International Conference on Elementary Education
Volume 8, Nomor 1
e-ISSN: 2808-8263
p-ISSN: 2829-0976

SmartEdu-Based Science Learning to Foster Collaboration and Problem-Solving

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Abstract. This study explores the implementation of the SmartEdu application as an innovative digital platform to enhance collaboration and problem-solving skills among pre-service elementary teachers in science learning. Using a qualitative case study approach, data were gathered through observation, interviews, and document analysis to investigate how SmartEdu supports interactive and reflective learning experiences. The results reveal that the integration of SmartEdu facilitates active engagement, teamwork, and analytical reasoning, enabling students to construct knowledge through meaningful interaction and contextual exploration. Furthermore, the digital environment encourages independent inquiry and critical reflection, which strengthen students' ability to connect scientific concepts with real-life contexts. These findings indicate that SmartEdu-based science learning not only improves students' collaborative and problem-solving abilities but also nurtures deeper understanding and higher-order thinking, which are essential competencies for future educators in the 21st century.

Keywords: SmartEdu, Science Learning, Collaboration, Problem-Solving, Higher-Order Thinking.

INTRODUCTION

The transformation of education is rapidly evolving, with digitalization permeating all sectors, including higher education (Tondeur et al., 2025). The competencies developed in pre-service teachers extend beyond mere knowledge; they must also possess collaboration, problem-solving, digital literacy, and strong reflective skills (Demir & Akpinar, 2021). Learning frameworks emphasize adaptive, human-centered approaches and technology integration, which can make learning activities more engaging while providing a foundation to orchestrate learning experiences (Demir & Akpinar, 2021; Olhe Paters et al., 2024). Backfisch et al. (2020) explain that the quality of technology-based lesson plans is determined not only by teachers' professional knowledge but also significantly influenced by their motivation and perceived value of technology, suggesting that competency development must be balanced with motivational support to achieve effective learning.

Collaboration has become an essential skill today (Griffin, 2014). In teacher education, evidence-based reasoning can be enhanced through cooperation and scaffolding with problem-solving scripts; however, its effectiveness depends on group composition and appropriate guidance to ensure collaboration produces meaningful solutions (Csanadi et al., 2021). The success of technology-enhanced learning relies on a combination of individual digital literacy, collaborative dynamics, and institutional support so that active interaction and participation yield meaningful learning (Deschênes, Wise, & Kali, 2024). Moreover, collaborative learning enables adaptive monitoring, analytics, and orchestration of interactions (Kovari et al., 2024; Ouyang et al., 2023), with collaboration serving as a key component of deep learning and a current focus in curriculum development.

In the context of elementary teacher education, deep learning is a foundational approach to help pre-service teachers understand science concepts conceptually rather than procedurally. They must be able to interpret concepts, explain cause-and-effect relationships, and link knowledge structures to real-world phenomena—skills that develop through reflective and collaborative learning (Biggs & Tang, 2011; Sawyer, 2014). Given the national curriculum's emphasis on higher-order thinking skills (HOTS) and scientific inquiry in elementary science education, integrating deep learning is increasingly relevant. Literature indicates that when pre-service teachers engage in collaborative activities—such as scientific discussions, peer explanations, and co-construction of knowledge—they develop more stable conceptual understanding ready to be applied in real teaching contexts (Hernández-Sellés et al., 2019; Ouyang & Chang, 2019). This is crucial as elementary teachers are expected not only to master content but also to facilitate meaningful knowledge construction for students through inquiry-based approaches.

Furthermore, the development of technology and smart education ecosystems requires pre-service teachers to master 21st-century competencies, particularly digital collaboration and complex problem-solving. Intelligent platforms and modern learning applications demand teachers capable of utilizing data, designing collaborative activities, and promoting higher-order reasoning among students (Yang, 2024; Kovari et al., 2024). Research confirms that pre-service teachers exposed to deep learning-based instruction show improvements in problem-solving, concept transfer, and pedagogical adaptation in technology-enhanced environments (Hmelo-Silver, 2004; Kirschner et al., 2018). Recent studies also reveal that deep collaborative learning in digital environments produces novice teachers who are more reflective, creative, and able to facilitate problem-solving in elementary students (Sharma et al., 2020; Ouyang et al., 2023). Therefore, integrating deep learning, collaboration, and

e-ISSN: 2808-8263
p-ISSN: 2829-0976

problem-solving is not only theoretically relevant but a strategic necessity for preparing elementary teachers to meet current educational and technological demands.

Collaborative learning can be implemented within the SmartEdu application (Zulkarnaen et al., 2019). SmartEdu features allow pre-service teachers to interact directly with lecturers and in-field teachers in real-time (Zulkarnaen et al., 2020). The integration of collaborative learning within a technology-enabled system can enhance professional reflective skills by providing adaptive feedback that fosters critical thinking and deep reflection on teaching practices (Wei et al., 2024). SmartEdu features such as Problem, Chat (reflective), and Learning (multimedia-integrated) facilitate deep collaborative learning, proven to produce pre-service teachers who are more reflective, creative, and capable of connecting science concepts with real-world elementary student contexts (Zulkarnaen et al., 2020; Sharma et al., 2020; Ouyang et al., 2023). Thus, the synergy of deep learning, digital collaboration, and SmartEdu features positions the platform as a crucial catalyst for enhancing conceptual understanding and problem-solving abilities of pre-service elementary teachers to meet the demands of 21st-century learning.

METHODOLOGY

The qualitative approach is a research method that emphasizes an in-depth understanding of social phenomena, behaviors, experiences, or specific practices within their natural contexts. Its aim is not to produce statistical generalizations but to explore meanings, processes, and complex interactions from the participants' perspectives (Creswell & Poth, 2018). One widely used qualitative research strategy is the case study, which allows researchers to explore a phenomenon intensively within a bounded context—such as an individual, group, organization, or program (Yin, 2018). Case studies are particularly appropriate when the research questions focus on "how" or "why" a phenomenon occurs and require a holistic understanding of its context. Sampling in this study employed purposive sampling, with a total of 32 students selected from 241 based on the predetermined criteria.

In case study research, data are typically collected from multiple sources, including in-depth interviews, participant observations, documents, and other relevant artifacts (Stake, 1995). The use of data triangulation combining multiple sources or methods of data collection—enhances the validity of findings by demonstrating consistency across different perspectives (Patton, 2015). Data analysis is conducted inductively by identifying patterns, categories, themes, and relationships among data to build a comprehensive understanding of the studied phenomenon (Merriam & Tisdell, 2016). The research method flow can be seen in Figure 1.

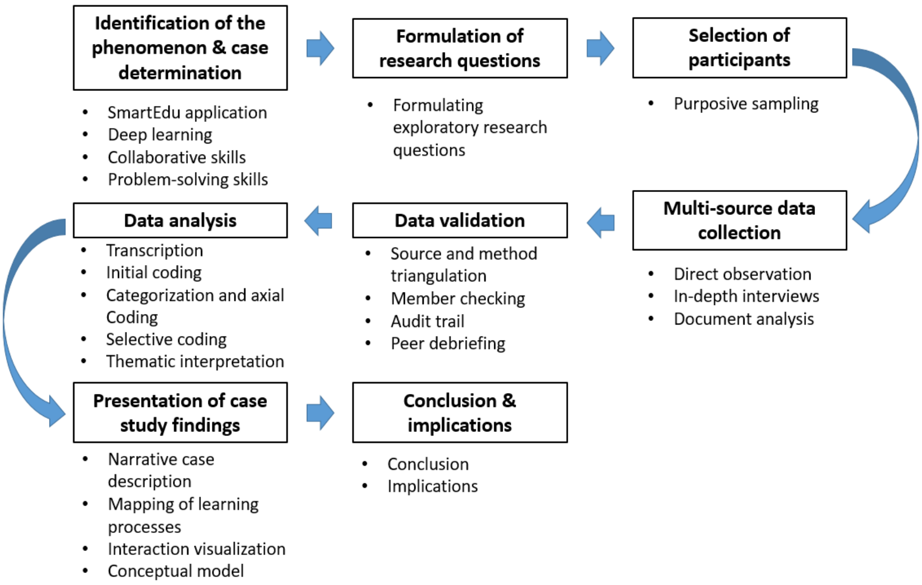


Figure 1. Research Flow Using A Qualitative Approach With A Case Study Method.

RESULTS AND DISCUSSION

This section discusses the findings of the conducted research. The discussion follows the flow of the research methodology employed, which can be seen in more detail in Figure 1. A more detailed explanation of Figure 1 is presented as follows.

1. Identification of the phenomenon & case determination

At this stage, the researcher conducted a literature review to deepen the understanding of the case variables under investigation, including the relationship between collaborative skills, problem-solving abilities, and the SmartEdu application being developed.

2. Formulation of research questions

In this section, the researchers and the research team conducted data analysis and literature review to develop the questions for the research instruments. The analysis and discussion activities related to this process are illustrated in Figure 2.

No.	Indikator Pembelajaran Mendalam	Kode	Sub indikator	Pertanyaan wawancara
1	**Pemahaman Konseptual & Konektivitas Pengetahuan**	PK1	Pemahaman konsep dasar	Bagaimana SmartEdu membantu Anda memahami konsep-konsep pembelajaran secara lebih mendalam?
2		PK2	Hubungan teori dengan praktik	Apakah Anda merasakan adanya keterhubungan antara teori yang dipelajari dengan praktik nyata melalui SmartEdu? Bisa diceritakan contohnya?
3		PK3	Konektivitas pengetahuan lama dengan baru	Sejauh mana SmartEdu membantu Anda mengaitkan pengetahuan baru dengan pengetahuan yang sudah dimiliki?
4	**Berpikir Kritis & Kreatif (Higher Order Thinking)**	BK1	Analisis masalah kritis	Bagaimana SmartEdu mendorong Anda untuk menganalisis permasalahan secara kritis?
5		BK2	Ide kreatif dan inovasi	Apakah fitur-fitur SmartEdu memfasilitasi Anda dalam mengembangkan ide-ide kreatif? Bisa Anda jelaskan?
6		BK3	Pemecahan masalah nyata	Bagaimana pengalaman Anda dalam menggunakan SmartEdu untuk mencari solusi atas permasalahan nyata?
7	**Motivasi, Kemandirian & Tanggung Jawab Belajar**	MK1	Motivasi belajar mandiri	Apakah SmartEdu meningkatkan motivasi Anda untuk belajar secara mandiri? Mengapa demikian?
8		MK2	Minat dan keterlibatan belajar	Bagaimana SmartEdu membuat proses belajar terasa lebih menarik bagi Anda?
9		MK3	Kepercayaan diri	Apakah penggunaan SmartEdu membuat Anda lebih percaya diri dalam menyampaikan ide atau hasil belajar?
10		MK4	Tanggung jawab belajar	Bagaimana SmartEdu mendorong Anda untuk lebih bertanggung jawab terhadap proses belajar Anda sendiri?
11	**Kolaborasi &**	KK1	Kolaborasi dalam	Bagaimana SmartEdu memfasilitasi Anda

No.	Indikator Pembelajaran Mendalam	No. Pernyataan	Penilai 1	Penilai 2	Penilai 3	V
1	Pemahaman Konseptual & Konektivitas Pengetahuan	1	5	4	5	0,92
2		2	5	5	4	0,92
3		4	5	5	5	1,00
4		13	5	5	4	0,92
5	Berpikir Kritis & Kreatif (Higher Order Thinking)	3	4	5	5	0,92
6		11	5	5	5	1,00
7		15	4	5	5	0,92
8		16	5	4	5	0,92
9	Motivasi, Kemandirian & Tanggung Jawab Belajar	5	5	5	5	1,00
10		6	5	4	5	0,92
11		7	5	5	4	0,92
12		8	5	5	5	1,00
13	Kolaborasi & Komunikasi	9	5	5	5	1,00
14		12	5	5	4	0,92
15	Refleksi & Evaluasi Diri	14	5	4	5	0,92
16		17	4	5	5	0,92
17		18	5	5	5	1,00
18	Integrasi Teknologi & Pemecahan Masalah Kontekstual	10	4	5	5	0,92

e-ISSN: 2808-8263
p-ISSN: 2829-0976

Figure 2. Analysis of Research Instrument Development

In Figure 2, the discussion activities and the prepared instrument are shown. Once the instrument was finalized, it underwent expert validation by three expert validators. The data from the validation process were then analyzed using the V-Aiken data processing method. Based on the data analysis, the instrument was determined to be “Valid”. The validation was conducted by three experts in accordance with their respective areas of expertise. The processed data show a value of ≥ 0.92 based on Aiken’s V table, indicating that the instrument is “Valid.”

3. **Selection of participants**

Sampling was conducted using a purposive sampling technique, involving 32 first-year students enrolled in the science education course

4. **Multi-source Data Collection**

In the 'Multi-source Data Collection' section, a discussion was conducted regarding data collection using a triangulation approach. The data were obtained from direct observations, in-depth interviews with students and lecturers, as well as an analysis of the activity logs from the SmartEdu application. Further details can be seen as follows.

Direct Observations

Direct observation was conducted to examine the learning activities occurring in the field, and an overview can be seen in Figure 3.

Figure 3. Observation of Lecture Implementation Using the SmartEdu Application

Based on Figure 3, the observation took place throughout the lecture sessions using a previously prepared observation sheet. Data analysis results indicate that an average of 95% of activities were successfully implemented, showing that "almost all learning activities were carried out successfully."

Interviews

Interviews were conducted with lecturers and pre-service teachers to obtain valid data using a source triangulation approach. The interview activities carried out are illustrated in Figure 4.

Figure 4. Interviews Conducted With Faculty And Students

Based on the interview results, data were obtained from lecturers and pre-service teachers as follows

- Faculty and students consistently stated that SmartEdu enhances collaborative skills and problem-solving abilities.
- The improvements occur through three main mechanisms:

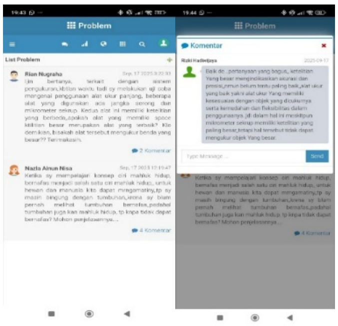
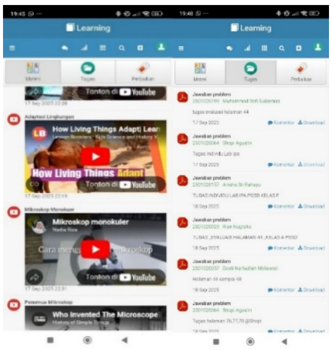
1. Structured collaboration facilitated by discussion features implemented in the chatting and problem tools.
2. Strengthening of conceptual understanding through the multi-representational learning feature.
3. Evidence-based argumentation and solution building supported by SmartEdu's digital documentation.

- Overall, the interviews indicate that SmartEdu serves as an effective facilitator in promoting deep learning, collaboration, and problem-solving among pre-service elementary teachers.

Analysis Of The Activity Logs From The Smartedu Application

Table 1. Analysis of SmartEdu Application Logs

e-ISSN: 2808-8263
p-ISSN: 2829-0976

Fiture Smartedu Applications	Explanation
	The deep learning activities within the problem feature of the SmartEdu application take place through the presentation of authentic problems that are relevant to real-world contexts, encouraging students to analyze the root of the issue, connect theory with practice, and develop alternative solutions critically and systematically. This feature enables students to collaborate with lecturers and in-field teachers through interactive discussions and feedback, ensuring that learning does not stop at conceptual understanding but progresses into in-depth inquiry that cultivates critical thinking, creativity, and reflective problem-solving skills.
	The chatting feature in SmartEdu serves as an important bridge that enables students to engage in in-depth discussions about concepts beyond scheduled class hours, allowing the learning process to extend beyond the boundaries of the formal classroom.
	The Learning feature in SmartEdu presents conceptual visualizations through interactive videos and multimodal materials that clarify and enrich students' understanding. Its flexible access allows students to learn at their own pace, revisit concepts they have not yet mastered, and connect theoretical ideas with the real-world cases presented. This variety of instructional materials not only strengthens core conceptual comprehension but also directly supports the problem-solving process, as students can analyze issues based on a more robust conceptual foundation, identify cause–effect relationships more accurately, and critically evaluate alternative solutions.

Data Reduction and Codification

This stage represents the core of qualitative analysis, aiming to filter and organize the data to make it more meaningful. Data reduction is carried out by selecting, simplifying, and abstracting information obtained from interviews, observations, and documents, allowing initially complex data to become more focused on the research objectives. This process does not arbitrarily remove data; rather, it emphasizes information relevant to answering the research questions. Subsequently, data codification is conducted by assigning labels or categories to selected data segments to identify themes, patterns, and relationships that enhance the understanding of the studied phenomenon.

Tabel 2. Matrix of Data Reduction and Codification of Questionnaire Results Based on Miles & Huberman for the SmartEdu Application in Enhancing Collaboration and Problem-Solving

Raw Data (Interview/Observation)	Data Reduction (Core Statements)	Codification (Category)	Data Display (Patterns/Relationships)	Conclusion Drawing
"I feel that the chat feature in SmartEdu allows me to ask the lecturer questions at any time, which helps me better understand difficult concepts"	Chatting facilitates lecturer–student interaction to deepen conceptual understanding	K1 – Contextual and Deep Understanding K4 – Collaboration and Communication	Students use the chat feature to clarify concepts individually	The chat feature enhances student–lecturer connectedness and supports deeper conceptual understanding.
"The problem feature encourages me to think more critically because I have to work with my peers to find solutions	The problem feature develops students' critical thinking and collaboration skills	K2 – Higher Order Thinking Skills (critical, creative, 4C)	Students actively engage in discussions and seek solutions before receiving guidance from the lecturer	The Problem feature stimulates critical, collaborative, and creative thinking skills in addressing

e-ISSN: 2808-8263
p-ISSN: 2829-0976

before the lecturer discusses them."	real-world problems

Data Validation & Analysis

Based on the results of data triangulation and the coding analysis conducted, the findings indicate that the use of SmartEdu provides clear benefits in enhancing the collaborative and problem-solving skills of pre-service elementary teachers. Through the Problem, Learning, and Chat features, students are able to analyze contextual problems more critically, connect concepts to real situations, and formulate evidence-based solutions systematically. At the same time, digital interactions facilitated by structured discussions, coordinated group tasks, and intensive academic communication strengthen effective collaboration among students. Data validation through observations, interviews, questionnaires, and application documentation confirms that SmartEdu functions as a learning ecosystem that fosters deep learning, cultivates critical and creative thinking, and develops students' ability to work together in solving authentic problems. Thus, SmartEdu is proven to be a strategic tool for developing collaborative and problem-solving competencies essential for pre-service elementary teachers in the era of digital education.

CONCLUSION

The results of the study indicate that the use of the SmartEdu application has a consistently positive impact on the learning process of pre-service elementary teachers in the science education course. Observations show that the implementation of learning activities reached 95%, indicating an optimal learning process, and that SmartEdu features, such as discussion forums in the chatting and problem tools and multi-representational conceptual content in the learning feature, effectively promote collaboration, meaning negotiation, and deep knowledge construction. These findings are reinforced by interview data, in which students reported that SmartEdu helped them better understand science concepts, collaborate more effectively, and improve their problem-solving skills. Document analysis further demonstrates increased quality of reasoning, evidence-based argumentation, and the ability to connect scientific concepts to real-world contexts. The consistency across these three data sources confirms that SmartEdu strengthens deep learning, collaboration, and problem-solving, making it a highly relevant instructional strategy.

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