarah West, and Glyn Everett. Understanding motivations for citizen science. *Final report on behalf of UKEOF, University of Reading, Stockholm Environment Institute (University of York) and University of the West of England*, 78, 2016.

[35] Sarah Elizabeth West and Rachel Mary Pateman. Recruiting and retaining participants in citizen science: What can be learned from the volunteering literature? *Citizen science: Theory and practice*, 2016.

[36] David A Kolb. *Experiential learning: Experience as the source of learning and development*. FT press, 2014.

[37] Mahmoud Abdulwahed and Zoltan K Nagy. Applying kolb's experiential learning cycle for laboratory education. *Journal of engineering education*, 98(3):283–294, 2009.

[38] Barry J Wadsworth. *Piaget's theory of cognitive and affective development: Foundations of constructivism*. Longman Publishing, 1996.

[39] George E Hein. Constructivist learning theory. *Institute for Inquiry*, 14, 1991.

[40] Jerome Bruner. The narrative construction of reality. *Critical inquiry*, 18(1):1–21, 1991.

[41] Jennifer Rowsell and DR Collier. Researching multimodality in language and education. *Research methods in language and education*, pages 311–324, 2017.

[42] Jana Holsanova. New methods for studying visual communication and multimodal integration, 2012.

[43] Claude E Shannon. A mathematical theory of communication. *The Bell system technical journal*, 27(3):379–423, 1948.

[44] Wilbur Ed Schram. The process and effects of mass communication. 1954.

[45] David M Sobel. Science, technology, engineering, and mathematics (stem) engagement from parent-child interaction in informal learning environments. *Current Directions in Psychological Science*, 32(6):454–461, 2023.

[46] Wahyu Setioko and Lin Ding. Influence of parents' views about science on parent–child science talk at home. *International Journal of Science Education, Part B*, 13(3):195–215, 2023.

[47] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. Research through design as a method for interaction design research in hci. In *Proceedings*

of the SIGCHI conference on Human factors in computing systems, pages 493–502, 2007.

[48] Terry Anderson and Julie Shattuck. Design-based research: A decade of progress in education research? *Educational researcher*, 41(1):16–25, 2012.

[49] National Research Council et al. *Learning science in informal environments: People, places, and pursuits.* 2009.

[50] Amy E Lesen, Ama Rogan, and Michael J Blum. Science communication through art: objectives, challenges, and outcomes. *Trends in Ecology & Evolution*, 31(9):657–660, 2016.

[51] Georgette Yakman. Steam education: An overview of creating a model of integrative education, 2008.

[52] Gunther Kress and Theo van Leeuwen. *Multimodal Discourse: The Modes and Media of Contemporary Communication.* Arnold, London, 2001.

[53] Gloria Ladson-Billings. Toward a theory of culturally relevant pedagogy. *American educational research journal*, 32(3):465–491, 1995.

[54] Glen S Aikenhead. *Science education for everyday life: Evidence-based practice.* Teachers College Press, 2006.

[55] Charles Forceville et al. Relevance theory as model for analysing visual and multimodal communication. *Visual communication*, 4(51):10–1515, 2014.

[56] Stuart Hall. Encoding and decoding in the television discourse. In *CCCS selected working papers*, pages 402–414. Routledge, 2007.

[57] Emily E Scott, Mary Pat Wenderoth, and Jennifer H Doherty. Design-based research: A methodology to extend and enrich biology education research. *CBE—Life Sciences Education*, 19(2):es11, 2020.

[58] John W Creswell and Vicki L Plano Clark. *Designing and conducting mixed methods research.* Sage publications, 2017.

[59] Sharon J Derry, Roy D Pea, Brigid Barron, Randi A Engle, Frederick Erickson, Ricki Goldman, Rogers Hall, Timothy Koschmann, Jay L Lemke, Miriam Gamoran Sherin, et al. Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The journal of the learning sciences*, 19(1):3–53, 2010.

[60] Anthony R Artino Jr, Jeffrey S La Rochelle, Kent J Dezee, and Hunter Gehlbach. Developing questionnaires for educational research: Amee guide no. 87. *Medical teacher*, 36(6):463–474, 2014.

[61] Mary Ainley and John Ainley. Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary educational psychology*, 36(1):4–12, 2011.

[62] James D Kirkpatrick and Wendy Kayser Kirkpatrick. *Kirkpatrick's four levels of training evaluation.* Association for Talent Development, 2016.

[63] Harry N Boone Jr and Deborah A Boone. Analyzing likert data. *The Journal of extension*, 50(2):48, 2012.

[64] Youzhi Song, Jianjun Wu, Zongkui Zhou, Yuan Tian, Weina Li, and Heping Xie. Parent-adolescent discrepancies in educational expectations, relationship quality, and study engagement: a multi-informant study using response surface analysis. *Frontiers in Psychology*, 15:1288644, 2024.

[65] Janet C Read. Validating the fun toolkit: an instrument for measuring children's opinions of technology. *Cognition, Technology & Work*, 10:119–128, 2008.

[66] Susan Harter and Robin Pike. The pictorial scale of perceived competence and social acceptance for young children. *Child development*, pages 1969–1982, 1984.

[67] Angelina Joy, Fidelia Law, Luke McGuire, Channing Mathews, Adam Hartstone-Rose, Mark Winterbottom, Adam Rutland, Grace E Fields, and Kelly Lynn Mulvey. Understanding parents' roles in children's learning

and engagement in informal science learning sites. *Frontiers in Psychology*, 12:635839, 2021.

[68] Virginia Braun and Victoria Clarke. Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2):77–101, 2006.

[69] Nancy Carter. The use of triangulation in qualitative research. *Number 5/September 2014*, 41(5):545–547, 2014.

[70] Toyin Tofade, Jamie Elsner, and Stuart T Haines. Best practice strategies for effective use of questions as a teaching tool. *American journal of pharmaceutical education*, 77(7):155, 2013.

[71] Richard White and Richard Gunstone. *Probing understanding.* Routledge, 2014.

[72] Maxi Becker, Xinhao Wang, and Roberto Cabeza. Surprise!—clarifying the link between insight and prediction error. *Psychonomic Bulletin & Review*, pages 1–10, 2024.

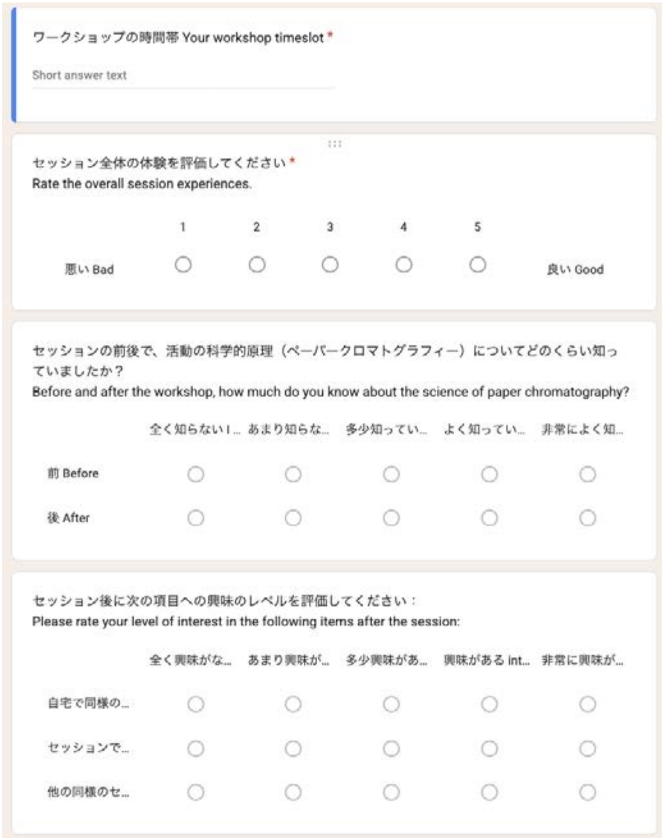
[73] Jerry Trusty and Giacomo M Oliva. The effect of arts and music education on students' self-concept. *Update: Applications of Research in Music Education*, 13(1):23–28, 1994.

[74] Jennifer O Spicer and Caroline G Coleman. Creating effective infographics and visual abstracts to disseminate research and facilitate medical education on social media. *Clinical Infectious Diseases*, 74(Supplement_3):e14–e22, 2022.

[75] Activate Learning. Culturally responsive science curriculum: The key to unlocking student potential, 2024. URL: `https://activatelearning.com/culturally-responsive-science-curriculum-the-key-to-unlocking-student-potential/`.

Appendices

A. Workshop 2


ワークショップの時間帯 Your workshop timeslot *

Short answer text

セッション全体の体験を評価してください *
Rate the overall session experiences.

	1	2	3	4	5	
悪い Bad	○	○	○	○	○	良い Good

セッションの前後で、活動の科学的原理（ペーパークロマトグラフィー）についてどのくらい知っていましたか？
Before and after the workshop, how much do you know about the science of paper chromatography?

	全く知らない I...	あまり知らな...	多少知ってい...	よく知ってい...	非常によく知...
前 Before	○	○	○	○	○
後 After	○	○	○	○	○

セッション後に次の項目への興味のレベルを評価してください：
Please rate your level of interest in the following items after the session:

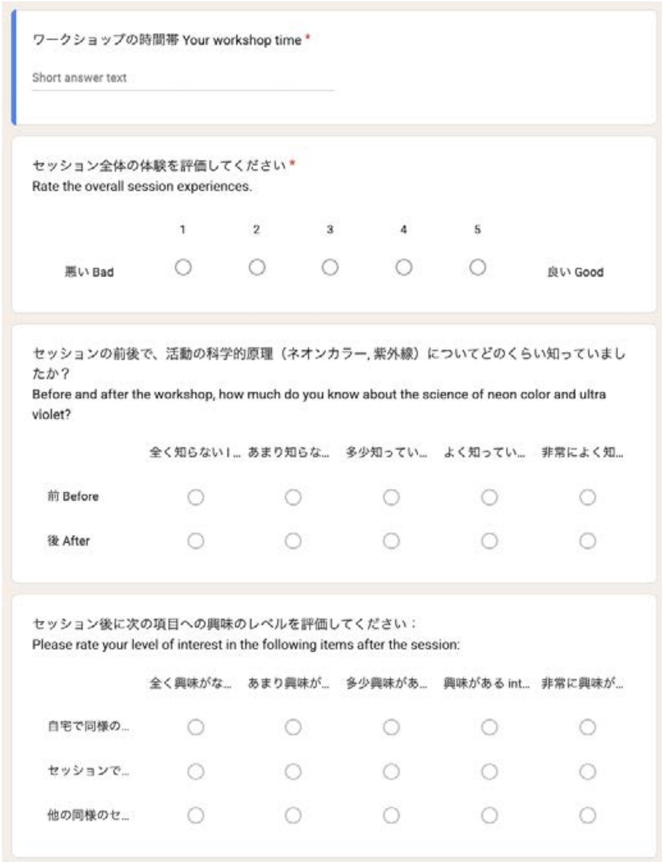
	全く興味がな...	あまり興味が...	多少興味があ...	興味がある int...	非常に興味が...
自宅で同様の...	○	○	○	○	○
セッションで...	○	○	○	○	○
他の同様のセ...	○	○	○	○	○

Figure A.1 WS2 Day1 Questionnaire Page 1

Figure A.2 WS2 Day1 Questionnaire Page 2

B. Workshop 3

C. Workshop 4



ワークショップの時間帯 Your workshop time *

Short answer text

セッション全体の体験を評価してください *
Rate the overall session experiences.

	1	2	3	4	5	
悪い Bad	○	○	○	○	○	良い Good

セッションの前後で、活動の科学的原理（ネオンカラー，紫外線）についてどのくらい知っていましたか？
Before and after the workshop, how much do you know about the science of neon color and ultra violet?

	全く知らない I...	あまり知らな...	多少知ってい...	よく知ってい...	非常によく知...
前 Before	○	○	○	○	○
後 After	○	○	○	○	○

セッション後に次の項目への興味のレベルを評価してください：
Please rate your level of interest in the following items after the session:

	全く興味がな...	あまり興味が...	多少興味があ...	興味がある int...	非常に興味が...
自宅で同様の...	○	○	○	○	○
セッションで...	○	○	○	○	○
他の同様のセ...	○	○	○	○	○

Figure A.3 WS2 Day2 Questionnaire Page 1

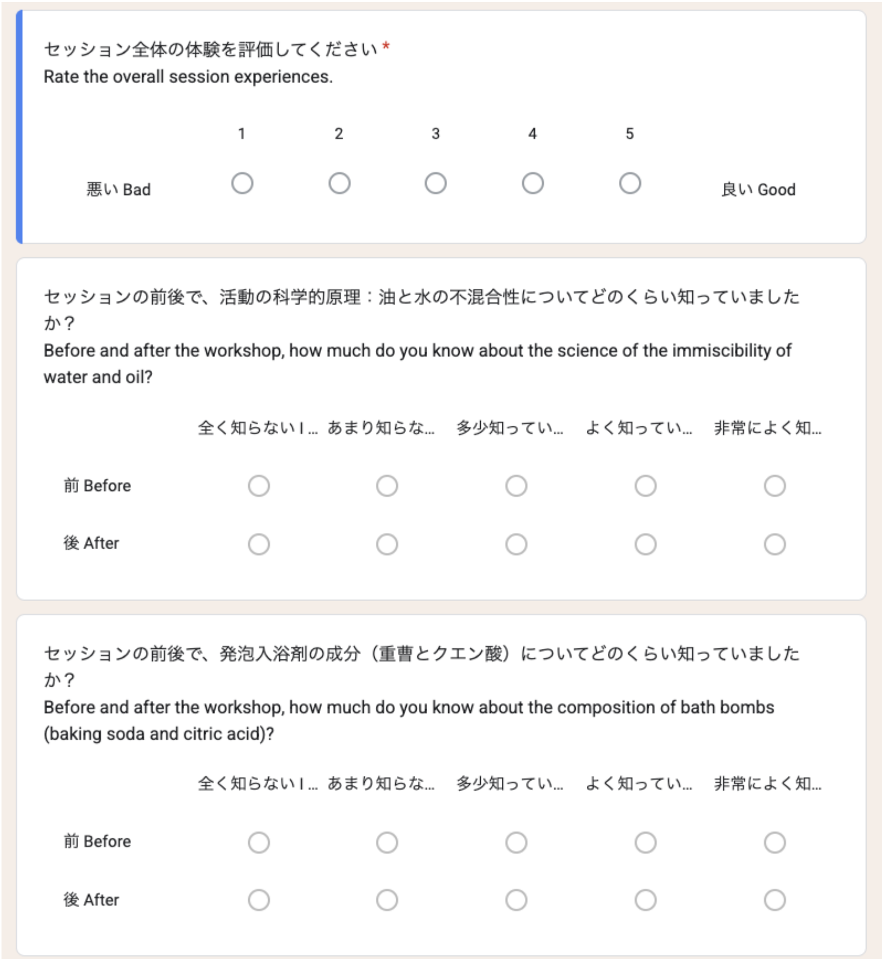
セッション後に次の文にどの程度同意するかを選択してください：

	全く同意しない	同意しない	どちらとも言...	同意する	非常に同意する
私は科学がよ...	○	○	○	○	○
将来、もう一...	○	○	○	○	○
他の人に勧める	○	○	○	○	○

(任意)その他にご意見やご感想がございましたら、こちらにご自由にお書きください！
(Optional)If you have any comments, please feel free to write them here!

Long answer text

Figure A.4 WS2 Day2 Questionnaire Page 2



セッション全体の体験を評価してください *
Rate the overall session experiences.

	1	2	3	4	5	
悪い Bad	○	○	○	○	○	良い Good

セッションの前後で、活動の科学的原理：油と水の不混合性についてどのくらい知っていましたか？
Before and after the workshop, how much do you know about the science of the immiscibility of water and oil?

	全く知らない I...	あまり知らな...	多少知ってい...	よく知ってい...	非常によく知...
前 Before	○	○	○	○	○
後 After	○	○	○	○	○

セッションの前後で、発泡入浴剤の成分（重曹とクエン酸）についてどのくらい知っていましたか？
Before and after the workshop, how much do you know about the composition of bath bombs (baking soda and citric acid)?

	全く知らない I...	あまり知らな...	多少知ってい...	よく知ってい...	非常によく知...
前 Before	○	○	○	○	○
後 After	○	○	○	○	○

Figure B.1 WS3 Questionnaire Page 1

セッションの前後で、活動の科学的原理：酸塩基反応・中和反応についてどのくらい知っていましたか？
Before and after the workshop, how much do you know about the science of acid-base reaction/neutralization?

	全く知らない I...	あまり知らな...	多少知ってい...	よく知ってい...	非常によく知...
前 Before	○	○	○	○	○
後 After	○	○	○	○	○

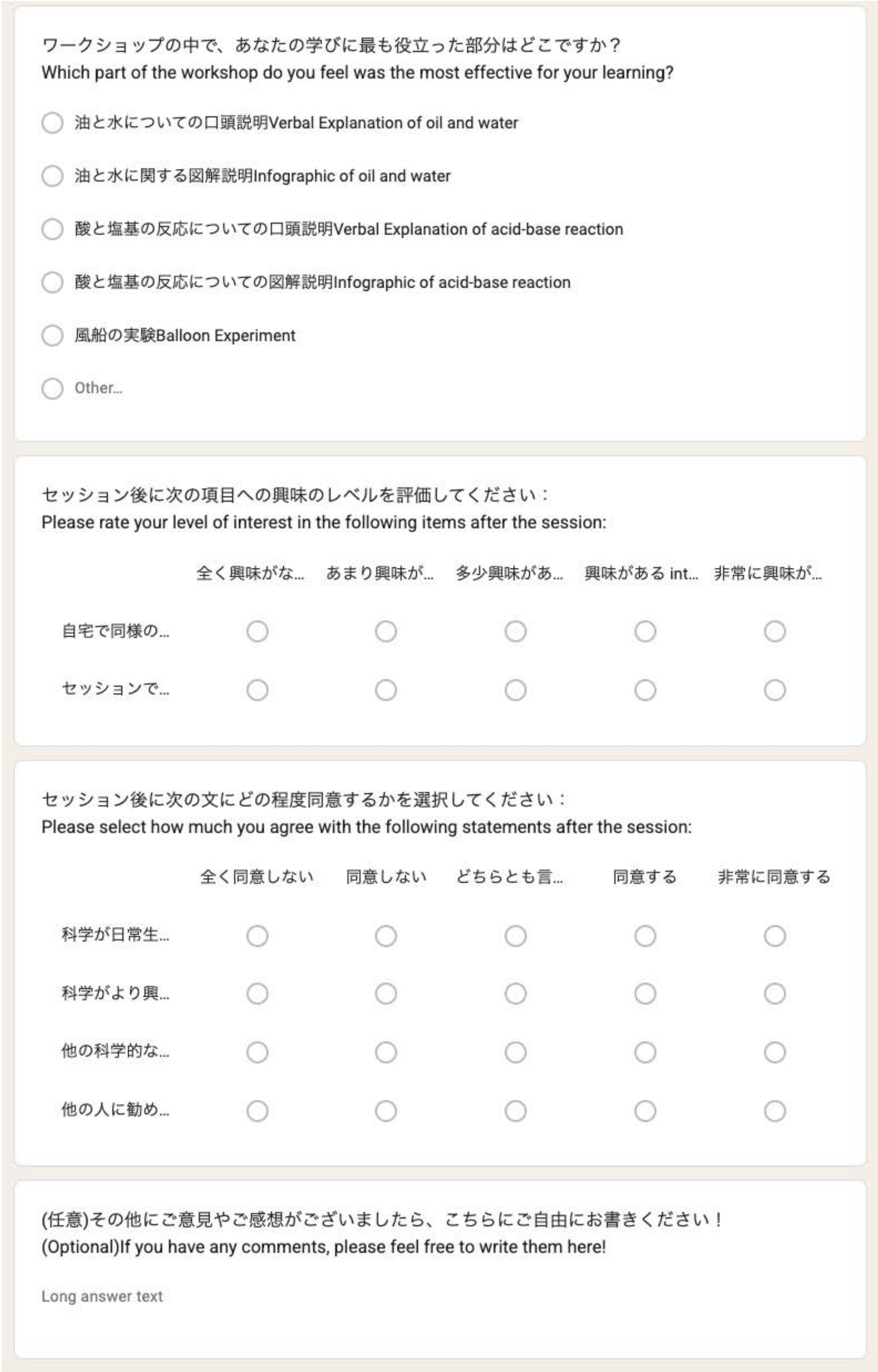
セッション後に次の文にどの程度同意するかを選択してください：
Please select how much you agree with the following statements after the session:

	全く同意しない	同意しない	どちらとも言...	同意する	非常に同意する
ワークショッ...	○	○	○	○	○
スライドや図...	○	○	○	○	○
使われた例や...	○	○	○	○	○
ファシリテー...	○	○	○	○	○
実践的な活動...	○	○	○	○	○

ワークショップの中で最も印象に残った部分はどこですか？
What part of the workshop left the strongest impression on you?

- ○ ボトルを振ったとき（油と水）Shake the bottle (oil and water)
- ○ 小ボトルに入浴剤を入れたときPut the bath bomb in the small bottle
- ○ 風船の実験Balloon Experiment
- ○ 手作りクリスマス飾り瓶Handmade Christmas Jar
- ○ Other...

Figure B.2 WS3 Questionnaire Page 2



ワークショップの中で、あなたの学びに最も役立った部分はどこですか？
Which part of the workshop do you feel was the most effective for your learning?

- 油と水についての口頭説明Verbal Explanation of oil and water
- 油と水に関する図解説明Infographic of oil and water
- 酸と塩基の反応についての口頭説明Verbal Explanation of acid-base reaction
- 酸と塩基の反応についての図解説明Infographic of acid-base reaction
- 風船の実験Balloon Experiment
- Other...

セッション後に次の項目への興味のレベルを評価してください：
Please rate your level of interest in the following items after the session:

	全く興味がな...	あまり興味が...	多少興味があ...	興味がある int...	非常に興味が...
自宅で同様の...					
セッションで...					

セッション後に次の文にどの程度同意するかを選択してください：
Please select how much you agree with the following statements after the session:

	全く同意しない	同意しない	どちらとも言...	同意する	非常に同意する
科学が日常生...					
科学がより興...					
他の科学的な...					
他の人に勧め...					

(任意)その他にご意見やご感想がございましたら、こちらにご自由にお書きください！
(Optional)If you have any comments, please feel free to write them here!

Long answer text

Figure B.3 WS3 Questionnaire Page 3

参加したワークショップの時間枠を教えてください。

- 10:30 - 11:30
- 11:45 - 12:45
- 13: 30 - 14:30
- 14: 45 - 15:45
- 16:00 - 17:00

整理券の番号を教えてください。(1-9)

Short answer text

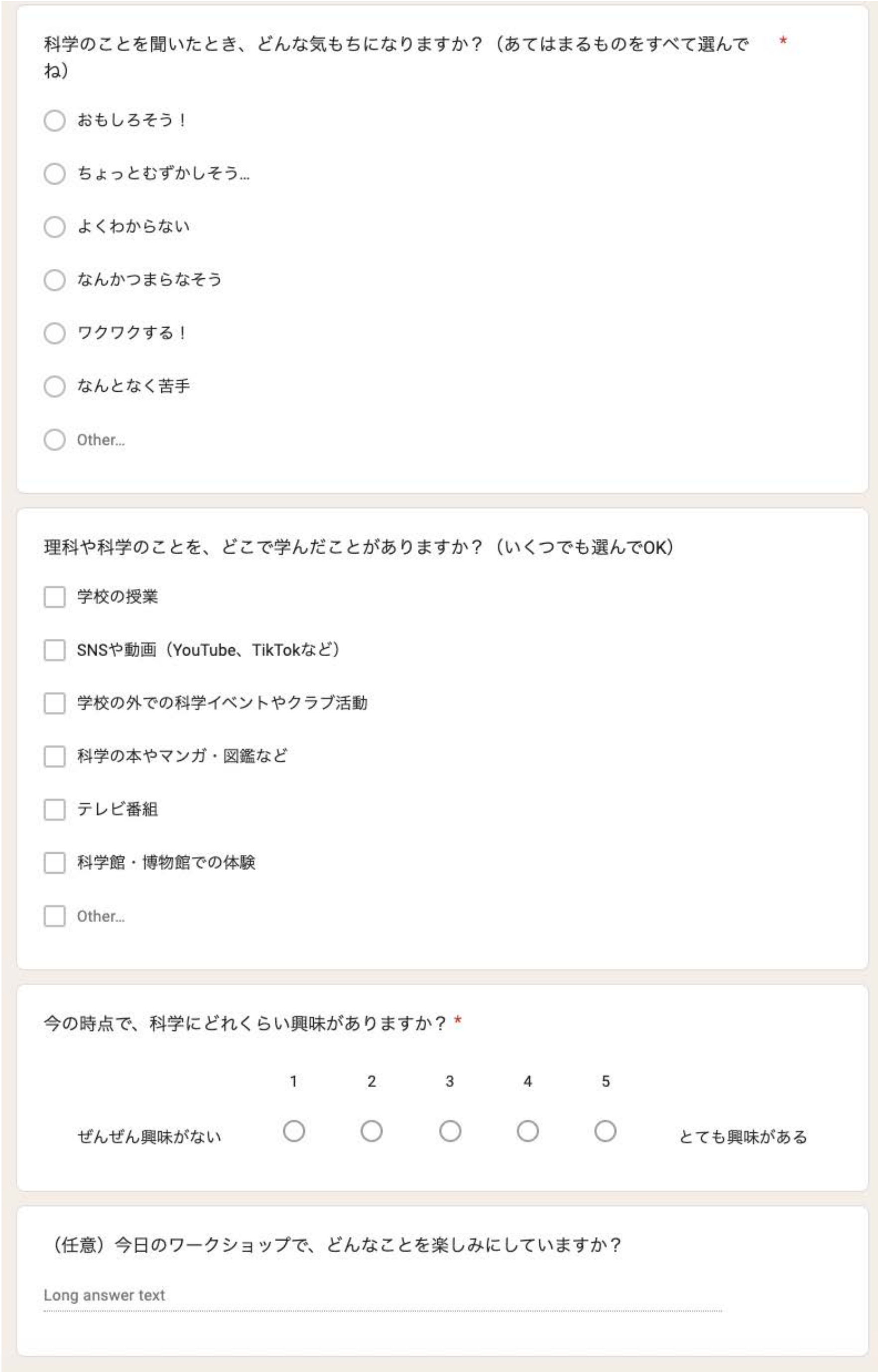
自分はどちらかというと… *

	1	2	3	4	5	
文系タイプ（ことば・アート・表現が好き）	○	○	○	○	○	理系タイプ（科学・実験・数字が好き）

次の中で、ワクワクするもの・やってみたいものはどれ？（いくつでもOK） *

- きれいな作品をつくること
- じぶんの手で実験してみること
- みんなと何かを作ること
- おみやげとして持って帰れること
- 新しいことを学べること
- その他（自由記入）
- Other...

Figure C.1 WS4 Pre-Questionnaire Page 1



科学のことを聞いたとき、どんな気もちになりますか？（あてはまるものをすべて選んでね） *

- おもしろそう！
- ちょっとむずかしそう…
- よくわからない
- なんかつまらなそう
- ワクワクする！
- なんとなく苦手
- Other...

理科や科学のことを、どこで学んだことがありますか？（いくつでも選んでOK）

- 学校の授業
- SNSや動画（YouTube、TikTokなど）
- 学校の外での科学イベントやクラブ活動
- 科学の本やマンガ・図鑑など
- テレビ番組
- 科学館・博物館での体験
- Other...

今の時点で、科学にどれくらい興味がありますか？ *

	1	2	3	4	5	
ぜんぜん興味がない	○	○	○	○	○	とても興味がある

（任意）今日のワークショップで、どんなことを楽しみにしていますか？

Long answer text

Figure C.2 WS4 Pre-Questionnaire Page 2


ワークショップ
アンケート

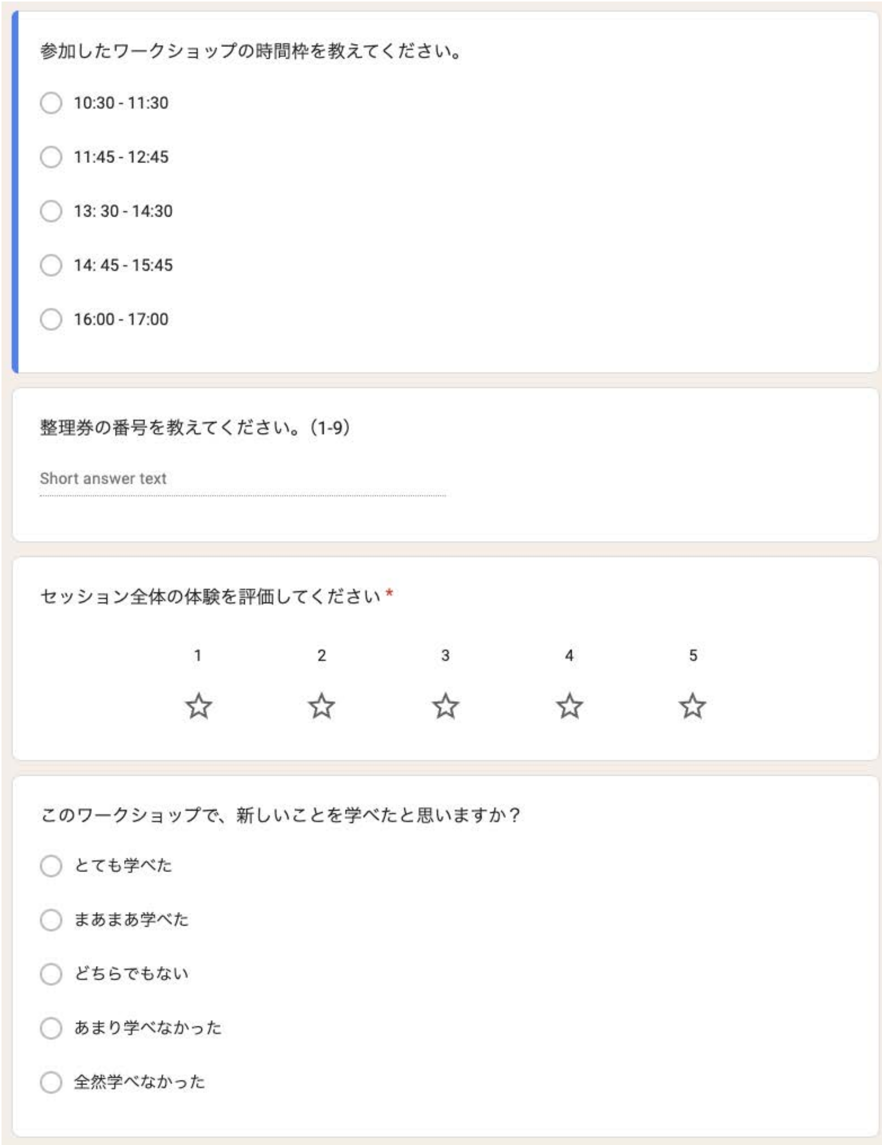
今日のイベントは楽しかったですか？

科学のしくみについて、よくわかりましたか？

またこのようなイベントに遊びたいですか？

KEIO MEDIA DESIGN
KEIO UNIVERSITY GRADUATE SCHOOL OF MEDIA DESIGN

Figure C.3 WS4 Post-Questionnaire (Children 4-7)



参加したワークショップの時間枠を教えてください。

- 10:30 - 11:30
- 11:45 - 12:45
- 13: 30 - 14:30
- 14: 45 - 15:45
- 16:00 - 17:00

整理券の番号を教えてください。(1-9)

Short answer text

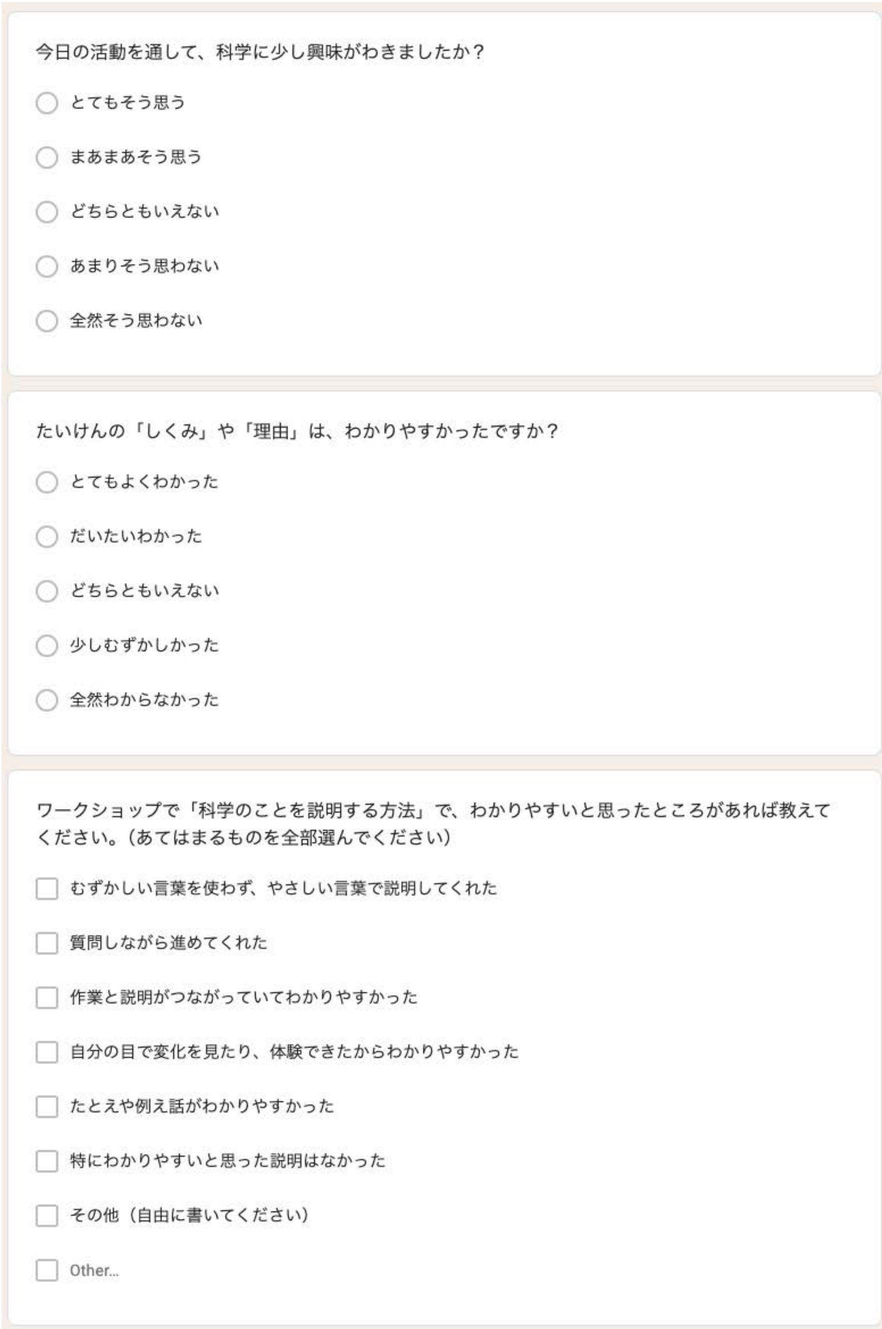
セッション全体の体験を評価してください *

1 2 3 4 5

このワークショップで、新しいことを学べたと思いますか？

- とても学べた
- まあまあ学べた
- どちらでもない
- あまり学べなかった
- 全然学べなかった

Figure C.4 WS4 Post-Questionnaire Page 1 (Children)


今日の活動を通して、科学に少し興味がわきましたか？

- ○ とてもそう思う
- ○ まあまあそう思う
- ○ どちらともいえない
- ○ あまりそう思わない
- ○ 全然そう思わない

たいけんの「しくみ」や「理由」は、わかりやすかったですか？

- ○ とてもよくわかった
- ○ だいたいわかった
- ○ どちらともいえない
- ○ 少しむずかしかった
- ○ 全然わからなかった

ワークショップで「科学のことを説明する方法」で、わかりやすいと思ったところがあれば教えてください。（あてはまるものを全部選んでください）

- ☐ むずかしい言葉を使わず、やさしい言葉で説明してくれた
- ☐ 質問しながら進めてくれた
- ☐ 作業と説明がつながっていてわかりやすかった
- ☐ 自分の目で変化を見たり、体験できたからわかりやすかった
- ☐ たとえや例え話がわかりやすかった
- ☐ 特にわかりやすいと思った説明はなかった
- ☐ その他（自由に書いてください）
- ☐ Other...

Figure C.5 WS4 Post-Questionnaire Page 2 (Children)

ワークショップの中で、どんなことが科学のしくみを理解するのに役立ちましたか？（1つ選んでください）

- マニュアルや作り方の図解
- スタッフや先生の説明
- 実際に手を動かしたこと（じっけん・こうさく）
- 周りの人のようすを見ること
- その他（下の欄にご記入ください）
- Other...

家でもまた作ってみたいと思いますか？

- ぜひやってみたい
- まあまあやってみたい
- どちらともいえない
- あまりやりたくない
- 全然やりたくない

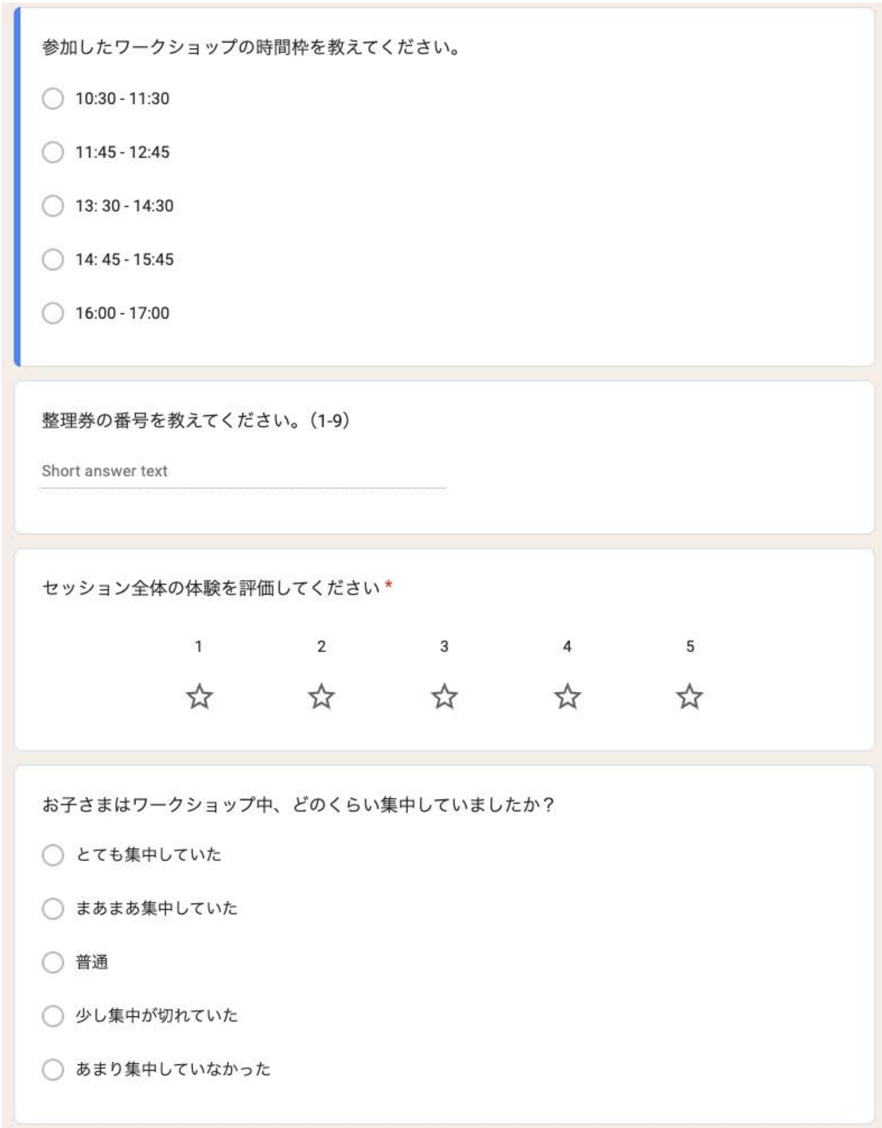
またこのような「科学×アート」のイベントに参加したいと思いますか？

- とても参加したい
- まあまあ参加したい
- どちらでもない
- あまり参加したくない
- 全然参加したくない

(任意)最後に、今日のワークショップや説明についての感想があれば自由に書いてください。

Long answer text

Figure C.6 WS4 Post-Questionnaire Page 3 (Children)



参加したワークショップの時間枠を教えてください。

- 10:30 - 11:30
- 11:45 - 12:45
- 13: 30 - 14:30
- 14: 45 - 15:45
- 16:00 - 17:00

整理券の番号を教えてください。(1-9)

Short answer text

セッション全体の体験を評価してください *

1 2 3 4 5

お子さまはワークショップ中、どのくらい集中していましたか？

- とても集中していた
- まあまあ集中していた
- 普通
- 少し集中が切れていた
- あまり集中していなかった

Figure C.7 WS4 Post-Questionnaire Page 1 (Parents)

このワークショップは、お子様にとって新しい学習や知識を得るのに役立ちましたか？

- ◯ とてもそう思う
- ◯ ややそう思う
- ◯ どちらともいえない
- ◯ あまりそう思わない
- ◯ 全くそう思わない

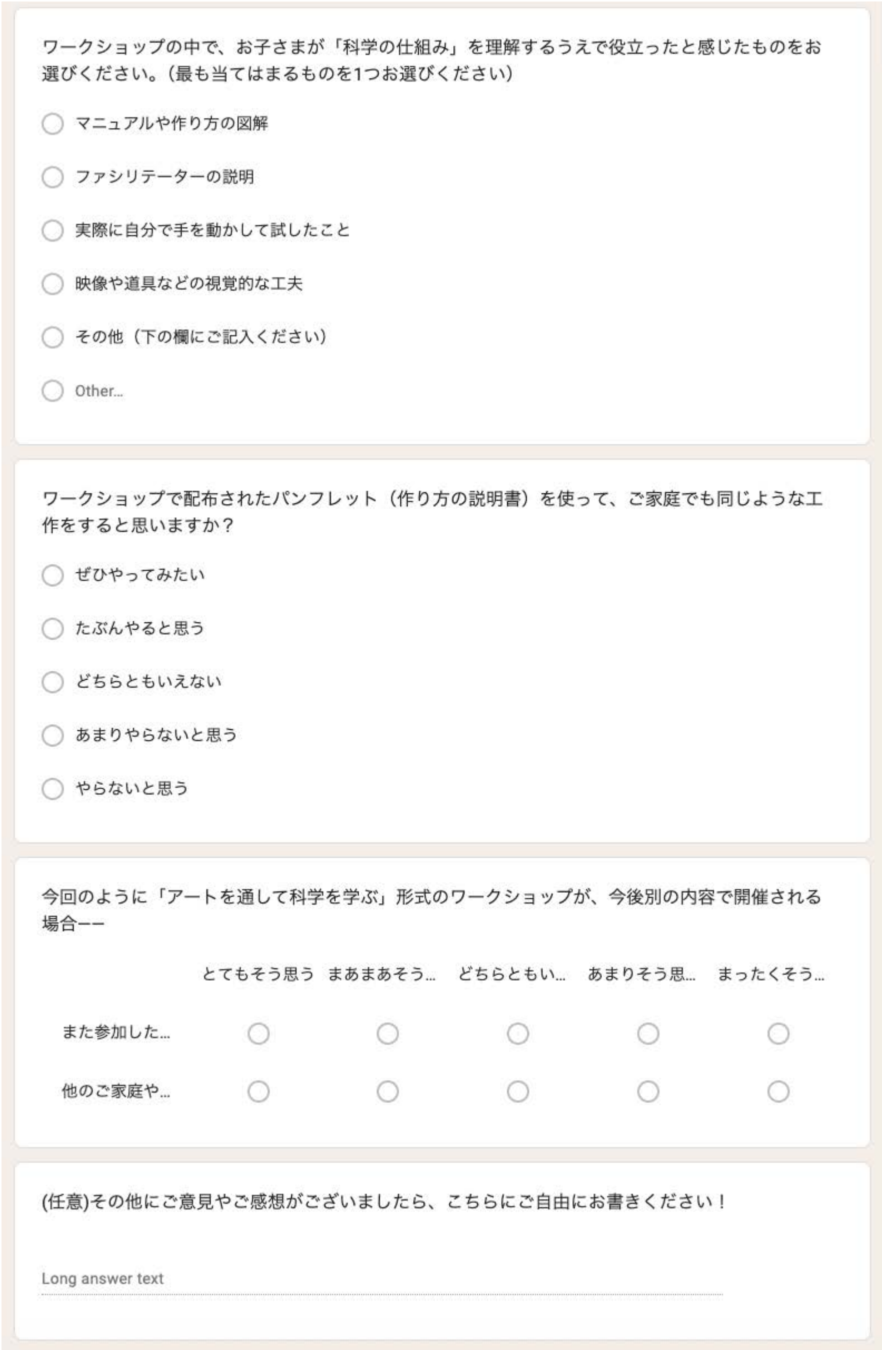
ワークショップ内の「科学の説明（仕組みや原理など）」は、お子さまにとって：

- ◯ とてもわかりやすかった
- ◯ まあまあわかりやすかった
- ◯ どちらともいえない
- ◯ 少し難しかった
- ◯ とても難しかった

ワークショップの中での「科学の伝え方」について、良かったと感じた点があれば教えてください。（複数選択可）

- ☐ 難しい言葉を使わず、やさしい言葉で説明していた
- ☐ 子どもに問いかけるように進めていた
- ☐ 作業と説明がリンクしていた
- ☐ 実際に見て変化を体験することで伝わった
- ☐ 比喩や例えでわかりやすくしていた
- ☐ 特に印象に残った説明はなかった
- ☐ その他（自由記述）
- ☐ Other...

Figure C.8 WS4 Post-Questionnaire Page 2 (Parents)



ワークショップの中で、お子さまが「科学の仕組み」を理解するうえで役立ったと感じたものをお選びください。（最も当てはまるものを1つお選びください）

- マニュアルや作り方の図解
- ファシリテーターの説明
- 実際に自分で手を動かして試したこと
- 映像や道具などの視覚的な工夫
- その他（下の欄にご記入ください）
- Other...

ワークショップで配布されたパンフレット（作り方の説明書）を使って、ご家庭でも同じような工作をすると思いますか？

- ぜひやってみたい
- たぶんやると思う
- どちらともいえない
- あまりやらないと思う
- やらないと思う

今回のように「アートを通して科学を学ぶ」形式のワークショップが、今後別の内容で開催される場合ーー

	とてもそう思う	まあまあそう...	どちらともい...	あまりそう思...	まったくそう...
また参加した...					
他のご家庭や...					

(任意)その他にご意見やご感想がございましたら、こちらにご自由にお書きください！

Long answer text

Figure C.9 WS4 Post-Questionnaire Page 3 (Parents)