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Integrating Project-Based Learning and Community Outreach for Science Communication: A Case Study in the Chemistry Project Course.

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Abstract: Integrating Project-Based Learning and Community Outreach for Science Communication "A Case Study in the Chemistry Project Course." 21st century chemistry education requires students to master scientific concepts while developing science communication skills relevant to societal needs. However, the gap between theoretical classroom learning and its real-world application remains a significant educational challenge. This study aims to explore the implementation of the Project-Based Learning–Exhibition-Based Community Outreach (PjBL-ECO) model to enhance students' content mastery and science communication skills. This research employed a qualitative approach with a case study design involving Tadris Kimia students enrolled in the Chemistry Project course. Data were collected through participant observation, in-depth interviews, documentation, and students' written reflections. The data were analyzed using thematic analysis to identify patterns of meaning emerging from participants' experiences. The findings revealed three major themes: the transformation of conceptual understanding through authentic experiences, the negotiation of meaning in science communication, and the development of professional identity and social awareness. These findings reflect a dialogic, reflective, and contextual learning process within academic and community settings. The study confirms that the PjBL-ECO model strengthens constructivist learning and science communication while supporting innovative curriculum development and enhancing public scientific literacy.

Keywords: Project-Based Learning, science communication, qualitative case study, chemistry education, community outreach..

Abstrak:Integrasi Model Pembelajaran Project-Based Learning Exhibition Based Community Outreach (PjBL-ECO)Untuk Komunikasi Sains : Studi Kasus Pada Matakuliah Chemistry Project. *Pendidikan kimia abad ke-21 menuntut mahasiswa menguasai konsep ilmiah sekaligus memiliki keterampilan komunikasi sains yang relevan dengan kebutuhan masyarakat. Namun, kesenjangan antara pembelajaran teoritis di kelas dan penerapannya dalam kehidupan nyata masih menjadi tantangan untuk mahasiswa calon guru kimia. Penelitian ini bertujuan mengeksplorasi implementasi model Project-Based Learning–Exhibition-Based Community Outreach (PjBL-ECO) untuk meningkatkan penguasaan konsep dan keterampilan komunikasi sains mahasiswa. Penelitian ini menggunakan pendekatan kualitatif dengan desain studi kasus pada mahasiswa Tadris Kimia yang mengikuti mata kuliah Chemistry Project. Data dikumpulkan melalui observasi partisipatif, wawancara mendalam, dokumentasi, dan refleksi tertulis mahasiswa. Selanjutnya, data dianalisis menggunakan teknik analisis tematik untuk mengidentifikasi pola makna yang muncul dari pengalaman partisipan. Hasil penelitian mengungkapkan adanya yaitu transformasi pemahaman konseptual melalui pengalaman langsung, negosiasi makna dalam komunikasi sains, serta pembentukan identitas* *profesional dan kesadaran sosial mahasiswa calon guru kimia, hal ini mencerminkan proses pembelajaran yang dialogis, reflektif, dan kontekstual dalam lingkungan akademik dan masyarakat. Temuan ini menegaskan bahwa model PjBL-ECO berkontribusi terhadap penguatan teori konstruktivisme dan komunikasi sains dalam pendidikan kimia. Secara praktis, model ini relevan untuk pengembangan kurikulum inovatif serta peningkatan literasi sains mahasiswa dan masyarakat. Selain itu, pendekatan ini membuka peluang integrasi pembelajaran berbasis proyek dengan kegiatan pengabdian masyarakat dalam pendidikan tinggi.*

***Kata Kunci**: Project-Based Learning, Exhibition, community outreach, komunikasi sains, studi kasus kualitatif, pendidikan kimia,.*

▪ INTRODUCTION

Food safety is a strategic issue of global concern, including in Indonesia, as it directly relates to public health and well-being. The use of hazardous preservatives such as borax and formaldehyde in food products reflects a gap between scientific advancement and the level of public scientific literacy. In this context, communities are often in a vulnerable position due to their limited ability to identify chemical risks in daily life. This phenomenon underscores the importance of science education that focuses not only on conceptual mastery but also on contextual science communication skills.

In higher education, chemistry education students mostly learn through cognitive approaches. These approaches focus on theoretical understanding rather than application. Nevertheless, science communication skills are essential for facing 21st-century challenges. Preliminary observations in the Chemistry Project course show a notable gap. Students have good conceptual knowledge but struggle to simplify scientific information. They find it hard to communicate complex ideas to the general public. This challenge reflects a broader pattern in science education. Traditional instruction rarely offers authentic experiences in public communication. As a result, students remain unprepared for real-world science dialogue.

Project-Based Learning (PjBL) is considered an effective approach to address this issue. This model enables students to gain authentic learning experiences, increase engagement, and deepen conceptual understanding. Numerous studies have shown that PjBL can enhance scientific literacy, critical thinking skills, and collaborative abilities (Zulyusri et al., 2023; Hindun et al., 2024). Moreover, integrating local contexts into project-based learning has proven effective in improving students' science communication skills (Syahdani & Tyas, 2025).

Nevertheless, most previous studies have focused on quantitative measurements of learning outcomes and have not extensively explored students' experiences in communicating science to the public. The dimensions of experience, social interaction, and meaning-making in learning are important aspects of comprehensively understanding the effectiveness of learning models. This gap indicates the need for a qualitative approach to explore the learning process more deeply.

In this context, the integration of Project-Based Learning with Exhibition-Based Community Outreach (PjBL-ECO) represents a relevant and contextual pedagogical innovation. This model allows students not only to develop scientific projects but also to disseminate their results through educational exhibitions to the community. This approach aligns with the principles of contextual learning and experiential learning, which emphasize direct involvement in real-world situations.

Based on the above explanation, this study aims to describe the implementation of the PjBL-ECO model in the Chemistry Project course. It also analyzes students' conceptual understanding in the context of detecting food preservatives and explores their science communication skills. A case study approach was used to gain a deep and contextual understanding of the learning process. Theoretically, this study is expected to enrich the field of chemistry education, particularly regarding the integration of project-based learning and science communication. Practically, the findings are expected to serve as a reference for developing innovative learning models relevant to societal needs.

▪ METHOD

This study used a qualitative approach with a case study design (Yin, 2018). Research design choices fundamentally shape qualitative study outcomes. Creswell and Creswell (2018) provided updated guidance for case study methodology. Their work emphasizes rigorous data collection and analysis procedures. This study adopted a qualitative case study design accordingly. Data were gathered through multiple techniques including interviews and observations. Thematic analysis followed systematic phases as recommended. This methodological rigor ensured trustworthy and credible findings. This approach was chosen to deeply understand the PjBL-ECO model implementation. A case study allows holistic exploration of educational phenomena in natural contexts (Creswell & Poth, 2018; Stake, 2006). Researchers can uncover student learning experiences and social interaction dynamics. The design also enables deep contextual analysis of innovative chemistry education practices. This approach aligns with educational research emphasizing process understanding and meaning-making. It does not merely focus on measuring learning outcomes (Merriam & Tisdell, 2016). Thus, the qualitative case study provides a strong scientific foundation. It interprets learning phenomena reflectively and comprehensively.

Chemistry Education Program. Learning activities took place in the Chemistry Project course. Community outreach activities were carried out at SMA Negeri 1 Sungayang. This school served as an educational partner. The research context focused on project-based learning about food safety issues. Students used local materials like turmeric and purple cabbage. These served as natural indicators to detect borax and formaldehyde. This location was chosen based on its alignment with research goals. Access for in-depth observation and data collection was also considered (Patton, 2015).

Participants were selected using a purposive sampling technique (Patton, 2015). This technique matched specific criteria relevant to the research objectives. It also allowed researchers to obtain relevant informants with direct experience (Palinkas et al., 2015). The main participants of this study were 15 Chemistry Education students enrolled in the Chemistry Project course. For the community outreach component, SMA Negeri 1 Sungayang served as a partner school. Two chemistry teachers from this school acted as educational partners. Additionally, 30 high school students participated as respondents to enrich perspectives (Flick, 2018). Inclusion criteria required active attendance in the course and full project participation. Students also needed to join the educational exhibition and provide informed consent voluntarily (Creswell, 2014).

To protect participant anonymity and facilitate data tracking, each student participant was assigned a unique identification code. The coding format consisted of the data source type, the word "Student," a sequential number, and the participant's gender. For example, the code (Interview, Student 07, Female) indicates an interview quote from female participant number 07. The numbers assigned (ranging from 03 to 26) were randomly generated and do not represent the total number of participants. A total of 15 unique codes were assigned to the 15 student participants. This coding system was consistently applied across interviews, questionnaires, and written reflections. High school student respondents were coded separately using the label "High School Student" followed by a unique code (e.g., HS-03, Female) to distinguish them from the main participants.

The research procedure consisted of four systematic stages (Creswell, 2014). The first stage was planning. Researchers designed project-based learning integrated with community outreach. The main focus was on food safety issues. The second stage was project implementation. Students conducted laboratory projects using local natural indicators. These indicators detected borax and formaldehyde in food samples. The third stage was exhibition and community education. Students presented their projects through educational outreach at the partner school. The fourth stage was reflection. Researchers and students evaluated learning experiences and science communication processes. Community responses to the exhibition activities were also assessed. These four stages ensured systematic learning aligned with research goals (Kolb, 2015).

Data collection used multiple techniques or triangulation (Flick, 2018; Denzin & Lincoln, 2018). It continued until data saturation was achieved. First, participatory observation was conducted. Researchers directly observed learning activities and exhibitions systematically (Spradley, 2016). Second, semi-structured in-depth interviews were performed. Interviews explored experiences, perceptions, and reflections of participants (Kvale & Brinkmann, 2015). Each interview lasted 30 to 60 minutes and was recorded with consent. Third, document analysis was used. Researchers analyzed project reports, educational media, and written reflections (Bowen, 2009). Fourth, open-ended questionnaires collected written responses from students and teachers. Fifth, visual documentation included photos and videos. This provided authentic empirical evidence to support findings (Harper, 2012).

Data analysis followed thematic analysis based on six phases by Braun and Clarke (2006). First, data familiarization was performed through repeated reading of transcripts and reflections. Second, initial codes were generated by identifying meaningful units systematically. Third, potential themes were searched by grouping similar codes together. Fourth, themes were reviewed to ensure internal consistency and validity. Fifth, themes were defined and named by formulating their essence clearly. Sixth, the final report was produced by presenting findings narratively with participant quotes. This iterative and reflective process allowed natural emergence of meaning patterns (Nowell et al., 2017). All themes were continuously verified through discussions with fellow researchers and participants Data trustworthiness was established using four criteria proposed by Lincoln and Guba (1985). These criteria included credibility, transferability, dependability, and confirmability. Credibility was enhanced through source triangulation, technique triangulation, and member checking. Source triangulation involved comparing data from students, partner teachers, and high school respondents. Technique triangulation combined participatory observation, in-depth interviews, documentation, and written reflections. Member checking was conducted by confirming interview summaries with all 15 student participants. This step ensured that interpretations accurately reflected their experiences. Transferability was achieved through thick description of the research context. Dependability and confirmability were maintained using a well-documented audit trail (Nowell et al., 2017). This trail included raw data, interview transcripts, coding notes, and methodological decisions.

▪ RESULT AND DISCUSSION

This study explored the PjBL-ECO model implementation in a Chemistry Project course. Data analysis produced three primary themes that emerged from participant experiences during the learning process. These findings suggest learning extends beyond simple knowledge transfer into meaning formation, identity construction, and social responsibility. The results confirm that contextual chemistry learning integrates cognitive, affective, and social dimensions holistically.

Figure 1. Students conducting food preservative detection experiments using natural indicators (turmeric and purple cabbage extract) in the laboratory.

Students demonstrated conceptual understanding changes through direct project involvement in detecting food preservatives using locally available natural materials. Students designed experiments and conducted laboratory testing independently, enabling meaningful and contextual knowledge construction. The finding supports constructivist theory and experiential learning principles, both emphasizing knowledge building through real experiences with critical reflection. Within PjBL frameworks, authentic experiences connect theory with practical application effectively. This outcome aligns with Guo et al. (2020), who found PjBL enhances conceptual understanding, while Chen and Yang (2019) and Condliffe et al. (2020) showed project-based learning increases engagement and motivation. Zulyusri et al. (2023) added that PjBL improves critical thinking skills and scientific literacy. Project-based learning in chemistry teacher education has gained significant attention recently. Bennett and Smith (2023) found that PjBL enhances pedagogical content knowledge among preservice teachers. Their research demonstrated improved student engagement and conceptual retention. This study confirms those findings through authentic community outreach experiences. Students demonstrated deeper understanding of food preservative detection methods. They also developed confidence in explaining chemistry to lay audiences. These outcomes support Bennett and Smith's (2023) conclusions about PjBL effectiveness.

Local materials such as turmeric and purple cabbage enriched student learning experiences significantly by introducing green chemistry principles and integrating local wisdom into chemistry learning activities. Consequently, learning becomes more contextual and relevant to daily life, transforming chemistry from an abstract discipline into applied science that responds to societal needs. Green chemistry principles can be integrated into project-based learning effectively. Khery and Nufida (2022) demonstrated this through local natural indicator projects. Their research showed improved student scientific literacy outcomes. This study used turmeric and purple cabbage as natural indicators. These materials align with green chemistry and local wisdom principles. Students learned to detect borax and formaldehyde without synthetic chemicals. This approach reflects Khery and Nufida's (2022) recommendations for contextual chemistry learning.

One student explained how the project deepened understanding by stating: *"Textbooks only taught me that borax and formaldehyde are dangerous. Making natural indicators from turmeric helped me truly understand their properties. Now I can explain the color changes that occur during testing"* (Interview, Student 07, Female). Another student shared a parallel experience: *" Before, borax felt abstract to me, but after this activity, I now understand what it looks like and how to detect it."* (Interview, Student 14, Female). Written reflections further confirmed this transformation. One student admitted: *"I used to memorize chemical reactions only for examinations. Now I understand why this knowledge matters. Testing market meatball samples revealed chemistry exists everywhere in daily life"* (Reflection, Student 22, Male). Another reflection highlighted: *"Making turmeric paper as a natural indicator was simple yet eye-opening. I never imagined kitchen ingredients could enable scientific testing. This project directly connected chemistry to my everyday experiences"* (Reflection, Student 10, Female).

The educational exhibition at SMA Negeri 1 Sungayang revealed important communication dynamics where students negotiated meaning when explaining science to high school students and teachers. Students faced a significant dilemma between maintaining scientific accuracy and simplifying concepts for easy audience understanding simultaneously. This process reflects science communication as dialogic, participatory, and deeply contextual in nature. The finding aligns with Fähnrich (2021), who emphasized two-way interaction importance, while Mercer-Mapstone and Kuchel (2020) showed public communication improves inclusive science explanation. Science communication requires meaningful engagement between scientists and communities. Aikenhead (2022) emphasized that effective communication involves mutual understanding and respect. This perspective aligns with community-based outreach activities. In this study, students engaged directly with high school audiences. They learned to adapt scientific language for public understanding. This process reflects Aikenhead's (2022) principles of dialogic science communication. The PjBL-ECO model facilitated such two-way interactions authentically.

Science communication for the 21st century requires new pedagogical approaches. The National Research Council (2022) outlined essential competencies for effective public engagement. These include adaptability, listening skills, and audience awareness. This study's educational exhibition addressed those competencies directly. Students practiced simplifying complex chemical concepts for high school audiences. They learned to read audience reactions and adjust explanations accordingly. This experience developed precisely the skills identified by the National Research Council (2022)

Baram-Tsabari and Lewenstein (2020) affirmed that science communication enhances public scientific literacy. These findings extend previous research by demonstrating that Exhibition-Based Community Outreach functions as knowledge dissemination and learning reflection. Science communication represents a social practice involving meaning negotiation and cultural adaptation, where the paradox between simplification and accuracy deepens student understanding of science's true essence.

Figure 2. Students presenting their project results during the educational exhibition at SMA Negeri 1 Sungayang.

One student described this communication challenge: *"Explaining borax detection to high school students required balance. I could not use terms like 'complexometric reaction.' Instead, I said the natural indicator changes color with dangerous chemicals. This was difficult but rewarding work"* (Interview, Student 05, Male). Another student emphasized audience adaptation importance: *"Initially, I explained everything using scientific language. The high school students appeared confused by my presentation. I changed my approach using everyday analogies and direct demonstrations. Their faces showed understanding. That moment taught me what science communication truly means"* (Interview, Student 18, Female).

Figure 3. High school students observing color changes in food samples during the exhibition.

Exhibition-based learning has proven effective for developing science communication skills. Widiyatmoko and Pamelasari (2024) demonstrated this through school-based science exhibitions. Their research showed increased student confidence in public presentations. This study extended those findings to chemistry education contexts. Students presented food safety information to thirty high school respondents. Questionnaire results showed 93% reported improved communication confidence. This evidence supports Widiyatmoko and Pamelasari's (2024) conclusions about exhibition effectiveness.

After the exhibition, 28 out of 30 students (93%) reported increased confidence in explaining scientific concepts publicly. Questionnaire responses reinforced these findings. One student stated: *"Good science communication requires being a good listener first. I needed to understand what the audience already knew. Only then could I decide how to explain effectively"* (Questionnaire, Student 09, Female). Another student noted: *"This experience taught me science communication is not about showing knowledge. It is about helping others understand and care about science"* (Questionnaire, Student 26, Male). A third student reflected: *"Before this exhibition, I thought science communication meant giving lectures. Now I understand it is a dialogue. I asked questions, listened carefully, and adapted my message. That is real communication"* (Questionnaire, Student 12, Female).

High school students as audience members provided positive feedback confirming improved communication effectiveness. One high school student stated: *"The university students explained everything very clearly. I previously thought chemistry was scary and difficult. Now I understand chemistry helps check food safety. I want to learn more about this subject"* (Interview, High School Student, HS-03, Female). Another high school student shared: *"I enjoyed watching the direct color changes during demonstrations. The purple cabbage solution turned from purple to green. That was amazing to see. Their explanations were easy to follow completely"* (Interview, High School Student, HS-11, Male). A third high school student expressed newfound awareness: *"Now I know borax is dangerous for human health. I will tell my parents not to buy overly shiny or long-lasting food. Thank you to the university students for teaching us this important information"* (Interview, High School Student, HS-07, Female).

Student involvement in the educational exhibition also shaped professional identity formation as prospective chemistry teachers. Direct interaction with high school students and teachers encouraged reflection on roles as future educators and agents of social change. This process confirms learning is not merely cognitive but also transformative and reflective. The finding aligns with experiential learning theory principles. Morris (2020) stated experience-based learning enhances professional readiness and pedagogical competence. Radović et al. (2021) showed authentic experiences promote communication skills, collaboration abilities, and self-confidence simultaneously. Professional identity development among preservice chemistry teachers is a complex process. Rahmawati and Ridwan (2023) found that community-based projects strengthen teacher identity formation. Their research highlighted the importance of authentic teaching experiences. This study confirmed those findings through exhibition-based community outreach. Students reported feeling like real teachers for the first time. They expressed pride and responsibility toward public science education. These emotional shifts indicate professional identity internalization, aligning with Rahmawati and Ridwan (2023).

Integrating community outreach strengthens social responsibility in teacher education because students understand chemical concepts at deeper levels while contributing to improving public scientific literacy. The social awareness formed reflects transformative education values prioritizing community empowerment. Students experienced emotional dynamics like nervousness and pride, indicating professional identity internalization through authentic community-engaged experiences.

Figure 4. Group photo of preservice chemistry teachers with high school students and teachers after the community outreach exhibition.

One student expressed this professional transformation: *"This project changed how I view myself as a future teacher. I am not someone who only teaches chemical formulas. I help people make safer food choices for their families. This responsibility feels deeply meaningful to me"* (Interview, Student 19, Female). Another student shared: *"Standing before those high school students felt different from practice. I was explaining something real and useful to real people. I felt like a genuine teacher for the first time. That feeling was incredibly powerful for me"* (Interview, Student 03, Male). A third student reflected on emotional dynamics: *"I felt very nervous before the exhibition started. What if they did not understand my explanation? What if I made a mistake publicly? But after my first explanation, nervousness turned into pride. I realized I could do this well. I could become a good teacher"* (Interview, Student 20, Female).

Questionnaire results showed 27 out of 30 students (90%) reported increased social awareness about their role in improving public scientific literacy. One student wrote: *"I never considered food safety issues in my own community before. Now I realize many people near me do not know about borax in food. As a future chemistry teacher, I have responsibility to share this knowledge widely"* (Questionnaire, Student 15, Female). Another student reflected: *"This project taught me teaching extends beyond classroom walls. Teaching means making positive differences in people's lives. I want to become that kind of teacher for my future students"* (Questionnaire, Student 08, Male). A third student added: *"I feel more confident now in multiple ways. Not only in chemistry knowledge but also in helping others understand. That is exactly what a good teacher should be able to do"* (Questionnaire, Student 04, Female).

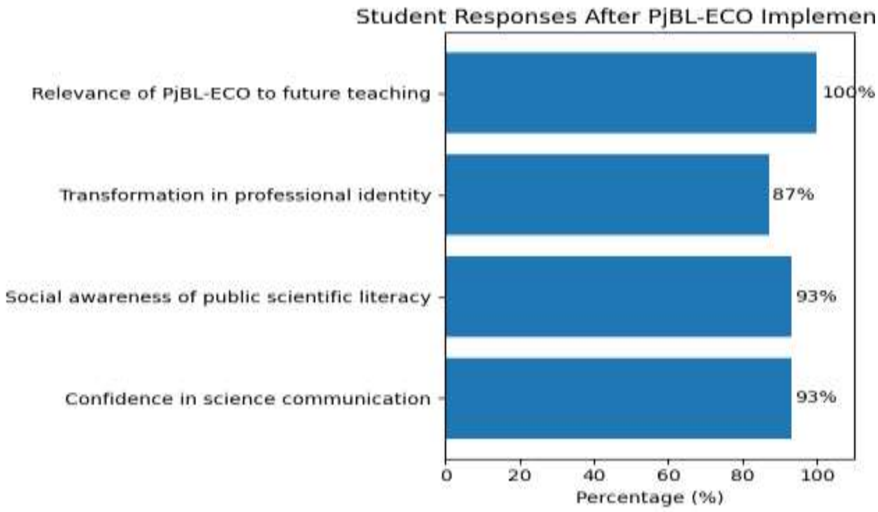

Figure 5. Graph showing percentage of students reporting positive outcomes after PjBL-ECO implementation.

This study contributes significantly to community-based chemistry education. The PjBL-ECO model offers an innovative pedagogical perspective integrating conceptual understanding with science communication skills while developing student social awareness simultaneously. Theoretically, these findings strengthen Project-Based Learning's position with science communication and experiential learning theories providing additional support. The integration of these three perspectives produces a conceptual framework positioning learning as constructive, dialogic, and transformative. The sociocultural context of West Sumatra influenced learning experiences as participants brought collectivist values and mutual cooperation culture (gotong royong) that reinforced collaboration spirit and community service motivation. The researcher served as lecturer and facilitator, providing deep contextual understanding while maintaining scientific reflexivity and objectivity. Thus, the PjBL-ECO model transforms conceptual understanding through authentic and contextual experiences. Science communication develops as a dialogic process involving meaning negotiation between students and community. Community outreach involvement shapes professional identity and social awareness of preservice chemistry teachers positively. These findings enrich chemistry education through a holistic, humanistic pedagogical approach relevant to 21st-century demands.

▪ CONCLUSION

This study identified three main meaning patterns from PjBL-ECO implementation. These patterns include conceptual understanding transformation through authentic experiences. They also include meaning negotiation in science communication activities. Finally, they cover professional identity and social awareness development among preservice chemistry teachers. These findings confirm that learning extends beyond knowledge transfer alone. Learning functions as a meaning-making process connecting science with social reality.

A key insight emerged from direct student interaction with school communities. Project-based learning integrated with educational exhibitions bridges academic and community gaps. Preservice teachers develop scientific understanding while building empathy and self-reflection. They also cultivate social responsibility through this integrated approach. This perspective enriches chemistry education by framing science communication as social practice. Such practice involves dialogue, cultural adaptation, and human value internalization.

Students experienced emotional shifts from nervousness to genuine pride. This emotional journey indicates authentic professional identity internalization. Direct community engagement triggered this transformative process meaningfully. Conceptually, these findings strengthen three theoretical frameworks together. Project-Based Learning, science communication, and experiential learning form a holistic pedagogical foundation. This foundation effectively addresses 21st-century educational demands.

Practically, this study offers concrete implications for multiple domains. Policymakers can use the PjBL-ECO model as a policy reference. Higher education policies should integrate learning, research, and community service sustainably. Curriculum developers should strengthen contextual project-based courses for preservice science teachers. Educational exhibitions also improve public scientific literacy about food safety. This approach strengthens university-community relationships through inclusive knowledge dissemination.

This study has several limitations requiring critical consideration. The research focused on a narrow regional context only. Participants came from one Chemistry Education program and one partner school. This homogeneous composition limits perspective diversity significantly. Time constraints also prevented exploration of long-term implementation impacts. Awareness of these limitations reveals reflective space for future research.

Future research should expand context and population diversity substantially. Researchers could involve various educational institutions across different regions. Mixed methods or longitudinal studies would enrich analysis depth and breadth. Unexamined aspects deserve attention in subsequent investigations. These include digital technology integration in science communication. Strengthening environmental literacy represents another promising direction. Developing local wisdom-based innovations also warrants further exploration.

Thus, this study presents empirical findings with progressive perspectives. It contributes to developing humanistic and contextual chemistry education. This conclusion serves as a conceptual reflection on science education's strategic role. Science education builds generations that are literate, critical, and globally competitive.

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