

Integrating Socioscientific Issues into Worksheets: Enhancing Student Understanding of Chemical Kinetics

Sri Haryati¹, Erviyenni², Guspatni³, Tri Padila Rahmasari⁴, Siti Nazhifah⁵

¹ Universitas Riau, Pekanbaru, Indonesia; sri.haryati@lecturer.unri.ac.id

² Universitas Riau, Pekanbaru, Indonesia; ervi.yenni@lecturer.unri.ac.id

³ Universitas Negeri Padang, Padang, Indonesia; patni@fmipa.unp.ac.id

⁴ Universitas Riau, Pekanbaru, Indonesia; tri.padila@lecturer.unri.ac.id

⁵ Universitas Riau, Pekanbaru, Indonesia; siti.nazhifah@lecturer.unri.ac.id

ARTICLE INFO

Keywords:

Chemical Kinetics;
Socioscientific Issues;
Worksheet

Article history:

Received 2025-01-05

Revised 2025-04-29

Accepted 2025-09-05

ABSTRACT

Socioscientific Issues (SSIs) are real-world topics that integrate science content with societal relevance. This study aims to integrate SSIs into basic chemistry education—specifically chemical kinetics—by developing an Electronic Student Worksheet (E-LKM) that enhances conceptual understanding through contextualized issues. The E-LKM was developed using the 4D model: Define, Design, Develop, and Disseminate. The development process employed *Flip Builder* software to create an interactive, digital format that simulates an engaging e-book. Expert validation was conducted with two subject-matter experts through construct validation. Revisions were made based on detailed feedback. A small-scale trial was also conducted involving 13 students to assess usability and comprehensibility. Validation results indicated strong validity, with scores of 0.90 (content aspect) and 0.91 (media aspect). The trial revealed the need for clearer, more accessible language. Revisions included the integration of contextual news and simplified explanations to enhance student comprehension. The final version of the E-LKM successfully aligned with SSI syntax and pedagogical principles. The validated E-LKM effectively supports the teaching of chemical kinetics by engaging students with relevant, real-life issues. The integration of SSIs through interactive media fosters critical thinking and contextual learning. The findings confirm that the developed E-LKM can serve as an effective instructional tool in SSI-based chemistry education.

This is an open access article under the [CC BY-NC-SA](https://creativecommons.org/licenses/by-nc-sa/4.0/) license.



Corresponding Author:

Sri Haryati

Universitas Riau, Pekanbaru, Indonesia; sri.haryati@lecturer.unri.ac.id

1. INTRODUCTION

Learning is the core activity of the entire educational process in higher education, and the quality of learning outcomes is a key indicator of educational success. These outcomes are significantly influenced by the quality of the learning process itself (Dalaila et al., 2022; Hidayatullah et al., 2023; Kadi & Awwaliyah, 2017). As institutions that prepare students to meet the demands of the 21st century, universities are expected to produce graduates who possess not only academic knowledge but also a

broad range of competencies. These include six basic literacy skills—reading and writing, numeracy, science, digital, financial, cultural, and civic—and the 4C competencies: critical thinking, collaboration, communication, and creativity (Cahyadi, 2019).

Among these competencies, scientific literacy stands out as a critical skill that empowers individuals to make informed decisions based on evidence and reasoned judgment. A scientifically literate population is better equipped to tackle societal challenges and improve overall quality of life (Pratiwi et al., 2016; Rundgren & Chang Rundgren, 2018). Scientific literacy encompasses both knowledge of scientific concepts and the ability to apply scientific reasoning in real-life contexts. According to the U.S. National Center for Education Statistics, it involves understanding the processes and knowledge necessary for personal and societal decision-making (Amahoroe et al., 2020). In higher education, scientific literacy is closely linked to students' comprehension of scientific concepts and reasoning abilities—particularly in chemistry (Rundgren & Chang Rundgren, 2018).

Basic chemistry courses offer a valuable opportunity to build students' scientific literacy, as they emphasize analytical problem-solving, molecular reasoning, and conceptual understanding. Designing appropriate teaching materials for these courses is essential to actively involve students in the learning process and to address the demands of 21st-century education. Effective instructional materials support deeper engagement and understanding by aligning content with students' learning needs and encouraging critical thinking, collaboration, and creativity (Sari & Yusmaita, 2022). When thoughtfully designed, such materials bridge abstract scientific concepts and real-world applications, enabling students to construct meaningful knowledge through active learning.

In this context, the integration of contextual, issue-based materials can significantly enhance students' scientific, environmental, and social literacy. Teaching materials that relate chemistry content to current societal issues—for example, environmental degradation or public health—help students connect classroom learning with real-life concerns (Salim & Prasetyo, 2018). One effective format for delivering such materials is the Electronic Student Worksheet (E-LKM). Compared to traditional worksheets, E-LKMs provide interactive features such as multimedia, simulations, hyperlinks, and real-time feedback. These tools support differentiated instruction and foster student-centered learning, making E-LKMs a valuable innovation in digital education.

A particularly relevant pedagogical strategy in this regard is the socio-scientific issues (SSI) approach. SSIs are complex, real-world issues that require students to engage in reasoning, evidence evaluation, and argumentation based on scientific principles. The approach promotes critical thinking and scientific communication while encouraging learners to view science within broader societal contexts (Rahayu, 2019; Zeidler et al., 2019). For example, topics like CO₂ emissions, plastic pollution, and chemical risks in consumer products can serve as authentic learning contexts for chemical concepts. SSI-based instruction has been shown to improve chemical literacy and transferable skills, such as evidence-based reasoning and scientific communication (Rahayu, 2019).

Given that chemical kinetics deals with phenomena directly observable in daily life, this topic provides a compelling entry point for SSI-based learning. Therefore, this study aims to develop an SSI-based Electronic Student Worksheet (E-LKM) for chemical kinetics. The objective is to enhance students' scientific literacy through contextual, interactive, and evidence-based learning materials that link chemistry to relevant societal issues.

2. METHODS

This study employed a research and development (R&D) approach aimed at producing a valid and practical learning tool in the form of a Student Activity Sheet (Lembar Kegiatan Mahasiswa or LKM) focused on chemical kinetics for use in basic chemistry courses. The development process followed the 4D model proposed by Thiagarajan, Semmel, and Semmel, which includes four systematic stages: Define, Design, Develop, and Disseminate. In some adaptations, these stages are referred to as 4P: Pendefinisian, Perancangan, Pengembangan, and Penyebaran, aligning with Indonesian terminology.

The 4D development model was selected due to its clarity, structured approach, and suitability for the creation of educational tools, particularly in the field of science education. It is widely used and proven effective for developing learning media that align with specific student needs and educational goals. Its step-by-step framework allows developers to identify learning problems, design appropriate interventions, test their effectiveness, and disseminate the final product for broader use.

This model is especially relevant when designing instructional materials that incorporate Socio-Scientific Issues (SSI), as it supports iterative refinement and validation processes. Previous studies have successfully utilized the 4D model for developing SSI-based educational tools, such as mobile learning applications (Jacinda et al., 2024) and acid-base modules (Firanti & Erna, 2024). Therefore, the 4D model was deemed appropriate for developing the SSI-based E-LKM on chemical kinetics in this study.

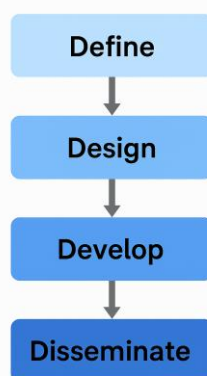


Figure 1. Stages of the 4D Development Model

The data collected in this study were descriptive qualitative data. In this study, data collection techniques included descriptive qualitative data obtained from responses on the materials of substances and their changes. In the qualitative data test, data will be presented using simple statistics to see the increase in students' abilities in learning chemical kinetics material before and after the use of LKM. The data to be presented includes the average value data after the trial.

The student worksheet developed in this study was assessed for its characteristics, validity, and practicality at Universitas Riau. The object of this study was a student worksheet based on SSIBL on the material of substances and their changes. The subjects in this study consisted of material experts, media experts, teachers, and students. The assessment aspects in the validation questionnaire of material experts, media experts, teachers, and students used the same score with the following assessment criteria. In the validation process, a research instrument is used, namely an open questionnaire addressed to the validator regarding data presentation. The purpose of using an open questionnaire is to provide freedom to the validator in commenting on the LKM created. Here are some questions asked in the validation questionnaire in Table 1.

Table 1. Questions on The Empirical Validation Questionnaire

Number	Questions	Goal
1	Are the problems presented in the LKM issues related to the material to be discussed?	SSI context
2	Can the questions in each activity guide students in learning?	LKM Activity
3	Are the sources presented able to help students find solutions to problems in this case?	Learning Source

The instrument used in this study was validated quantitatively through construct and content validity tests by two material experts and one media expert. Validity was declared very high with scores of 0.90 for the content aspect and 0.91 for the media aspect, respectively. The assessment criteria used a Likert scale of 1–4 covering content suitability, readability, understandability, and media relevance. In addition, to empirically measure the increase in student understanding, a product trial was conducted on 13 students using a simple pretest and posttest that were analyzed quantitatively descriptively. The increase in understanding was analyzed based on a comparison of the average scores before and after using E-LKM. The research design used was the 4D development model (Define, Design, Develop, Disseminate), but in this study only reached the Develop stage. The Disseminate stage has not been carried out widely due to time and research scope limitations, but is planned in further research.

3. FINDINGS AND DISCUSSION

3.1 Start-Finish Analysis

A front-end analysis was conducted to identify the challenges faced by both lecturers and students in basic chemistry courses, with particular focus on the availability and use of instructional materials for the chemical kinetics topic (Gorbi Irawan et al., 2018). Data were collected through questionnaires administered to both groups, revealing several key issues. One prominent problem reported by lecturers was the limited time available to design and prepare instructional tools. As a result, students often did not use structured learning materials such as worksheets (LKPD), and instead relied heavily on standard university textbooks, including those by Raymond Chang and Brady. To better understand students' learning needs, an open-ended questionnaire was distributed, allowing students to express their preferences and challenges related to chemistry learning. The findings from this questionnaire are presented in Table 2.

Table 2. Resume of Questionnaire "Student Needs Analysis"

Number	Respondent	Suggestion
1	Respondent A	The presentation of chemical material still uses a context that is difficult to understand. I have never found a problem that I can easily understand the solution to
2	Respondent B	So far, learning has been done using basic university chemistry books and working on practice questions.
3	Respondent C	It is difficult for me to understand chemistry material properly, especially the sub-topics that use a lot of formulas.
4	Respondent D	Maybe it would be more interesting if there was more interactive teaching media so it wasn't monotonous.

The analysis of student responses revealed several key challenges in the current chemistry learning process. Respondent A indicated that the contextual presentation of chemical material was difficult to grasp and lacked real-life relevance, making it hard to understand and solve problems effectively. Respondent B mentioned that the learning process primarily relied on traditional university textbooks and routine practice problems, which limited engagement. Respondent C expressed difficulty in comprehending the material, particularly sub-topics involving complex formulas. Meanwhile, Respondent D suggested that the learning experience could be more engaging if interactive teaching media were incorporated to reduce monotony. These responses highlight the urgent need for innovative, student-centered learning tools such as interactive, context-based E-Worksheets.

Overall, it can be seen that students suggest improvements in the basic chemistry learning process. Researchers take a solution to present chemistry learning through the presentation of questions and problem contexts that are more recent and hotly discussed. This is certainly in accordance with the SSIs approach which demands the presentation of related issues. In line with the SSIs concept put forward by Sadler (2004) that social issues with conceptual or technological ties to science have captured the

national spotlight during the recent past. By presenting issues, students will gain new learning experiences in viewing a science from various perspectives.

3.2 Student Analysis

The student analysis phase was conducted to identify learner characteristics, needs, and obstacles in understanding chemical kinetics within the basic chemistry curriculum. This analysis aimed to ensure that instructional materials are designed to align with students' cognitive levels and learning preferences. Interviews revealed that many students struggled with comprehending complex concepts—particularly those involving reaction mechanisms, rate laws, and mathematical formulas—which are central to chemical kinetics. These difficulties were largely attributed to the lack of conceptual explanations and contextualization during lessons.

Students reported that instructors often skipped foundational reviews and directly presented problem sets without clearly connecting them to prior knowledge. Additionally, teaching methods heavily relied on conventional resources, such as standard university textbooks (e.g., Raymond Chang, Brady), with minimal incorporation of interactive or real-life applications. This led to a perception of the material as abstract, monotonous, and disconnected from everyday experiences. Several students expressed that they were unable to visualize how chemical kinetics applies outside the classroom, further hindering engagement and comprehension.

The absence of student-centered learning tools and real-world relevance in the delivery of content emphasized the need for more innovative instructional strategies. These findings reinforce the importance of developing SSI-based Electronic Worksheets (E-LKM) that incorporate Socioscientific Issues-Based Learning (SSIBL). By embedding chemical kinetics topics within authentic, real-life contexts—such as environmental pollution, drug reactions, or industrial chemical processes—students are more likely to develop a deeper understanding, critical thinking skills, and scientific literacy. Such approaches also promote greater motivation and engagement by making science learning meaningful and relatable.

3.3 Task and Concept Analysis

Task analysis aims to analyze material achievements related to the main material given to students. Concept analysis aims to identify, detail, and systematically organize concepts that are relevant to learning tools. The chemical kinetics material consists of 4 indicators in 2 meetings. Based on the outcome-based education curriculum implemented at the University of Riau, the learning outcomes assigned to the chemical kinetics material in basic chemistry courses are listed in Table 3.

Table 3. Learning Outcomes of Chemistry

Subject: Basic Chemistry I		
Criteria	Learning Outcomes	Indicators
LO 1	Students are able to explain the law of reaction rates	<ul style="list-style-type: none"> Students are able to explain the law of reaction rates
LO 2	Students are able to analyze factors that influence reaction rates.	<ul style="list-style-type: none"> Students are able to explain the 4 factors of reaction rate correctly Students are able to distinguish the 4 factors that influence reaction rate
LO 3	Students can determine the reaction order	<ul style="list-style-type: none"> Students are able to explain the reaction order Students are able to determine 3 types of reaction order
LO 4	Students are able to write reaction mechanisms	<ul style="list-style-type: none"> Students are able to write reaction mechanisms

In the chemical kinetics material, there are four clearly defined learning outcomes that students are expected to achieve. These outcomes include understanding the law of reaction rates, analyzing the factors that influence reaction rates, determining the order of a chemical reaction, and constructing reaction mechanisms. Given the scope and complexity of these objectives, it was determined that the material could be effectively delivered across two separate class sessions, each focusing on different aspects of the topic. Therefore, two Student Worksheets (LKM) were developed to fully support and structure the learning process during these meetings, ensuring that each learning outcome is addressed comprehensively.

To ensure the quality and relevance of the worksheet content, the researcher conducted an in-depth review of secondary data by examining several prior studies related to chemical kinetics and the implementation of Socio-Scientific Issues (SSI) in chemistry education. These studies provided valuable references and insights into the integration of real-life issues with scientific content. However, rather than simply replicating previous work, the researcher took a more innovative approach by modifying and adapting the findings from existing research to suit the current context, target audience, and instructional objectives. These modifications included refining the learning tasks, updating the issue-based scenarios, and aligning the worksheets more closely with the university's outcome-based education framework, ultimately enhancing both the instructional quality and student engagement. According to Rery & Rahmasari (2023) the material that is very appropriate to the presentation of the issue is the subtopic on factors that affect reaction rates. Therefore, a new analysis was prepared regarding the issues that will be presented in the worksheet that will be developed, as shown in Table 4.

Table 4. Framework issues for the chemical kinetics topic.

Number	Sub-topic	Issue
1	Concentration factor	Murder of a police officer by his wife using gasoline
2	Temperature and surface area factor	Frozen food can cause diabetes
5	Reaction order and mechanism	Alcohol consumption: a teenager dies after consuming mixed liquor

3.4 Analysis of Learning Objectives

The researcher describes the objectives in accordance with the results of the concept and task analysis carried out by the researcher and then arranges them into learning objectives that are in accordance with the learning outcomes that will be applied to the learning tools. The worksheet design process begins with the preparation of the material concept, then continues with the design of the display components and applications. The results of the component display design can be seen in the table below.

Table 5. Worksheet Components

Beginning	Front Cover, Foreword, Table of Contents, Learning Instructions, Content Standards (Learning Outcomes and Learning Objectives)
Content	Introduction, Learning Activity
End	Evaluation, Glossary, and Author Biodata

The design stage of the electronic worksheet (E-LKM) was systematically carried out based on the findings gathered from the needs analysis conducted during the earlier phase of the study. This analysis provided valuable insights into student learning difficulties, preferences for interactive content, and the need for contextualized materials that could better engage learners with real-world chemistry applications. Guided by these inputs, the design process began with the careful collection and organization of core chemistry concepts relevant to the topic of chemical kinetics. These concepts were

mapped against the intended learning outcomes to ensure that the worksheet content would align with the academic curriculum and competency standards.

Following the conceptual framework, the initial draft of the E-LKM layout was created. This included selecting suitable media formats, color schemes, font types, and interface structures that would be both visually appealing and pedagogically effective. The visual and structural design of the worksheet was intended to enhance navigation, readability, and student engagement, with particular attention paid to accessibility and user-friendliness. The worksheet was developed using Microsoft Word 2019 as the primary design tool, allowing for flexible formatting and integration of multimedia components, such as images, icons, and interactive questions.

In parallel with the content and layout design, a storyboard was also constructed to provide a visual and sequential representation of the instructional flow. The storyboard helped ensure logical progression from one activity to another and served as a blueprint for the development team to visualize how each section of the worksheet would be experienced by students.

Additionally, during this design stage, a key component of the research instrument—a structured validation questionnaire—was also developed. This instrument was intended for use in the expert review phase, where the worksheet would be evaluated by subject matter experts, media experts, and end users (students and instructors). The questionnaire was designed to assess multiple aspects of the E-LKM, including content accuracy, instructional clarity, media quality, interactivity, and alignment with learning objectives. The input gathered from these validation tests would later be used to refine and finalize the worksheet prior to implementation in the classroom.

3.5 Development Results

The development of the Socio-Scientific Issues (SSI)-based electronic student worksheet (E-LKM) on chemical kinetics followed the 4D development model proposed by Thiagarajan, Semmel, and Semmel, which includes four structured stages: Define, Design, Develop, and Disseminate.

During the Define stage, a preliminary needs analysis was conducted using questionnaires and interviews involving both students and lecturers. The analysis revealed several challenges, including students' difficulties in understanding abstract concepts in chemical kinetics and the limited availability of contextual, interactive teaching materials. These findings highlighted the need for learning tools that connect chemistry concepts to real-world issues and promote student engagement.

In the Design stage, learning objectives were formulated based on the curriculum and the competencies expected in higher education. Relevant SSI topics were selected—such as alcohol-related accidents and fuel misuse—as contextual entry points for teaching chemical kinetics. A preliminary structure for the electronic worksheet was developed, incorporating interactive activities, discussion prompts, and scientific reading materials to stimulate critical thinking and real-world application.

The Develop stage involved the creation of the E-LKM prototype using *Flip Builder* software. The prototype was then subjected to expert validation to assess its content and media quality. Validation was conducted by two content experts—chemistry lecturers from Riau University—and one media expert, a chemistry lecturer from Sultan Syarif Kasim State Islamic University, Riau. The validation used a structured questionnaire based on a 4-point Likert scale, evaluating aspects such as material relevance, visual design, clarity, interactivity, and overall usability. The validation results indicated high levels of validity, with a score of 0.90 for content and 0.91 for media, confirming the worksheet's suitability for instructional use.

Following the expert validation, the worksheet was revised based on the validators' suggestions to enhance its clarity and effectiveness. A limited-scale trial was then conducted involving 13 chemistry students, aiming to assess the practicality and initial impact of the worksheet. Student feedback was positive, and results showed improved conceptual understanding and engagement with the material.

Although the Disseminate stage was not fully implemented due to time constraints, it is planned for future classroom applications and broader-scale impact evaluation. This final stage will involve

distributing the E-LKM to a wider audience and gathering feedback for further refinement and long-term integration into the chemistry curriculum.

Table 6. Expert Validation Questionnaire

No.	Evaluated Aspects	Indicators
A Content/material suitability		
A1	Alignment with learning objectives	The material is in line with the expected learning outcomes.
A2	Conceptual accuracy	The material is presented in accordance with correct scientific concepts.
A3	Alignment with the student level	
A4	Relevance to SSIs issues	
B Media Display and Design		
B1	Layout suitability	The layout of the content is attractive and easy to navigate.
B2	Color and font selection	The colors and fonts used are easy on the eyes.
B3	Clarity of illustrations/images	The images support understanding and are relevant to the material.
C Comprehensibility and Interactivity		
C1	Language used	The language used is communicative and appropriate for the students' level.
C2	Activity guide	The activity instructions are easy for students to understand and carry out.
C3	Critical thinking stimulus	The questions and activities stimulate students' critical thinking skills.

The results of the validation of media and materials in the student worksheet, carried out by experts, can be seen in Table 7.

Table 7. Expert Validation Test Assessment

Validators	Validity Score	Criteria
Subject Matter Expert	0.90	Very High (Very Valid)
Media Expert	0.91	Very High (Very Valid)

Based on the results of the validation test from material experts and media experts, the electronic worksheet based on SSI on the material of substances and their changes that was developed obtained scores of 0.90, respectively, which meet the criteria with very valid qualifications.

Table 6. Practicality Test Assessment by Teachers and Students

Validator	Practicality Score	Criteria
Teacher	3.68	Very Practical
Student	3.42	Very Practical

After the electronic worksheet was validated by material experts and media experts, a practicality test was conducted for teachers and students. This practicality test was carried out at Universitas, involving science subject teachers and 13 students. The results of the teacher's assessment showed an average score of 3.68, and students showed an average score of 3.42, which is included in the very

practical category. This is in line with the opinion of Rahayu (2019) which states that the use of teaching materials in learning can help students improve their understanding, present data in an interesting and reliable way, and facilitate data interpretation and information conclusions. Not only are SSIs able to enhance students' scientific literacy skills through the presentation of issues that can be seen from various aspects of life (Uzpen & Houseal, 2019).

This development research resulted in a product in the form of an educational tool—specifically, a student worksheet (LKM) integrating Socio-Scientific Issues (SSIs)—designed to support the teaching and learning process of chemical kinetics at the University of Riau. The development process followed a structured model to ensure that the final product was both valid, as determined by expert evaluations, and practical, based on positive feedback from students and instructors. The incorporation of SSI into the worksheet proved to be highly effective in facilitating conceptual understanding, particularly for abstract and often challenging topics such as reaction rates, reaction mechanisms, and factors affecting chemical kinetics.

By embedding real-world socio-scientific problems into the learning materials, students were provided with meaningful contexts that made chemistry concepts more relatable and easier to grasp. These issues—ranging from the health impacts of alcohol consumption to environmental consequences of chemical use—served as catalysts for discussion, inquiry, and critical thinking. The problem-solving tasks within the worksheet allowed students to analyze and evaluate each issue from scientific, ethical, and social perspectives, thereby promoting not only chemical literacy but also the development of higher-order thinking skills.

Importantly, the SSIs approach emphasizes that learning is not solely about arriving at a single "correct" answer, but rather about constructing well-reasoned arguments grounded in scientific evidence. In this framework, students are encouraged to explore multiple viewpoints, justify their reasoning, and articulate informed decisions. This pedagogical flexibility respects the complexity of real-life issues and acknowledges that students' responses may vary as long as they are scientifically sound. As such, the SSI-based worksheet not only supports cognitive development but also nurtures transferable skills essential for students' academic and societal roles.

4. CONCLUSION

This development research successfully produced a valid and practical learning tool in the form of an SSI-based electronic worksheet (E-LKM) on chemical kinetics for use in the basic chemistry curriculum at the University of Riau. The main findings indicate that integrating Socio-Scientific Issues (SSIs) into chemistry instruction enhances students' conceptual understanding by making abstract content more relatable and contextual. The worksheet effectively facilitated student engagement, promoted critical thinking, and encouraged scientific reasoning without focusing on absolute correctness, as long as arguments were supported by valid scientific evidence. However, the study had certain limitations, including a limited sample size of only 13 students in the trial phase and the incomplete implementation of the dissemination stage, which restricts the generalizability of the results. Future research should involve a larger and more diverse group of participants, implement the worksheet across multiple institutions or learning settings, and evaluate its long-term impact on student learning outcomes. Moreover, further development of SSI-based tools should consider incorporating digital simulations, gamification elements, or adaptive learning technologies to increase interactivity and personalization in science learning.

REFERENCES

- Amahoroe, R. A., Arifin, M., & Solihin, H. (2020). Penerapan desain praktikum berbasis STEM pada pembuatan tempe dari fermentasi biji nangka (*Artocarpus heterophyllus*) untuk meningkatkan literasi sains siswa SMK. *Molluca Journal of Chemistry Education (MJoCE)*, 10(2), 89–100.

- Cahyadi, R. A. H. (2019). Pengembangan bahan ajar berbasis ADDIE model. *Halaqa: Islamic Education Journal*, 3(1), 35–42. <https://doi.org/10.21070/halaqa.v3i1.2124>
- Dalaila, I., Widiyaningrum, P., & Saptono, S. (2022). Developing E-module based on socio-scientific issues to improve students' scientific literacy. *Journal of Innovative Science Education*, 11(3), 285–294. <https://journal.unnes.ac.id/sju/index.php/jise/article/view/54500>
- Firanti, F. F., & Erna, M. (2024). Uji kelayakan e-modul asam basa berbasis SSI (Socio-Scientific Issues) berbantuan Flip PDF Professional. *Jurnal Pendidikan Sains*, 8(1), 20–28.
- Gorbi Irawan, A., Padmadewi, N. N., & Artini, L. P. (2018). Instructional materials development through 4D model. *SHS Web of Conferences*, 42, 00086. <https://doi.org/10.1051/shsconf/20184200086>
- Hidayatullah, M. T., Asbari, M., Ibrahim, M. I., & Faidz, A. H. H. (2023). Urgensi aplikasi teknologi dalam pendidikan di Indonesia. *Journal of Information Systems and Management (JISMA)*, 2(6), 70–73. <https://jisma.org/index.php/jisma/article/view/785>
- Jacinda, S. S., Nirwana, R. R., & Setiowati, H. (2024). Innovation mobile learning media based socio-scientific issue (SSI) in petroleum material. *Social, Humanities, and Educational Studies (SHES)*, 7(2), 137–145.
- Kadi, T., & Awwaliyah, R. (2017). Inovasi pendidikan: Upaya penyelesaian problematika pendidikan di Indonesia. *Jurnal Islam Nusantara*, 1(2), 144–155. <https://doi.org/10.33852/jurnalin.v1i2.32>
- Pratiwi, Y. N., Rahayu, S., & Fajaroh, F. (2016). Socioscientific issues (SSI) in reaction rates topic and its effect on the critical thinking skills of high school students. *Jurnal Pendidikan IPA Indonesia*, 5(2), 164–170. <https://doi.org/10.15294/jpii.v5i2.7676>
- Rahayu, S. (2019). Socio-scientific issues (SSI) in chemistry education: Enhancing both students' chemical literacy and transferable skills. *Journal of Physics: Conference Series*, 1227(1), 012008. <https://doi.org/10.1088/1742-6596/1227/1/012008>
- Rery, R. U., & Rahmasari, T. P. (2023). Research trend of socio-scientific issues on chemical kinetic materials: Literature review. *Al-Ishlah: Jurnal Pendidikan*, 15(4), 5121–5130. <https://doi.org/10.35445/alishlah.v15i4.3787>
- Rundgren, C.-J., & Rundgren, S.-N. C. (2018). Aiming for responsible and competent citizenship through teacher professional development on teaching socioscientific inquiry-based learning (SSIBL). *Asia-Pacific Forum on Science Learning and Teaching*, 19(2).
- Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, 41(5), 513–536. <https://doi.org/10.1002/tea.20009>
- Salim, T. H. N., & Prasetyo, Z. K. (2018). Pengaruh pendekatan socio-scientific issues berbasis STEM terhadap literasi sains siswa. *Pendidikan Ilmu Pengetahuan Alam - S1*, 7(5), 262–267. <http://journal.student.uny.ac.id/ojs/ojs/index.php/ipa/article/view/12079/11634>
- Sari, D. R., & Yusmaita, E. (2022). Validitas konten dan validitas konstruk panduan teknis pembelajaran project-based learning berbasis literasi kimia pada materi laju reaksi. *Entalpi Pendidikan Kimia*, 7(1), 61–68.
- Uzpen, B., & Houseal, A. K. (2019). Using socio-scientific issues in problem-based learning to enhance science literacy. *Journal of Physics: Conference Series*, 1233(1), 012073. <https://doi.org/10.1088/1742-6596/1233/1/012073>
- Zeidler, D. L., Herman, B. C., & Sadler, T. D. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research*, 1(11), 1–9. <https://doi.org/10.1186/s43031-019-0018-5>