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Research Trends on Socio-Scientific Issues in Chemistry Learning: A Systematic Review

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Abstract: Socio-scientific concerns have emerged as a prominent focus in contemporary chemistry education research. This study aims to analyze the trends used in socio-scientific issues in chemistry learning based on the results of research that has been carried out. This study uses a meta-analysis research design. This meta-analysis uses Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Data was acquired from the Scopus and Google Scholar databases utilizing scholarly publications from esteemed worldwide journals with the Scopus Q1-Q3 classification. Conduct an article search utilizing the title and keywords "Socio-Scientific Issues," "Socio-Scientific Issues Approach," or "Socio-Scientific Issues in Chemistry Learning," covering the last decade from 2015 to 2025. The results indicated that the database had a total of 10,982 articles, from which 35 articles were selected for examination. The results of the review found that: a) socio-scientific issues in chemistry learning have a very dominant relevance to case-based learning, namely inquiry (20.57%), PBL (10.29%) and PjBL (5.14%); b) the application of socio-scientific issues in chemistry learning is more dominant towards the aspects of argumentation, problem-solving, critical thinking and creative thinking. Consequently, the tendency in chemistry education on socio-scientific issues underscores case-based learning that prioritizes contextual difficulties.

Keywords: chemistry, learning, socio-scientific issues.

▪ INTRODUCTION

Now that we're in the 21st century, the world is getting faster and more complicated all the time. A number of shifts have taken place in the realm of information, technology, and knowledge on a worldwide scale, all with the goal of bettering contemporary society's standard of living (Dewi et al., 2019; Muntholib et al., 2020). Community members reap some benefits, but there are also some drawbacks, like increased greenhouse gas emissions, energy shortages, and environmental degradation (Aznam & Irwanto, 2021). Because of this, it's crucial for people to know how science works and how science, technology, and society are interconnected (Dewi & Rahayu, 2023).

Chemistry learning not only emphasizes understanding concepts but students are also required to be able to apply science concepts to solve problems related to science in daily life (Wiyarsi et al., 2021). So, the benefits of successful chemistry learning will be more pronounced if the learning can be applied to the reality of life (Aziz & Johari, 2023). Chemistry learning emphasizes the importance of understanding science concepts and the application of these science concepts to solve science-related problems in daily life (Arslan & Durak, 2024). Therefore, to optimize the ability to understand science issues in daily life, a learning that uses science issues is needed. Recent trends show increased attention to socio-scientific issues (SSI) (Anwar et al., 2024). SSI covers social issues that have a scientific aspect and require an understanding of science to discuss and solve them (Abrori et al., 2024). Therefore, chemistry learning that can be used is learning using socioscientific issues.

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Socio-scientific issue (SSI) is a depiction of social issues related to science in social aspects including moral, political, social, and economic that uses a scientific approach to integrating scientific concepts with the practice and construction of social knowledge (Ban & Mahmud, 2023). Socio-scientific issues (SSI) include social and controversial issues by responding to issues/problems/information/news in society and encouraging students to discuss and solve social problems related to science in social aspects, including scientific products and processes that can cause debate (Badeo & Duque, 2022; Ben-Horin et al., 2023). These topics should be present in various media sources such as articles, newspapers, brochures, advertisements, TV reports, and so on that are used to introduce the lesson plan and provoke questions and discussion (Dewi et al., 2022; Dewi & Rahayu, 2023). The topics discussed should have the potential to enable learning related to chemical content knowledge, as well as open group discussions and encourage an open decision-making process (Carroll Steward et al., 2024).

Socioscientific issues are issues that describe societal problems related to a conceptual, procedural, or technological context of science (Chen et al., 2024). The application of socioscientific issues in learning will lead students to develop solutions from various aspects of life, including aspects of science, culture, morals, and other cases (Cruz-Lorite et al., 2023). The purpose of providing an approach to socioscientific issues in science learning is to foster students to achieve decision-making (Dayan & Tsybulsky, 2024). Decision-making is important in the development of students' scientific literacy, which is the main key to making students produce solutions to problems in daily life (Friedrichsen et al., 2021; Hernández-Ramos et al., 2021).

However, there are several problems in learning socio-scientific issues, namely teachers' knowledge and understanding of SSI are still lacking (Jack et al., 2024); teachers have difficulty integrating SSI with the curriculum (Kumar et al., 2024); time limitations (Kammerer et al., 2021); Limited resources and teaching materials (Ke et al., 2021); teachers have difficulty managing discussions and debates (Koulougliotis et al., 2021); Learning focuses only on factual knowledge rather than critical thinking skills (Li & Guo, 2021). This is the reason why there hasn't been a thorough study of the social and scientific aspects of learning that can be used to improve chemistry education. This literature review is important because it can give us a well-organized look at socioscientific problems that can be used to help students learn chemistry. This review study aims to examine the trends in the instruction of socio-scientific topics within chemistry education. This review study aims to offer recommendations concerning socio-scientific topics that can be effectively integrated into chemistry education to enhance 21st-century competencies. Consequently, there is a want for effective mapping pertaining to socio-scientific concerns education that enhances 21st-century abilities, analysis, and synthesis.

This literature evaluation aims to identify the trend of integrating socio-scientific themes into chemistry education. The problem formulation from this literature review is: a) What is the relevance of socio-scientific issues in case-based learning?; b) How is the application of socio-scientific issues in chemistry learning?.

▪ METHOD

Research Design and Procedures

This study used a meta-analysis research methodology, a quantitative method that amalgamates the findings of multiple primary studies for analysis and synthesis into a cohesive outcome while proposing new focal points for future research by examining deficiencies in current analyses (Kumar et al., 2024). This meta-analysis employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to identify eligible research studies (Moher et al., 2009). Harzing's Publish or Perish program was utilized as a meta-search engine, employing three databases: Google Scholar, Scopus, and Web of Science, to identify research studies for this meta-analysis. Relevant keywords were entered into the four databases to discover qualifying research studies. Keywords like "socio-scientific issues," "Socio-Scientific Issues Approach," and "Socio-Scientific Issues in Chemistry Learning" were employed to refine the selection of research studies retrieved from the four databases. This study established predetermined qualifying criteria for selecting the most suitable research studies.

Participants

The population used in this study was 10982 articles from Scopus, Google Scholar, and Web of Science data sources. The sample used was 35 from the selection results that had been carried out. The sampling technique was based on inclusion criteria.

Study selection

The criteria utilized for inclusion in the meta-analysis studies are explained below:

1. The research must have employed SSI in chemistry education.
2. Participants must include junior high school, high school, and college students.
3. The study must regard science content learning, competency, decision-making, and reasoning as dependent variables.
4. The evaluation instruments employed in the research must possess sufficient validity and reliability.
5. There are no geographical limitations; however, the publications must be composed in English and published in peer-reviewed journals between 2015 and 2025.
6. Articles lacking complete data according to the inclusion criteria were excluded.

Data Collection

Upon finding research papers through keywords including "socio-scientific issues," "Socio-Scientific Issues Approach," and "Socio-Scientific Issues in Chemistry Learning," the cumulative amount of research studies retrieved from the three databases was 10928. Figure 1 illustrates the detailed process for selecting qualifying research studies for meta-analysis in accordance with PRISMA standards.

Identification of Data sources

In this study, a literature study was carried out by taking data from scientific articles from reputable international journals with the Scopus Q1-Q3 index. The database sources used are Scopus, Google Scholar and Web of Science with search keywords including 1) Socio-Scientific Issues, 2) Socio-Scientific Issues Approach, and 3) Socio-Scientific Issues in Chemistry Learning. Article search is limited to the last 10 years from 2015-2025. The search results for articles on database sources obtained a total of 10,982

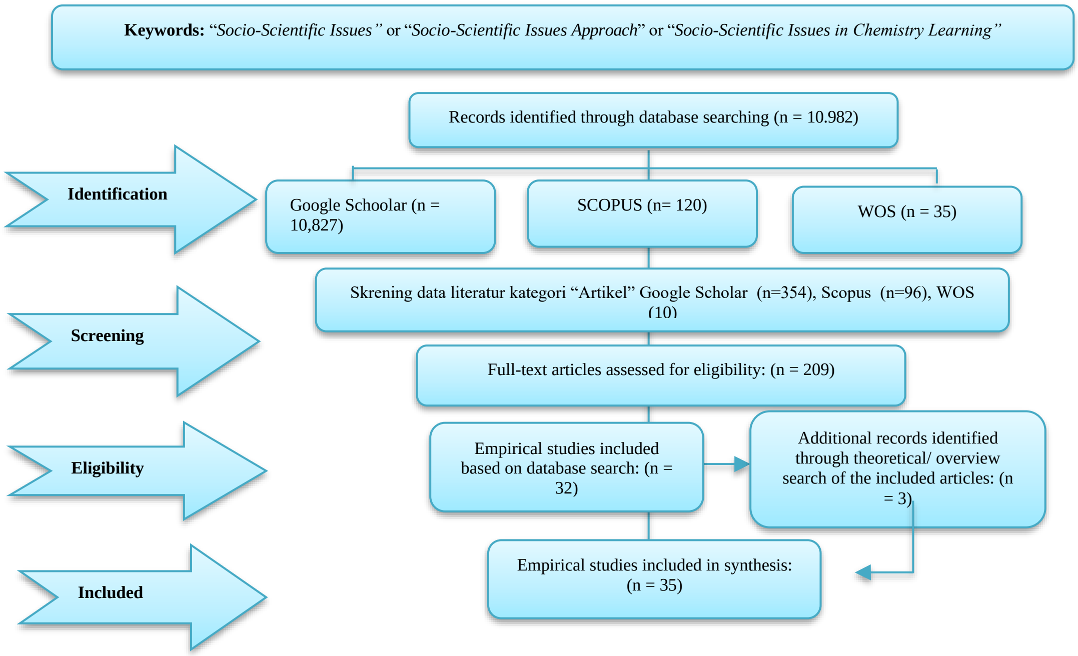

Figure1. The flowchart illustrates the mapping of the selection of relevant articles for systematic review Adoption from (Dewi & Rahayu, 2023)

articles, including those found in Scopus (n = 120), Wos (n = 20) and Google Scholar (n = 10,827). Then it was selected based on: 1) research topics, 2) research samples, 3) data collection tools, 4) type research, 5) Continental Locations of Different Countries, and 6) learning models.

Screening

The literature data screening process used the "Article" category and obtained articles on Google Scholar 354, Scopus 96 and Wos of 10. After that, a screening of the article title was carried out explicitly with the word "Socio-Scientific Issues" or "Socio-Scientific Issues Approach" or Socio-Scientific Issues in Chemistry Learning" so that 197 articles were found on Google Scholar and 62 articles on Scopus. Then, another screening was carried out by focusing on "Education Articles" and obtained as many as 161 articles on Google Scholar and 48 articles on Scopus. Furthermore, screening was carried out by focusing on the article quartile "Q1-Q3 articles" so that 32 articles were obtained on Scopus and 26 articles on Google Scholar.

Eligibility and Included

Eligibility required studies to concentrate on SSI or SSI-related topics within chemistry education contexts. Our definition of SSI and SSI-related content encompassed four essential characteristics that functioned as selection parameters. The subject examined in pertinent study must possess evident significance for future social advancements. The problem must be interdisciplinary and unstructured, incorporating a complexity of diverse elements, interests, and potential views. Third, scientific knowledge is essential for reasoning regarding the topic and making educated conclusions. Fourth, ethical viewpoints and values are intrinsic components of the decision-making process, irrespective of their explicit consideration during the student's educational experience. Only research publications authored in English were deemed eligible for inclusion in the systematic review. The research must be published in a peer-reviewed scientific journal classified as level 1, level 2, or level 3 in the Scopus scale. We incorporated studies completed in all countries.

The final stage involves reviewing the "full paper" and "eliminating duplicates" to yield 35 articles. Consequently, 35 publications were chosen for analysis in accordance with the research topic. The subsequent sections present insights from the evaluated papers, accompanied by chosen findings organized in tables for straightforward synthesis and analysis. Two researchers independently coded the articles, achieving a rater agreement of 95% due to the objective nature of the factors assessed from the text.

Data Analysis

Data analysis uses covidence software to categorize the articles analyzed according to the specified topics. In categorizing papers as chemistry-related or focused on SSI, the authors identified three study types: hypothetical or theoretical studies that outlined chemistry-focused SSI without implementation or examined the theoretical framework through existing literature; intervention studies that incorporated experimental designs and/or treatments; and descriptive studies that investigated participants' perspectives, values, argumentation skills, understanding, critical thinking, creative thinking, scientific thinking, and decision-making processes, while also assessing lesson plans and/or learning outcomes of chemistry-focused SSI. Consequently, the authors categorized the research studies into three classifications: hypothetical/theoretical, intervention, and descriptive. The authors modified the original matrix to deliver a thorough and systematic review, encompassing objectives, variables, samples/participants, chemical principles, SSI, SSI dimensions, and findings by Dewi & Rahayu (2023). They subsequently developed primary codes for each study related to the matrix and verified each code to ensure its compliance and usefulness. Subsequently, they developed secondary codes for each subject by an inductive examination of the primary codes. Consequently, overarching themes, parallels, distinctions, and distinctive characteristics of the study papers emerged. The writers methodically identified the 'relevance' components of the study papers through meticulous re-examination.

Research Validity and Reliability

The instrument used in this study is a quality assessment rubric adapted from Margot & Kettler (2019). To reduce the incidence of missing data, two chemistry educators independently categorized 259 research publications into two groups: chemistry-focused SSI and chemistry-related SSI. The inter-rater reliability was determined to be 0.87. All disputes were settled via negotiation. Moreover, a panel of experts (the authors and two chemistry educators) independently analyzed four randomly chosen research papers from the total of 35 to validate the reliability of the coding. The inter-rater consistency was determined to be 0.92, signifying full agreement in coding (MacPhail et al., 2016). Subsequently, the authors independently proceeded with the coding process and established primary codes for each study. Subsequently, they generated secondary codes through an inductive analysis of the primary codes. Furthermore, the writers verified each other's codes and affirmed their compatibility and usefulness. Subsequently, they individually examined the 'relevance' component in the research papers and subsequently reviewed each other's relevance components. This process demonstrated a high consistency rating of 0.95.

▪ RESULT AND DISSCUSSION

What is the relevance of socio-scientific issues in case-based learning?

Some themes that emerged to summarise the existing research related to the codes are the type of research, continental locations of different countries and learning models. Table 1 shows that the research trend on socio-scientific issues in chemistry learning is dominated by qualitative research types rather than quantitative and mixed-methods.

Table 1. Research types

Research types	Number of Articles	Percentage (%)
Qualitative	15	43
Quantitative	14	40
Mixed-Methods	6	17

Table 2. Continental locations of different countries

Continents	Countries
Asia	China, India, South Korea, Malaysia, Lebanon, Taiwan, Indonesia and Thailand
Europa	Denmark, Cyprus, Sweden, Turkey, UK, France, Netherlands, England, Germany, Portugal, and Greece
American	USA and Canada
Australia	Australia, New Zealand

Research on socio-scientific issues is dominated by the European continent rather than Asia, America, and Australia. The learning model applied in case-based socio-scientific issues is dominated by IBL rather than PBL and PjBL.

Table 3. Learning model

Learning Model	Number of Articles	Percentage (%)
Inquiry-Based Learning	20	57
Problem-Based Learning	10	29
Project-Based Learning	5	14

How is the application of socio-scientific issues in chemistry learning?

Several themes emerged to summarize existing research related to codes, namely data collection tools, research samples, and topic research. The data collection instruments used in measuring students' skills in learning socio-scientific issues are dominated by interviews and open-ended questions.

Table 4. Data collection tools

Data Collection Tools	Number of Articles	Percentage (%)
Interview	10	29
Open Ended Question	6	17
Questionnaire	4	11

Survey	4	11
Test	3	9
Essay	3	9
Short answer questions	2	6
Observation	2	6
Multiple Choice	1	3

Table 5. Research samples

Research Samples	Number of Articles	Percentage (%)
Middle and High School	8	23
Preservice Teacher	15	43
Undergraduate Students	12	34

The sample involved in research related to socio-scientific issues was more in preservice teachers than in undergraduate students, midlles and high schools. Research topics in learning socio-scientific issues are more dominant in argumentation than problem-solving, critical thinking and creative thinking.

Table 6. Topic research

Topic Research	Number of Articles	Percentage (%)
Argumentation	12	34
Problem-Solving	10	29
Critical Thinking	8	23
Creative Thinking	5	14

Relevance of socio-scientific issues in case-based learning

The significance of socio-scientific concerns in case-based learning is manifested in three educational models: inquiry-based learning, problem-based learning, and project-based learning. The subsequent graph illustrates the percentage significance of socio-scientific issues in case-based learning.

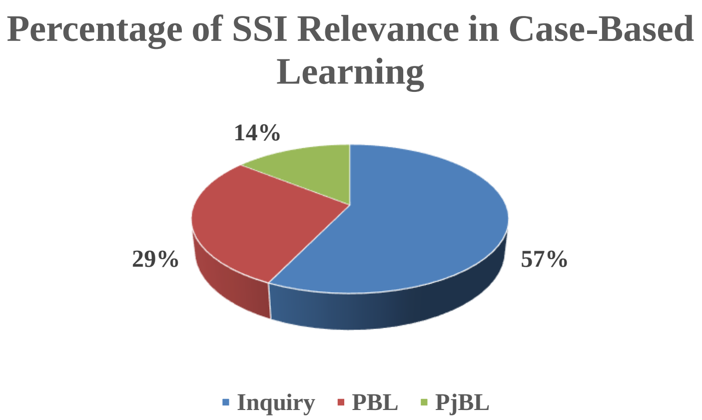

Figure 1. SSI relevance percentage in case-based learning

Graph 1 shows that the relevance of socio-scientific issues in dominant case-based learning is implemented through the inquiry learning model compared to PBL and PjBL. The inquiry-based learning model is most relevant in the context of SSI because it focuses on contemporary issues (e.g., climate change, global warming and others), uses scientific data and evidence, involves discussion and debate to understand different perspectives and can develop analytical and evaluation skills. This is because socio-scientific issues are a learning approach that involves controversial and controversial cases in society (López-Fernández et al., 2022; Muhid et al., 2020). Socio-scientific issues are questions or problems that arise from the interaction between science, technology, and society (Muis et al., 2021; Owens et al., 2021). Examples of SSI in a chemical context include issues such as environmental pollution, climate change, the use of hazardous chemicals, and ethics in scientific research. An understanding of these issues is important for students because they are often faced with day-to-day decisions that require scientific knowledge (Sakamoto et al., 2021; Shasha-Sharf & Tal, 2023). The relevance of SSI in case-based learning includes: real cases in daily life, involving scientific thinking and scientific procedures in solving problems (Anthonysamy, 2021; Sanchez et al., 2024).

Case-based learning is an active pedagogical approach that positions students at the core of the educational environment, necessitating their active engagement in the classroom and the construction of knowledge via the resolution of assigned cases (Dewi & Rahayu, 2023). Case-based learning is an educational model variant closely associated with Inquiry-Based Learning, Problem-Based Learning, and Project Learning, all integrated within the Active Learning framework (Dewi et al., 2022). The following is presented the syntax of CBL learning in Table 7.

Table 7. CBL type syntax in chemistry learning

Type CBL	**Sintax of Type CBL**
IBL	1. Formulating the Problem The formulation of the problem includes what questions need to be answered in relation to the problem being asked. 2. Collecting Data Students are asked to find supporting data to prove a hypothesis through experimental methods. 3. Drawing conclusions & Interpreting data A conclusion is drawn when the evidentiary steps are taken and the conclusions reached are communicated to the students (Chu et al., 2021; Morsink et al., 2021).
PjBL	1. Prepare a project question or assignment Questions should encourage students to complete an activity or project. 2. Design or make plans for projects The plan includes the supporting activities that will be carried out as well as the tools and materials that will help complete the project. 3. Prepare a schedule for the implementation of project completion Activities at this stage: (a) setting a schedule; (b) determine the final goal (deadline) of project completion; (c) planning new solutions; (d) explain why the new method was chosen. 4. Monitor project activities and progress Teachers are responsible for observing student activity during project completion. 5. Testing results

	Checking the results through presentations and project presentations. 6. Evaluate activities or experiences Review of activities and project results implemented (Chen & Yang, 2019; Ruslan et al., 2021).
PBL	1. Student orientation to problems. 2. Arrange for students to learn and discuss. 3. Guiding student investigations individually and in groups. 4. Analyze and evaluate the problem-solving process. 5. Create and present work results (García-Ponce et al., 2021; Veale et al., 2018).

Table 7 illustrates that the implementation of SSI in case-based learning within chemistry education encompasses:

1. Inquiry (IBL)

Inquiry emphasizes the educational process via empirical investigation, encompassing information retrieval, question formulation, and the examination of environmental occurrences to derive concepts or principles (Subiantoro et al., 2021; Subiantoro & Treagust, 2021). The inquiry learning model's strength lies in its focus on enhancing cognitive, affective, and psychomotor dimensions, fostering meaningful learning experiences while accommodating diverse learning styles. This approach facilitates the evolution of student learning psychology through behavioral changes driven by experiential learning (Darwis et al., 2021; Madhuri & Goteti, 2022; Morsink et al., 2021; Tsivitanidou et al., 2021; Vilardo et al., 2017).

2. Problem-Based Learning (PBL)

The PBL learning approach is predicated on the notion that challenges serve as a catalyst for acquiring or integrating new knowledge (Marra et al., 2022). According to cognitive psychology, three principles of learning pertinent to Problem-Based Learning (PBL) are: (1) Learning is a constructive process rather than just acceptance, (2) metacognition involves awareness of one's own knowledge, and (3) contextual and social elements significantly affect learning (Rivas et al., 2022). The principal attributes of problem-based learning encompass: (1) a focus on real-world problems, (2) the resolution of authentic issues that students may encounter in the future, (3) a knowledge framework organized around these problems, (4) student accountability for their own learning journey, (5) active engagement in the educational process, (6) the reinforcement of existing knowledge to facilitate the construction of new insights, (7) acquisition of knowledge within a meaningful context, and (8) opportunities for students to enhance and structure their understanding (Discipulo & Bautista, 2022) & (Stern & Hertel, 2022).

The PBL learning model is developed from constructivism, emphasizing student activities in building knowledge (Saleh et al., 2022). Learning with a constructivist approach is very relevant to the way of thinking, acting, and scientific inquiry (Pradini et al., 2022). Therefore, this PBL learning model is considered very relevant to SSI because it emphasizes student activities in conducting investigations that are oriented to solve problems (Vellanki et al., 2022). Such activities help develop higher-order thinking skills including problem-solving skills in students (Farid et al., 2022). Findings to Saleh et al. (2022) shows that learning with the PBL model taught to students with low academic ability and high academic ability can improve the meaningful learning process, will be followed by material that is remembered for a longer time. Exercises for problem-solving are one of the efforts to empower metacognitive skills (Stebner et al., 2022). Some researchers concluded that the effectiveness of PBL models can train metacognitive skills (Dwi et al., 2022), can improve problem-solving, critical thinking and retention skills (Palennari, 2016) & (Palennari et al., 2018), Potentially training students' metacognitive skills and conceptual understanding (Buku et al., 2016), can empower critical thinking skills which in turn improve student learning outcomes and retention (Adiansyah et al., 2021).

The advantages of PBL are encouraging students to discover new knowledge, supporting knowledge transfer to understand real-world problems, and developing students' critical thinking skills (Alt & Raichel, 2022; Mann et al., 2021; Shasha-Sharf & Tal, 2023). The PBL model's disadvantage lies in students' frequent struggle to identify problems appropriate to their cognitive level. Additionally, PBL requires more time than traditional learning methods, and students often encounter challenges as they must learn to gather data, analyze information, formulate hypotheses, and resolve issues (Haryani et al., 2018).

3. *Project-Based Learning (PjBL)*

The project-based learning model (PjBL) is a novel educational approach that emphasizes concepts engaging students in problem-solving and other significant activities (Rosas-Melendez, 2019). In the Project Based Learning learning model, the learning activities take place cooperatively in heterogeneous groups (Çelik et al., 2018). Because the nature of the project work is in groups, the development of learning skills takes place among students, which means that there is an activity between students and each other (Bressiani, 2020). These activities are in the form of findings in the skills of planning, organizing and designing tasks to be done, which can ultimately strengthen the overall teamwork (Turek, 2016). Through this learning model, students get a real learning experience because students can develop critical thinking patterns and make decisions in solving a newly discovered task/problem (Lu, 2021).

The focus on real-world issues in activities is the key learning mechanism in project-based learning (Miller et al., 2021). The benefits of project-based learning include fostering logical reasoning in problem-solving, cultivating the ability to formulate hypotheses, enhancing critical and contextual thinking for real-world issues, developing skills to conduct experiments for hypothesis validation, and improving decision-making regarding problem-solving strategies (Muhariyansah et al., 2021; Wayan Santyasa et al., 2021). The drawbacks of Project-Based Learning (PjBL) include its significant demands on time and financial resources, the necessity for extensive media and educational materials, the requirement for both educators and learners to be prepared for engagement and growth, and the apprehension that students may focus exclusively on a singular topic of study (Ruslan et al., 2021) & (Payoungkiattikun et al., 2022).

Application of socio-scientific issues in chemistry learning

Socio-scientific issues in chemistry learning are effectively applied in improving 21st-century skills by involving several important aspects in the chemistry learning process, namely scientific thinking, critical thinking, argumentation, problem-solving, and creative thinking. The following is a graph of the percentage of 21st-century skill aspects in the application of SSI.

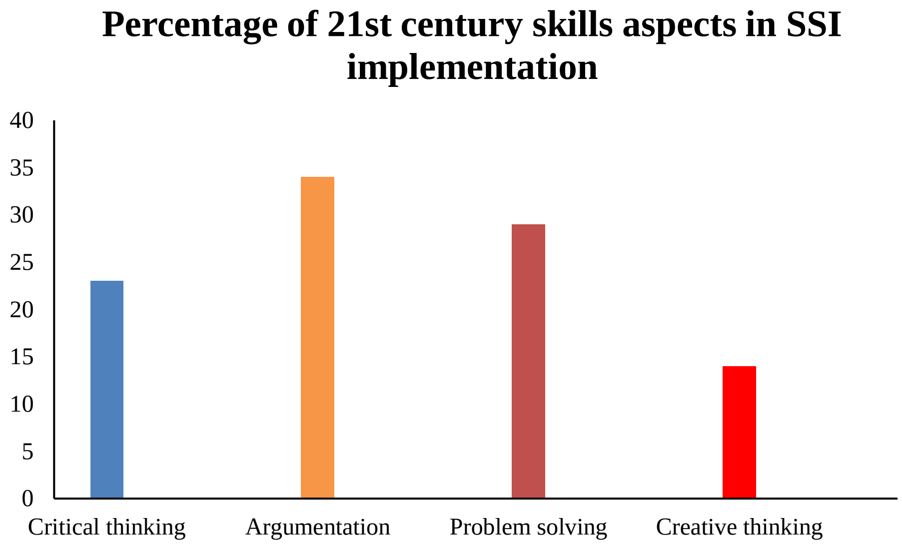

Figure 2. Percentage of 21st century skills aspects in SSI application

Graph 2 shows that the dominant aspects involved in the application of socio-scientific issues in chemistry learning to improve 21st-century skills are argumentation versus problem-solving, critical thinking and creative thinking. The application of SSI is more dominant in influencing students' argumentation because it can train students to defend opinions and respond to various criticisms by combining scientific concepts with social contexts in the form of contemporary issues that require data analysis, evidence evaluation and argument development so that students understand the impact of science on society. This indicates that socio-scientific issues in chemistry learning are oriented as experiences in the process of forming 21st-century skills. This experience is referred to as regulation in the formation of 21st-century skills (Sulistina & Hasanah, 2024; Tal & Ginosar, 2024). Several skills regulations need to be emphasized including understanding phenomena, connecting relevant concepts, conducting investigative activities, interpreting results and connecting with real problem-solving situations in life (Listiana et al., 2016; Suriyon et al., 2013b). According to research conducted by Suriyon et al., (2013a) 21st-century skills can be formed when students are given information by using real cases in daily life in the form of questions or tasks, then the aspects that play a lot in determining their regulation are skills in the 21st century, namely scientific thinking, reasoning, critical thinking and problem-solving. This means that self-regulation in receiving information and good learning is correlated with 21st-century skills (Wahono et al., 2021).

In Chemistry learning is not only teaching theoretical concepts and formulas but must also involve an understanding of social issues related to science. The socio-scientific issues (SSI) approach in chemistry learning aims to develop critical thinking skills, scientific thinking, reasoning, creative thinking, problem-solving and awareness of the ethical and social implications of science. However, the implementation of SSI in the context of chemistry education faces various challenges. Here are some of the key challenges to look out for:

1. Limitations of Teachers' Knowledge

One of the main challenges in the application of SSI in chemistry learning is the limited knowledge of teachers about social issues relevant to chemistry (Wiyarsi et al., 2021). Many chemistry teachers focus more on technical and academic aspects than on associating subject matter with social issues. This lack of understanding can hinder their ability to integrate SSI in chemistry teaching (Wiyarsi et al., 2024).

2. Lack of Resources and Learning Materials

Adequate resources are the key to success in SSI implementation. However, many schools still do not have access to teaching materials that support social-scientific problem-based learning (Wu & Yang, 2024). In addition, the lack of references or textbooks that discuss the relationship between chemistry and social issues makes the teaching process less effective (Fadly et al., 2022).

3. Challenges in Designing a Curriculum

Designing a curriculum that integrates SSI into chemistry learning is also a challenge (Saija et al., 2022). Curricula are often tightly structured, making it difficult to include dynamic and evolving social issues (Balgopal et al., 2017). Teachers need to adapt and design relevant learning activities, but this requires extra time and effort.

4. Resistance from Students

Students who are accustomed to traditional learning methods may find themselves disinterested or even reject SSI-based approaches (Leung, 2022). They may feel that social issues are irrelevant to the chemistry lessons they are studying (Badeo & Duque, 2022). Therefore, teachers must be able to explain the importance of SSI and how it can improve their understanding of chemistry and its impact in daily life.

5. Time Constraints

The implementation of SSI requires more time for in-depth discussion and critical reflection. However, many teachers face time constraints in a dense curriculum. This causes them to feel pressured to stick to a schedule without considering the social aspects that may be very important in the context of chemistry learning (Badeo & Duque, 2022; Rahayu, 2019).

6. Appropriate Learning Evaluation

Assessing a student's understanding of SSI can also be challenging. Traditional evaluation methods often do not include the aspects of mastering critical thinking skills, scientific thinking, argumentation, creative thinking, problem-solving and social awareness to be achieved (Balgopal et al., 2017). Teachers need to look for alternative assessment methods that can evaluate students' ability to apply scientific knowledge to social issues (Badeo & Duque, 2022).

Research Implications

The implications of this research for teachers are that they can provide insights into developing effective teaching skills, increasing knowledge about current socio-scientific issues, developing the ability to facilitate discussion and debate, improving the ability to integrate disciplines, developing the ability to measure students' critical thinking or argumentation skills, improving the ability to develop relevant curricula and developing the ability to cooperate with the community. The implications for students are that they can increase awareness and understanding of socio-scientific issues, develop critical and analytical thinking skills, improve argumentation and communication skills, develop complex problem-solving skills, increase curiosity and motivation to learn, develop cooperation and collaboration skills, increase awareness of social and environmental responsibility.

▪ CONCLUSION

A systematic review of the literature revealed that socio-scientific issues in chemistry education are significantly relevant to case-based learning methodologies, specifically inquiry-based learning, project-based learning (PBL), and project-based inquiry learning (PjBL). Furthermore, the application of socio-scientific issues in chemistry education predominantly enhances argumentation, problem-solving, critical thinking, and creative thinking skills. This study implies that it provides information and opportunities for educators and researchers to learn socio-scientific issues in chemistry learning that can effectively improve 21st-century skills in chemistry learning. Although there are various challenges in the implementation of socio-scientific issues in chemistry learning, efforts to integrate them are very important. By overcoming knowledge limitations, providing sufficient resources, and designing a flexible curriculum, teachers can create a more relevant and rewarding learning environment. In addition to enhancing students' chemistry comprehension, this method will provide them with crucial tools to tackle societal issues in the years to come.

▪ REFERENCES

Abrori, F. M., Saimon, M., Lavicza, Z., & Anđić, B. (2024). Challenges and opportunities of training teachers to develop comics for teaching socio-scientific issues. Media Practice and Education, 25(1), 56–76.

Adiansyah, R., Corebima, A. D., Zubaidah, S., & Rohman, F. (2021). The correlation between metacognitive skills and scientific attitudes towards the retention of male and female students in South Sulawesi, Indonesia. International Journal of Evaluation and Research in Education, 10(4), 1272–1281.

Alt, D., & Raichel, N. (2022). Problem-based learning, self- and peer assessment in higher education: towards advancing lifelong learning skills. Research Papers in Education, 37(3), 370–394. https://doi.org/10.1080/02671522.2020.1849371

Anthonysamy, L. (2021). The use of metacognitive strategies for undisrupted online learning: Preparing university students in the age of pandemic. Education and Information Technologies, 26(6), 6881–6899.

Anwar, L., Alimin, M., Copriady, J., & Rery, R. U. (2024). Pre-Service chemistry teachers’ attitude of socio-scientific issues and characters as citizens. Jurnal Pendidikan IPA Indonesia, 13(3).

Arslan, H. O., & Durak, B. (2024). Pre-service science teachers' evaluations of alternative perspectives on socio-scientific issues: Stem cell and cloning technologies. Teaching and Teacher Education, 141, 104493.
Aziz, A. A., & Johari, M. (2023). The effect of argumentation about socio-scientific issues on secondary students' reasoning pattern and quality. Research in Science Education, 53(4), 771–789.
Aznam, N., & Irwanto, I. (2021). Socio-Scientific issues as a vehicle to promote soft skills and environmental awareness. European Journal of Educational Research, 10(1), 161–174.
Badeo, J. M., & Duque, D. A. (2022). The effect of socio-scientific issues (ssi) in teaching science: a meta-analysis study. Journal of Technology and Science Education, 12(2), 291–302.
Balgopal, M. M., Wallace, A. M., & Dahlberg, S. (2017). Writing from different cultural contexts: How college students frame an environmental SSI through written arguments. Journal of Research in Science Teaching, 54(2), 195–218.
Ban, S., & Mahmud, S. N. D. (2023). Research and trends in socio-scientific issues education: a content analysis of Journal Publications from 2004 to 2022. Sustainability, 15(15), 11841.
Ben-Horin, H., Kali, Y., & Tal, T. (2023). The fifth dimension in socio-scientific reasoning: Promoting decision-making about socio-scientific issues in a community. Sustainability, 15(12), 9708.
Bressiani, T. S. C. (2020). Project-based learning in the discipline waste treatment and environment: A case study. Revista Virtual de Quimica, 12(2), 356–367. https://doi.org/10.21577/1984-6835.20200028
Buku, M. N. I., Corebima, A. D., & Rohman, F. (2016). The correlation between metacognitive skills and the critical thinking skills of the senior high school students in biology learning through the implementation of problem based learning (PBL) in Malang, Indonesia. International Journal of Academic Research and Development, 1(5), 58–63.
Carroll Steward, K., Gosselin, D., Chandler, M., & Forbes, C. T. (2024). Student outcomes of teaching about socio-scientific Issues in secondary science classrooms: Applications of EzGCM. Journal of Science Education and Technology, 33(2), 195–207.
Çelik, H. C., Ertas, H., & İlhan, A. (2018). The impact of project-based learning on achievement and student views: the case of AutoCAD Programming Course. Journal of Education and Learning.
Chen, C.-H., & Yang, Y.-C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. Educational Research Review, 26, 71–81.
Chen, W., Han, Y., Tan, J., Chai, A. S. C., Lyu, Q., & Lyna. (2024). Exploring students' computer-supported collaborative argumentation with socio-scientific issues. Journal of Computer Assisted Learning, 40(6), 3324–3337.
Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). 21st century skills development through inquiry-based learning from theory to practice. Springer.

Cruz-Lorite, I. M., Cebrián-Robles, D., Acebal-Expósito, M. del C., & Evagorou, M. (2023). Analysis of the informal reasoning modes of preservice primary teachers when arguing about a socio-scientific issue on nuclear power during a role play. Sustainability, 15(5), 4291.

Darwis, D., Rachmat, I. F., & Karim, A. (2021). The effectiveness of green chemistry practicum training based on experimental inquiry to improve teachers' science process skills. Ilkogretim Online, 20(4). https://doi.org/10.17051/ilkonline.2021.04.58

Dayan, E., & Tsybulsky, D. (2024). Designing and teaching socio-scientific issues online: digital curation in the science classroom. International Journal of Science Education, 1–20.

Dewi, C. A., Habiddin, H., Dasna, I. W., & Rahayu, S. (2022). Case-Based learning (cbl) in chemistry learning: a systematic review. Jurnal Penelitian Pendidikan IPA, 8(4), 1925–1936.

Dewi, C. A., Khery, Y., & Erna, M. (2019). An ethnoscience study in chemistry learning to develop scientific literacy. Jurnal Pendidikan IPA Indonesia, 8(2), 279–287.

Dewi, C. A., & Rahayu, S. (2023). Implementation of case-based learning in science education: A systematic review. Journal of Turkish Science Education, 20(4).

Discipulo, L. G., & Bautista, R. G. (2022). Students' cognitive and metacognitive learning strategies towards hands-on science. Int J Eval & Res Educ ISSN, 2252(8822), 8822.

Dwi Hastuti, I., Fuster-Guillén, D., Palacios Garay, J. P., Hernández, R. M., & Namaziandost, E. (2022). The effect of problem-based learning on metacognitive ability in the conjecturing process of junior high school students. Education Research International, 2022, 1–10.

Fadly, D., Rahayu, S., Dasna, I. W., & Yahmin, Y. (2022). The effectiveness of a soie strategy using socio-scientific issues on students chemical literacy. International Journal of Instruction, 15(1), 237–258. https://doi.org/10.29333/iji.2022.15114a

Farid, Y., Beiki, M., & Rashtchi, M. (2022). The impact of incorporated task-based instruction with metacognitive activities on listening comprehension ability. International Journal of Innovation Scientific Research and Review, 4(5), 2801–2807.

Friedrichsen, P. J., Ke, L., Sadler, T. D., & Zangori, L. (2021). Enacting co-designed socio-scientific issues-based curriculum units: A case of secondary science teacher learning. Journal of Science Teacher Education, 32(1), 85–106.

García-Ponce, Á. L., Martínez-Poveda, B., Blanco-López, Á., Quesada, A. R., Suárez, F., Alonso-Carrión, F. J., & Medina, M. Á. (2021). A problem-/case-based learning approach as an useful tool for studying glycogen metabolism and its regulation. Biochemistry and Molecular Biology Education, 49(2), 236–241. https://doi.org/10.1002/bmb.21449

Haryani, S., Wijayati, N., & Kurniawan, C. (2018). Improvement of metacognitive skills and students' reasoning ability through problem-based learning. Journal of Physics: Conference Series, 983, 012174. https://doi.org/10.1088/1742-6596/983/1/012174

Hernández-Ramos, J., Pernaa, J., Cáceres-Jensen, L., & Rodríguez-Becerra, J. (2021). The effects of using socio-scientific issues and technology in problem-based learning: A systematic review. Education Sciences, 11(10), 640.

Jack, B. M., Hong, Z.-R., Lin, H., & Smith, T. J. (2024). Ecological stimuli predicting high school students' genuine interest in socio-scientific issues. Science & Education, 33(4), 831–851.

Kammerer, Y., Gottschling, S., & Bråten, I. (2021). The role of internet-specific justification beliefs in source evaluation and corroboration during web search on an unsettled socio-scientific issue. Journal of Educational Computing Research, 59(2), 342–378.

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. J. (2021). Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues. Science & Education, 30(3), 589–607.

Koulougliotis, D., Antonoglou, L., & Salta, K. (2021). Probing Greek secondary school students' awareness of green chemistry principles infused in context-based projects related to socio-scientific issues. International Journal of Science Education, 43(2), 298–313.

Kumar, V., Choudhary, S. K., & Singh, R. (2024). Environmental socio-scientific issues as contexts in developing scientific literacy in science education: A systematic literature review. Social Sciences & Humanities Open, 9, 100765.

Leung, J. S. C. (2022). Shifting the Teaching Beliefs of Preservice Science Teachers About Socioscientific Issues in a Teacher Education Course. International Journal of Science and Mathematics Education, 20(4), 659–682. https://doi.org/10.1007/s10763-021-10177-y

Li, Y., & Guo, M. (2021). Scientific literacy in communicating science and socio-scientific issues: Prospects and challenges. Frontiers in Psychology, 12, 758000.

Listiana, L., Susilo, H., Suwono, H., & Suarsini, E. (2016). Empowering students' metacognitive skills through new teaching strategy (group investigation integrated with think talk write) in biology classroom. Journal of Baltic Science Education, 15(3), 391–400. https://doi.org/10.33225/jbse/16.15.391

López-Fernández, M. del M., Gonzalez-Garcia, F., & Franco-Mariscal, A. J. (2022). How can socio-scientific issues help develop critical thinking in chemistry education? A reflection on the problem of plastics. Journal of Chemical Education, 99(10), 3435–3442.

Lu, S. Y. (2021). Project-based learning oriented STEAM: the case of micro–bit paper-cutting lamp. International Journal of Technology and Design Education. https://doi.org/10.1007/s10798-021-09714-1

MacPhail, C., Khoza, N., Abler, L., & Ranganathan, M. (2016). Process guidelines for establishing intercoder reliability in qualitative studies. Qualitative Research, 16(2), 198–212.

Madhuri, J. V, & Goteti, L. N. S. P. (2022). Using virtual laboratories in Chemistry through guided inquiry-based approach. Journal of Positive School Psychology, 6(2), 369–374.

Mann, L., Chang, R., Chandrasekaran, S., Coddington, A., Daniel, S., Cook, E., Crossin, E., Cosson, B., Turner, J., Mazzurco, A., Dohaney, J., O'Hanlon, T., Pickering, J., Walker, S., Maclean, F., & Smith, T. D. (2021). From problem-based learning to practice-based education: a framework for shaping future engineers. European Journal of Engineering Education, 46(1), 27–47. https://doi.org/10.1080/03043797.2019.1708867

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. International Journal of STEM Education, 6(1), 1–16.

Marra, R. M., Hacker, D. J., & Plumb, C. (2022). Metacognition and the development of self-directed learning in a problem-based engineering curriculum. Journal of Engineering Education, 111(1), 137–161.

Miller, E. C., Severance, S., & Krajcik, J. (2021). Motivating teaching, sustaining change in practice: design principles for teacher learning in project-based learning contexts. Journal of Science Teacher Education, 32(7), 757–779. https://doi.org/10.1080/1046560X.2020.1864099

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group*, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of Internal Medicine, 151(4), 264–269.

Morsink, M. C., van der Valk, C. M. T., Tysma, O., van der Griendt, J. C., van Leeuwen, W. B., & van der Aar, A. (2021). Virtual labstore: a tool to facilitate inquiry-based laboratory research education. Bioscene: Journal of College Biology Teaching, 47(1), 14–28.

Muhariyansah, J., Rahmawati, A., & Fibonacci, A. (2021). Exploring Scientific Literacy of Chemistry Education Pre-Service Teachers Through Socio-Scientific Issues Approach. JTK (Jurnal Tadris Kimiya), 6(2), 243–253. https://doi.org/10.15575/jtk.v6i2.15145

Muhid, A., Amalia, E. R., Hilaliyah, H., Budiana, N., & Wajdi, M. B. N. (2020). The effect of metacognitive strategies implementation on students' reading comprehension achievement. International Journal of Instruction, 13(2), 847–862.

Muis, K. R., Chevrier, M., Denton, C. A., & Losenno, K. M. (2021). Epistemic emotions and epistemic cognition predict critical thinking about socio-scientific issues. Frontiers in Education, 6, 669908.

Muntholib, M., Ibnu, S., Rahayu, S., Fajaroh, F., Kusairi, S., & Kuswandi, B. (2020). Chemical literacy: performance of first year chemistry students on chemical kinetics. Indonesian Journal of Chemistry, 20(2), 468–482. https://doi.org/10.22146/ijc.43651

Owens, D. C., Sadler, T. D., & Friedrichsen, P. (2021). Teaching practices for enactment of socio-scientific issues instruction: An instrumental case study of an experienced biology teacher. Research in Science Education, 51(2), 375–398.

Palennari, M. (2016). Exploring the correlation between metacognition and cognitive retention of students using some biology teaching strategies. Journal of Baltic Science Education, 15(5), 617–629.

Palennari, M., Taiyeb, M., & Saenab, S. (2018). Profile of students' metacognitive skill based on their learning style. Journal of Physics: Conference Series, 1028, 012030. https://doi.org/10.1088/1742-6596/1028/1/012030

Payoungkiattikun, W., Intanin, A., Thongsuk, T., & Hemtasin, C. (2022). Project-Based learning model to promote preservice science teachers' metacognitive skills. Journal of Educational Issues, 8(2), 576–588.

Pradini, M. R., Lusiana, L., & Kesumawati, N. (2022). Problem based learning and self-regulated learning: Impact on mathematical reasoning ability in the circle material. Desimal: Jurnal Matematika, 5(3), 235–246.

Rahayu, S. (2019). Socio-scientific Issues (SSI) in chemistry education: enhancing both students' chemical literacy & transferable skills. Journal of Physics: Conference Series, 1227(1). https://doi.org/10.1088/1742-6596/1227/1/012008

Rivas, S. F., Saiz, C., & Ossa, C. (2022). Metacognitive strategies and development of critical thinking in higher education. Frontiers in Psychology, 13.

Rosas-Melendez, S. A. (2019). Project-based learning in the Chemistry Laboratory: A case of Mexico. In 2019 9th IEEE Integrated STEM Education Conference, ISEC 2019 (pp. 211–214). https://doi.org/10.1109/ISECon.2019.8881964

Ruslan, M. S. H., Bilad, M. R., Noh, M. H., & Sufian, S. (2021). Integrated project-based learning (IPBL) implementation for first year chemical engineering student: DIY hydraulic jack project. Education for Chemical Engineers, 35, 54–62.

Saija, M., Rahayu, S., Fajaroh, F., & Sumari. (2022). Enhancement of high school students' scientific literacy using local-socioscientific issues in oe3c instructional strategies. Jurnal Pendidikan IPA Indonesia, 11(1), 11–23. https://doi.org/10.15294/jpii.v11i1.33341

Sakamoto, M., Yamaguchi, E., Yamamoto, T., & Wakabayashi, K. (2021). An intervention study on students' decision-making towards consensus building on socio-scientific issues. International Journal of Science Education, 43(12), 1965–1983.

Saleh, A., Phillips, T. M., Hmelo-Silver, C. E., Glazewski, K. D., Mott, B. W., & Lester, J. C. (2022). A learning analytics approach towards understanding collaborative inquiry in a problem-based learning environment. British Journal of Educational Technology, 53(5), 1321–1342.

Sanchez, J. M., Picardal, M., Fernandez, S., & Caturza, R. R. (2024). Socio-scientific issues in focus: A meta-analytical review of strategies and outcomes in climate change science education. Science Education International, 35(2), 119–132.

Shasha-Sharf, H., & Tal, T. (2023). Energy policy as a socio-scientific issue: Argumentation in the context of economic, environmental and citizenship education. Sustainability, 15(9), 7647.

Stebner, F., Schuster, C., Weber, X.-L., Greiff, S., Leutner, D., & Wirth, J. (2022). Transfer of metacognitive skills in self-regulated learning: effects on strategy application and content knowledge acquisition. Metacognition and Learning, 1–30.

Stern, M., & Hertel, S. (2022). Relationship between maternal scaffolding and preschooler's metacognitive strategies in a problem-solving situation. Learning and Instruction, 80, 101631.

Subiantoro, A. W., & Treagust, D. F. (2021). Development and validation of an instrument for assessing high-school students' perceptions of socio-scientific issues-based learning in biology. Learning Environments Research, 24(2), 223–237.

Subiantoro, A. W., Treagust, D., & Tang, K.-S. (2021). Indonesian biology teachers' perceptions about socio-scientific issue-based biology instruction. Asia-Pacific Science Education, 7(2), 452–476.

Sulistina, O., & Hasanah, S. M. (2024). Improving chemical literacy skills: integrated socio-scientific issues content in augmented reality mobile. International Journal of Interactive Mobile Technologies, 18(5).

Suriyon, A., Inprasitha, M., & Sangaroon, K. (2013a). Contextual factors in the open approach-based mathematics classroom affecting development of students' metacognitive strategies. Sociology Mind, 3(04), 284.

Suriyon, A., Inprasitha, M., & Sangaroon, K. (2013b). Students' metacognitive strategies in the mathematics classroom using open approach. Psychology, 4(07), 585.

Tal, T., & Ginosar, A. (2024). Wild boars in the streets: applying a socio-scientific issue framework to analyze news items. International Journal of Science Education, Part B, 14(3), 367–382.

Tsivitanidou, O. E., Georgiou, Y., & Ioannou, A. (2021). A learning experience in inquiry-based physics with immersive virtual reality: student perceptions and an interaction effect between conceptual gains and attitudinal profiles. Journal of Science Education and Technology, 30(6), 841–861. https://doi.org/10.1007/s10956-021-09924-1

Turek, D. (2016). A project-based case study of data science education. In Data Science Journal (Vol. 15). https://doi.org/10.5334/dsj-2016-005

Veale, C. G. L., Krause, R. W. M., & Sewry, J. D. (2018). Blending problem-based learning and peer-led team learning, in an open ended 'home-grown'' pharmaceutical chemistry case study.' Chemistry Education Research and Practice, 19(1), 68–79. https://doi.org/10.1039/c7rp00180k

Vellanki, S. S., Mond, S., Khan, Z. K., & Nair, L. G. (2022). Teachers' viewpoint of metacognitive strategy instruction in listening during remote teaching in oman: challenges and strategies. International Journal of Learning, Teaching and Educational Research, 21(7), 82–106.

Vilardo, D. A., MacKenzie, A. H., & Yezierski, E. J. (2017). Using students' conceptions of air to evaluate a guided-inquiry activity classifying matter using particulate models. Journal of Chemical Education, 94(2), 206–210. https://doi.org/10.1021/acs.jchemed.5b01011

Wahono, B., Chang, C.-Y., & Khuyen, N. T. T. (2021). Teaching socio-scientific issues through integrated STEM education: an effective practical averment from Indonesian science lessons. International Journal of Science Education, 43(16), 2663–2683. https://doi.org/10.1080/09500693.2021.1983226

Wayan Santyasa, I., Agustini, K., & Eka Pratiwi, N. W. (2021). Project based e-learning and academic procrastination of students in learning chemistry. International Journal of Instruction, 14(3), 909–928. https://doi.org/10.29333/iji.2021.14353a

Wiyarsi, A., Çalik, M., Priyambodo, E., & Dina, D. (2024). Indonesian prospective teachers' scientific habits of mind: a cross-grade study in the context of local and global socio-scientific issues. Science & Education, 33(5), 1257–1283.

Wiyarsi, A., Prodjosantoso, A. K., & Nugraheni, A. R. E. (2021). Promoting students' scientific habits of mind and chemical literacy using the context of socio-scientific issues on the inquiry learning. Frontiers in Education, 6, 660495.

Wu, S.-Y., & Yang, K.-K. (2024). Influence and behavioral pattern of university students' participation in decision-making on socio-scientific issues. Research in Science & Technological Education, 42(2), 431–449.