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Development of Science E-Worksheet Based on Socio Scientific Issues on the Human Respiratory System

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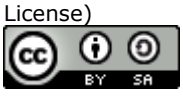

Abstract. Learning in schools still tends to be teacher-centered, with student worksheets often being overly simplistic. Additionally, students generally prefer kinesthetic learning activities. To address this, we developed an electronic student worksheet (e-worksheet) based on socio-scientific issues (SSI) for the human respiratory system topic using a design-based research (DBR) approach. This study aimed to: (1) design and iteratively refine the SSI-based E-Worksheet through expert collaboration and user testing; (2) evaluate its feasibility; and (3) explore student responses. Conducted in a private junior high school in Yogyakarta, the DBR process involved four interconnected phases: problem analysis (interviews with teachers and classroom observations), prototype design, implementation cycles (with 10 and 77 students respectively), and reflective evaluation. Data were collected from science education experts, teachers, and eighth-grade students through observations, interviews, and questionnaires, then analyzed descriptively. Results indicate that the DBR process successfully produced a contextually grounded e-worksheet, rated highly feasible by experts (content suitability: 86%, graphics: 82%) and teachers. Student responses showed strong approval (85% relevance perception, 82% engagement increase), confirming its suitability for supporting science learning.
Keywords: Design-based research; human respiratory system; science e-worksheet; socio scientific issues

Introduction

Technological developments have brought significant transformations to various aspects of life, including education (Akour & Alenezi, 2022; Timotheou et al., 2023). In this digital era, the use of innovative teaching materials has become an urgent need to create more effective and engaging learning (Alenezi et al., 2023; Rizvi & Nabi, 2021). One of the key demands of 21st-century education is the integration of the 4C skills (communication, critical thinking, collaboration, and creativity) through a student-centered learning approach (Herlinawati et al., 2024). These skills are crucial for preparing students to face increasingly complex global challenges.

Although the 2013 curriculum and the independent curriculum have directed student-centered learning, their implementation in the field still faces various challenges. Teachers

often struggle to implement scientific approaches and active learning due to limited time, pedagogical skills, and a lack of supporting resources (Yuliani & Hartono, 2020). Furthermore, the learning process, which should develop critical thinking and participatory skills, is still dominated by lecture methods, thus not optimally reflecting the curriculum's emphasis on student-centered learning (Astuti et al., 2022; Kuncoro et al., 2023). In many cases, learning interactions still tend to be dominated by the teacher as the primary facilitator, while active student participation in constructing knowledge needs to be continuously improved (Mansour, 2024; Zhou, 2025). This challenge is further complicated by the limited use of digital teaching materials that can support contemporary approaches, even though this approach is very effective in connecting science learning with current issues in society and developing 21st-century skills (Hernández-Ramos et al., 2021; Mang et al., 2021).

Previous research has shown that although teachers have understood the essence of the 2013 curriculum and the independent curriculum, many still revert to the lecture method in their implementation due to a lack of resources and time for developing active learning (Susanti et al., 2022). This is reinforced by findings that reveal that teachers struggle to design learning that promotes scientific literacy due to limited teaching materials and understanding of innovative learning approaches (Rahmawati & Herlina, 2021). The lack of interactive and context-based digital teaching materials is a major obstacle to realizing truly student-centered learning (Soubra et al., 2022; Sulistyowati et al., 2024). However, the socio scientific issues (SSI) approach through appropriate digital media can be a solution to increase student engagement in contextual problem-solving (Kumar et al., 2024), while accelerating the implementation of student-centered learning in accordance with the spirit of the applicable curriculum (Viehmann et al., 2024). Various studies have also highlighted that inadequate infrastructure, lack of teacher training, and limited access to educational technology are key obstacles to the implementation of a student-centered curriculum (Assem et al., 2023; Kusmawan et al., 2025). This situation indicates a gap between curriculum policy and actual classroom practice, influenced by various external factors.

Based on an in-depth review of various previous studies, several important gaps were identified that served as the basis for developing this research. Research shows that conventional student worksheets currently used have not been able to encourage active student interaction in the learning process (Fitriyah et al., 2024; Kholid et al., 2023). Similar findings also demonstrate the significant potential of e-worksheet in increasing student learning motivation, although it has not yet been linked to a SSI approach relevant to real-life situations (Sugianto et al., 2022; Wahyuniyati et al., 2025). On the other hand, the SSI approach in science learning is considered important, but its implementation is still limited to conventional print media (Badeo & Duque, 2022). Interactive platforms such as Liveworksheets have proven effective in learning but have not been widely utilized to systematically develop materials based on socio-scientific issues (Alya & Purwaningsih, 2025; Normawati et al., 2022). Meanwhile, students' critical thinking and problem-solving skills remain relatively low, despite the 2013 curriculum explicitly emphasizing the importance of strengthening the 4C skills (Weng et al., 2022). The SSI approach has significant potential for improving scientific literacy but has not been widely developed in the form of interactive, digital-based e-worksheet (Permanasari et al., 2021).

The use of SSI in the development of e-worksheet science is very important because it can connect scientific concepts with real issues in society, so that learning becomes more contextual and meaningful. In the material on the human respiratory system, social issues such as air pollution, cigarette smoke, and the use of e-cigarettes (vapes) are directly related to lung health. Through the SSI approach, students not only understand biological concepts but are also trained to think critically, conduct scientific reasoning, and make decisions based on evidence in dealing with multidimensional problems (Arifin et al., 2025;

Sari, et al., 2025). Furthermore, the integration of SSI in e-worksheet has proven effective in developing scientific literacy, critical thinking skills (CTS), and awareness of environmental and health issues, in accordance with the needs of 21st-century learning (Chomsun et al., 2025).

The selection of junior high school level as the target of research on the development of e-worksheets based on SSI is based on several considerations: 1) junior high school students are at the early formal operational cognitive development stage according to Piaget, so they are starting to be able to think abstractly, do hypothetical reasoning, and consider various points of view in decision making. This is in accordance with the characteristics of SSI-based learning which demands critical, analytical, and evaluative thinking skills (Zeidler et al., 2005); 2) The material on the human respiratory system is included in the junior high school science curriculum and is an important topic that is very close to students' daily lives, for example its relationship to air pollution, cigarette smoke, and healthy lifestyles. Thus, SSI-based contextual learning is expected to increase students' learning motivation as well as scientific literacy (Sadler, 2004; Slovinsky et al., 2021); 3) Developing SSI-based e-worksheets, such as those using the guided inquiry model, has been shown to improve conceptual understanding while fostering CTS and awareness of health and environmental issues (Saputri et al., 2023).

The development of e-worksheets is important because this medium can address the challenges of 21st-century learning, which demands the integration of digital technology into the teaching and learning process. E-worksheets allow teachers to present more varied content through links, interactive videos, animations, or simulations—features proven effective in visualizing abstract concepts, facilitating understanding of material such as the mechanics of the human respiratory system. For example, research by Alfira et. al. (2024) showed that the use of liveworksheets integrated with a contextual approach significantly increased student interactivity and understanding. The use of e-worksheets is also in line with the active learning approach because students not only receive material but also explore, discuss, and reflect independently through task-based activities (Prastowo, 2015). E-worksheets contribute significantly to improving learning efficiency and effectiveness because they can be practically designed, easily updated, and monitored online. The use of digital platforms like liveworksheets has also proven reliable, usable, efficient, and effective in improving student understanding and motivation (Maharani & Marhamah, 2024).

In this research, the clear novelty lies in the development of SSI-based science e-worksheets using the liveworksheets platform for the topic of the human respiratory system, a practice not previously explored in earlier studies. This innovation is expected to address the need for contextual and engaging digital teaching materials. The study integrates the SSI approach with various interactive digital features such as drag-and-drop, matching, and video embedding, specifically designed to comprehensively foster students' 4C skills. Furthermore, it structures the SSI (socio-critical and problem-oriented) stages into a more adaptable and user-friendly digital format, enabling students to connect scientific concepts with relevant real-life issues. Through this approach, students are expected not only to understand theoretical concepts but also to apply them in solving authentic social problems (Almulla & Al-Rahmi, 2023; Harini et al., 2023). These innovations are anticipated to make a significant contribution to the advancement of science learning media in the digital era (Akour & Alenezi, 2022).

Based on this novelty, this study has several important objectives. The main objective is to develop a valid and feasible SSI-based science electronic worksheet on the human respiratory system based on expert assessment. Another equally important objective is to evaluate student responses to the use of interactive e-worksheets. This evaluation includes aspects of ease of use, visual appeal, and media effectiveness in supporting the learning process. Thus, this study is expected to provide a comprehensive overview of the potential

for developing SSI-based digital teaching materials in the context of science learning in Indonesia.

This research is expected to make a significant contribution to solving various learning problems in the classroom. The main solution offered is through the development of contextual and interactive digital teaching materials, which are expected to increase students' active engagement in science learning. In addition, the findings of this study can serve as an important reference for the development of SSI-based e-worksheets for other materials in the science curriculum. Moreover, this research is expected to encourage more optimal use of technology in daily learning practices, while reducing excessive dependence on conventional printed teaching materials. With these various contributions, this research not only addresses the challenges of 21st-century learning but also enriches the treasure trove of innovative learning media development based on SSI that are relevant to the needs of modern education, namely contextual, interactive, technology-based learning, and encouraging students' CTS and scientific literacy.

Methods

This study uses a design-based research (DBR) approach with stages as shown in Figure 1. The research process begins with a contextual problem analysis through classroom observations and interviews with science teachers, which identified four main needs: (1) interactive teaching materials based on SSI, (2) increasing student engagement, (3) technology integration in learning and (4) human respiratory system material. Based on this analysis, e-worksheets design principles were developed that accommodate pedagogical and technical aspects. The instruments used included interview guidelines, observation sheets, and document analysis formats. Data were analyzed descriptively and qualitatively through a process of reduction, categorization, and drawing conclusions.

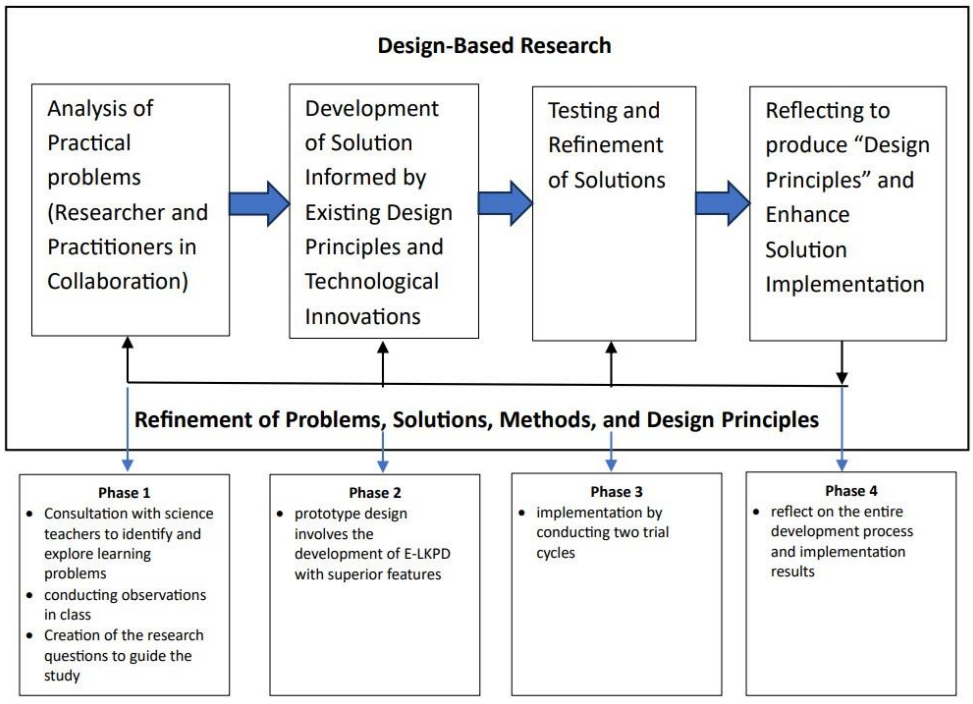

Figure 1. DBR stage diagram (Modified from Narayan et al., 2019)

The second stage is the prototype design involving the development of e-worksheets with superior features: (1) SSI case studies related to the respiratory system, (2) digital interactive activities, and (3) teacher guides. The initial product was validated by 2 experts and 2 teachers using an instrument in the form of a five-aspect assessment validation sheet (content suitability, SSI approach, language, graphics, and usability). Quantitative analysis by calculating the average score and percentage of the level of suitability, and supplemented with qualitative analysis of suggestions for improvement from the validator.

In the third phase, implementation, two trial cycles were conducted. The first cycle (10 students) identified the need for language and display improvements, while the second cycle (77 students) evaluated the effectiveness of the final product. Data were collected through a triangulation of methods (observation, questionnaires, and tests). The reflection phase (Figure 1) generated pedagogical recommendations for the development of the digital SSI, with key findings being a 35% increase in student engagement and an 85% satisfaction rate with the interactive format.

The final stage is reflection and generalization, where researchers reflect on the entire development process and implementation results. This reflection is used to develop design principles that can serve as a basis for developing similar teaching materials in different contexts and with different materials. This process also generates recommendations for learning practices and theoretical contributions to the development of SSI-based teaching materials in science education.

The DBR process in this study not only produced a tested e-worksheets product but also provided a systematic framework for developing socio-scientific issue-based teaching materials (Hanghøj et al., 2022). The diagram in Figure 1 visually clarifies the iterative and collaborative nature of the applied DBR method, where each stage is interconnected and forms a cycle of continuous improvement. These findings provide both practical (ready-to-use products) and theoretical (innovative development models) contributions to science education.

Results and Discussion

This section presents the results of the DBR process, which was carried out in four main stages: problem identification, prototype design, trial and evaluation, and reflection and refinement (Hanghøj et al., 2022). The purpose of this research is to develop a SSI-based electronic student worksheet on the human respiratory system that is not only graphically and content-appropriate but also able to increase student engagement in science learning. Each stage of the DBR process is systematically arranged and grounded in empirical data obtained through observation, interviews, expert validation, student response questionnaires, and teacher reflections.

The findings from each stage are presented in detail to provide a comprehensive picture of the iterative development process. This structure illustrates how the SSI approach was integrated into the design of the digital worksheet and refined through continuous feedback from experts, students, and teachers. In this way, the DBR process not only ensured the quality of the product but also demonstrated its potential to foster meaningful and contextualized science learning experiences.

Problem Identification Stage

The research began with a problem identification phase aimed at understanding the current state of science learning in a private junior high school in Yogyakarta. Data collection was conducted through classroom observations and interviews with science teachers. Observations showed that 85% of the learning process was still dominated by the use of conventional textbooks, while only 15% of teachers utilized digital teaching

materials. These findings indicate that the use of digital media in science learning is still very limited, necessitating innovative development in the form of e-worksheets. These data indicate that most teachers still rely on conventional textbooks to deliver science learning materials. The low use of digital teaching materials indicates a gap in the integration of technology into the teaching and learning process (Akram et al., 2022). This finding provides the initial basis for the need for learning innovation through the development of more engaging, interactive, and contextual digital media such as e-worksheets.

In addition to highlighting the dominance of conventional textbooks also reflect teachers' limited exposure to and familiarity with digital learning innovations. This condition not only affects the variety of instructional media but also reduces opportunities for students to experience more interactive, inquiry-based, and contextualized science learning (Wen et al., 2023). Consequently, identifying the specific challenges faced by teachers becomes essential to ensure that the development of digital teaching materials, such as SSI-based e-worksheets, is relevant to classroom needs and addresses the real obstacles in practice. These challenges were further explored through interviews with science teachers, the results of which are summarized in Table 1.

Table 1. Key problems identified by science teachers

Problems faced	Percentage of teachers who stated
Lack of current issue-based teaching materials (SSI)	67
Limitations of interactive media	58
Low student involvement in learning	72

Table 1 shows that the urgency for developing learning media based on SSI is very high. This data reflects the real challenges teachers face in creating relevant and engaging learning for students. The lack of teaching materials based on current issues, the limitations of interactive media, and low student engagement are indicators that conventional approaches are no longer adequate. These three issues form the basis for designing an intervention in the form of an e-worksheet that is expected to address field needs contextually and pedagogically. In addition, these findings highlight the importance of integrating SSI into science learning, as SSI has been shown to connect classroom content with real-world contexts, thereby fostering critical thinking, decision-making, and problem-solving skills. By embedding interactive features into SSI-based e-worksheets, teachers are provided with tools that not only make learning more dynamic and participatory but also align with 21st-century skills demanded in modern education (Karışan & Zeıdler, 2024). Thus, the challenges identified in Table 1 serve as both a justification and a direction for innovation in developing digital learning materials that are adaptive, student-centered, and responsive to the evolving educational landscape.

Prototype Design Stage

Based on the results of the needs analysis, the researchers designed a prototype of an e-worksheet based on SSI with the topic of the human respiratory system. This e-worksheet was designed to contain key features that not only support the science learning process but also integrate contextual and current issues in everyday life. Several important elements displayed in the prototype include: a visually appealing cover, a logically and coherently arranged respiratory system concept map, and user instructions in simple language so that they can be understood by junior high school students. The conceptual

framework for developing the e-worksheet is shown in Figure 2, which shows the relationship between content components, digital features, and SSI elements.

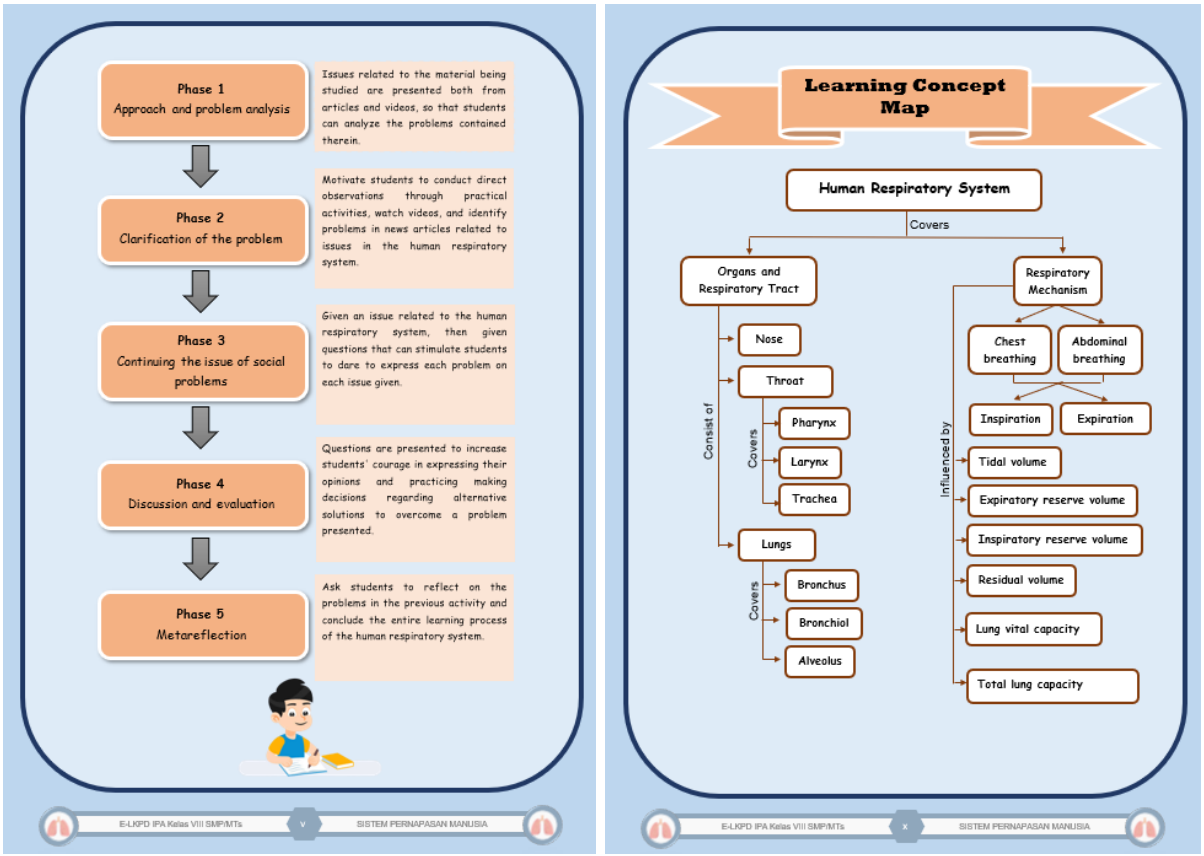

Figure 2. E-worksheets display

Figure 2 provides a comprehensive overview of the integrated conceptual structure of the e-worksheet. Each component within this framework is carefully designed to serve a complementary function, beginning with the presentation of learning materials, followed by issue-based activities, and strengthened by the integration of supporting digital media. This layered design ensures that students do not only receive information passively but are also actively guided to explore, question, and reflect on the issues presented.

The interrelationships among these elements are intentionally structured to create a systematic and meaningful learning flow. By combining scientific concepts with socio-scientific issues, the framework allows students to bridge theoretical knowledge with real-world challenges. In this way, the e-worksheet positions science learning not merely as a cognitive exercise but as a process of reasoning, decision-making, and problem-solving that is embedded in students' social and environmental contexts.

To illustrate the product's structure more concretely, Figure 3 presents a visual example of the initial e-worksheet interface. The cover page features a thematic graphic design that reflects the chosen socio-scientific issue, along with intuitive navigation tools that guide learners through the content. Sequential organization, ranging from concept maps to case-based activities, is arranged in a way that gradually leads students into deeper engagement with the material. This systematic flow is intended to maintain continuity and prevent cognitive overload during the learning process.

In addition, the interface includes interactive components such as clickable task icons, video access buttons, and embedded links to live worksheets. These features are designed not only to increase student engagement but also to promote multimodal learning experiences that integrate text, visuals, and digital interaction. By combining aesthetic design with functional interactivity, the e-worksheet aims to provide a user-friendly digital environment that motivates students to participate actively and sustain their interest throughout the learning activities.

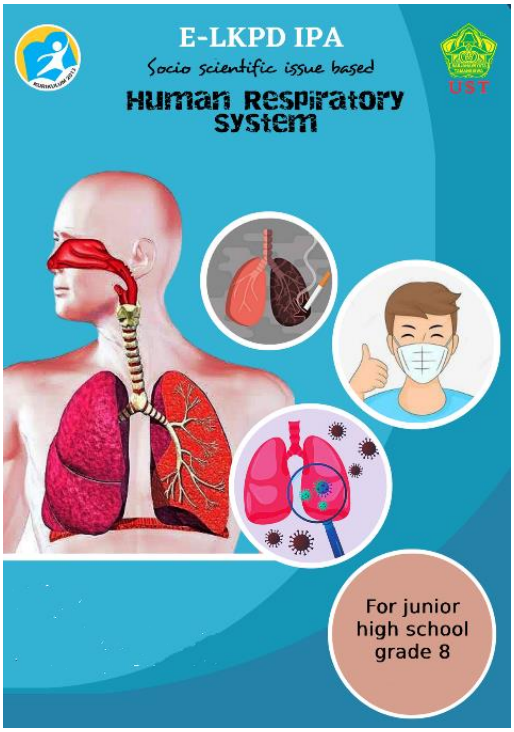

Figure 3. E-worksheets cover page

The initial appearance shown in Figure 3 is a crucial element in establishing students' first impressions of the learning media. The thematic visual design and user-friendly navigation ensure that learners can quickly adapt to the digital format and comfortably follow the learning flow. By proportionally integrating visual and interactive components, the prototype emphasizes not only the delivery of scientific content but also the creation of a participatory and enjoyable learning experience.

This emphasis on first impressions is particularly important because students' willingness to engage often depends on their initial interaction with the learning interface. A well-structured design that balances clarity, aesthetics, and functionality can minimize potential resistance to digital learning tools and encourage students to explore the material further. In this way, the e-worksheet is not merely a container for learning content but also a medium that motivates and sustains students' interest throughout the inquiry process.

Moreover, the incorporation of thematic graphics and intuitive navigation reflects the SSI embedded in the content, providing both contextual relevance and visual appeal. Such alignment between design and pedagogy reinforces the message that science is not an abstract body of knowledge but a meaningful discipline connected to real-world challenges. This intentional design strategy strengthens the role of the e-worksheet as a bridge between conceptual understanding and practical application.

Ultimately, the initial appearance of the e-worksheet serves as the foundation for deeper student engagement with the activities that follow, such as concept mapping, case analysis, and interactive problem-solving tasks. When combined with the digital features previously described, the design ensures a seamless transition from surface-level curiosity to sustained involvement in higher-order thinking processes. This progression underscores the dual function of the e-worksheet: as both an instructional tool and a catalyst for meaningful science learning.

Figure 4. E-worksheets cover page

Figure 4 illustrates an example of how SSI are embedded within the e-worksheet. At the problem-approach and analysis stage, the e-worksheet presents contextual problems closely related to students' daily lives, such as the issue of air pollution that directly affects the human respiratory system. By situating abstract concepts in concrete and relevant contexts, the SSI-based approach is intended to train students to connect scientific knowledge with real-world challenges, while simultaneously fostering critical thinking and decision-making skills. This design, however, required careful review to ensure that the materials were not only scientifically accurate but also pedagogically appropriate for junior high school students.

The expert validation process played a central role in refining the prototype to meet these requirements. Experts provided constructive feedback covering both graphical and

linguistic aspects, highlighting the importance of clarity, accessibility, and age-appropriateness in digital learning resources. Their evaluation emphasized that even small elements such as text color, sentence complexity, and visual layout could significantly influence students' comprehension and engagement. Therefore, revisions were systematically made to align the product with the dual goals of scientific accuracy and user-friendly design.

Several key improvements were carried out based on this feedback. These included changing the instruction text color from light green to dark green to enhance readability on digital device screens, simplifying instruction sentences to match the cognitive development of junior high school students, and restructuring the concept map layout to make it more systematic and less dense. All of these expert recommendations, along with the corresponding revision actions, are presented in Table 2.

Table 2. Expert validation results on the initial e-worksheet prototype

Rated aspect	Improvement suggestions	Revision action
Instruction text color	Change the color to light green because it is not clear enough	Changed to dark green
Instruction language	Too complex for junior high school students	Simplified with direct and concise sentences
Concept map layout	Too dense and unsystematic	Restructured for easier understanding

Table 2 summarizes the various expert inputs that served as the basis for refining the e-worksheet prototype. The revision process was carried out iteratively to ensure that the resulting product was not only visually and linguistically appropriate but also aligned with the cognitive development and learning needs of junior high school students. This validation stage is a crucial component of design-based research, as it provides evidence-based feedback that guarantees the feasibility and effectiveness of the instructional design before it is tested in the classroom.

The improvements made demonstrate how seemingly small adjustments, such as changing color contrasts or simplifying sentence structures, can have a significant impact on the accessibility and usability of digital learning media. These refinements are not merely cosmetic but pedagogically strategic, as they reduce potential barriers to understanding and allow students to focus more on engaging with socio-scientific issues rather than struggling with format or readability.

Moreover, the validation results highlight the importance of collaboration between researchers, educators, and subject matter experts in producing high-quality digital teaching resources. By integrating expert insights into the revision process, the e-worksheet evolves into a tool that is scientifically accurate, pedagogically sound, and practically relevant for classroom application. This collaborative refinement ensures that the product is not only innovative in concept but also reliable in practice. The incorporation of expert feedback strengthens the credibility of the developed media and provides a solid foundation for the next stage of the DBR cycle, namely trial and evaluation with students. At this stage, the revised e-worksheet will be tested for its effectiveness in fostering student engagement, promoting higher-order thinking, and connecting scientific concepts to real-world socio-scientific contexts.

Trial and evaluation stage

The revised e-worksheet prototype was then implemented in two trial cycles in eighth grade. Evaluation was conducted by observing student engagement and distributing a response questionnaire. Observations showed a significant increase in student engagement in learning, from 45% before using the e-worksheet to 82% after its use. This indicates that the developed learning media is able to effectively stimulate student learning interest.

The increase in student engagement indicates the effectiveness of e-worksheet in changing the dynamics of classroom learning. Previously, most students tended to be passive and only minimally followed teacher instructions. However, after using e-worksheet, more students actively discussed, asked questions, and showed initiative in completing issue-based assignments. This indicates that the developed learning media not only enhanced learning activities but also created a more interactive and participatory learning environment. Furthermore, the results of the student response questionnaire showed that 95% of students stated that e-worksheet was easy to use, and 85% of students considered the issues presented relevant to their lives. This suggests that a social and scientific issue-based learning approach can increase the relevance of science learning in the eyes of students.

The positive student responses, reinforce the finding that the e-worksheet is not only technically feasible but also pedagogically well-received. Ease of use is a crucial factor in ensuring students can access and utilize the media optimally without technical barriers. Meanwhile, the relevance of the issues raised in the e-worksheet encourages students to view science as something close to everyday life, not simply as rote learning. Thus, a socio-scientific issues-based approach directly contributes to increased meaning and engagement in science learning.

Throughout the learning process, students demonstrated high enthusiasm in completing case analysis-based activities, such as air pollution, presented through interactive liveworksheets. These activities not only hone CTS but also encourage students to connect scientific concepts to real-world conditions in their environment.

Reflection and Refinement Stage

Reflection on the implementation process yielded several important findings for further development. First, the integration of local case studies, such as air pollution in the area surrounding the school, was shown to increase the relevance of learning by 35%. Second, optimizing the visual display, involving the use of icons, coordinating colors, and consistent layout, also increased the media's appeal by up to 40%. Furthermore, the active involvement of teachers in the development process alongside researchers helped expedite the product's refinement process.

The final version of the e-worksheet was then supplemented with additional features, such as video explanations of concepts and interactive simulations, which strengthened the multimodal aspect of learning. Final validation of the product's feasibility showed improved scores in two key aspects: graphics and language.

Table 3. Product eligibility score improvement before and after revision

Rated aspect	Score before revision	Revision action
Graphics	72	86
Linguistics	68	82

The improved scores shown in Table 3 indicate that the product has met the eligibility standards as a relevant, engaging, and communicative digital learning medium. Improvements in the visual appearance make the e-worksheet more engaging and easier

for students to understand, while language refinements improve the clarity of instructions and the accessibility of the material. This demonstrates that revisions based on trial data and user feedback have a direct impact on the final quality of the product. The reflection and refinement process also emphasizes the importance of ongoing collaboration between teachers and researchers in creating contextual learning innovations that are oriented towards real needs in the field. Therefore, the developed e-worksheet is considered ready for broader implementation in the context of socio-scientific issues-based science learning at the junior high school level.

The results of this study indicate that the development of SSI-based e-worksheet has a positive impact on improving the quality of science learning at the junior high school level. This aligns with Kumar et al. (2024) who emphasized the effectiveness of environmental SSI contexts in developing scientific literacy. The finding of an increase in student engagement from 45 to 82% after the implementation of the e-worksheet indicates that learning media designed with a contextual and social issue-based approach are not only relevant but also engage students' learning interests in a real-world setting. This demonstrates that the SSI approach can bridge abstract science content with the realities of students' lives, enabling them to construct more personal and in-depth meanings for scientific concepts (Mang et al., 2021; Mathers et al., 2024; Zeidler & Sadler, 2023).

The e-worksheet designed in this study presents the case of air pollution as an entry point for students to learn about the respiratory system. The use of air pollution as an entry point directly responds to Viehmann et al. (2024) recommendation for locally relevant SSI implementation. This context proved effective because it linked biological material to students' everyday experiences in urban environments that frequently face pollution problems. This kind of learning is in line with the social constructivism model which emphasizes the importance of real experiences and social discourse in the process of building knowledge (Eryasar & Kilinc, 2022; Jia & Ren, 2025; Lee, 2022).

The positive outcomes of this study demonstrate that SSI-based digital media can function not only as a tool for delivering content but also as a platform for cultivating 21st-century skills such as critical thinking, collaboration, and decision-making. By situating scientific concepts within real and socially relevant contexts, the e-worksheet encourages students to negotiate meaning, evaluate evidence, and propose solutions, thereby fostering deeper engagement with both the scientific and social dimensions of the issues under discussion (Herman et al., 2021). These findings reinforce the argument that integrating SSI with interactive digital resources can transform traditional science learning into a more participatory and transformative educational experience.

The issue of air pollution directly impacting the human respiratory system is illustrated in figure 4 taken from authentic sources, both in the form of news articles and videos, so that students can gain a real picture of the relationship between biological concepts and social and environmental phenomena. For example, the e-worksheet features an article entitled "Why do we need to study the respiratory system?" reported by Merdeka.com (February 7, 2023), which contains an explanation of the threat of air pollution to the health of the lungs and the human respiratory system.

Through this presentation, students are guided to identify problems contained in the article, such as the causes of air pollution, its impact on health, and preventive measures. Next, students are asked to analyze the problem by connecting the information obtained from the reading with scientific concepts about the structure and function of the respiratory system. This activity is expected to train CTS, evidence-based decision-making abilities, and improve students' scientific literacy (Jones & Donaldson, 2022). Thus, the approach and problem analysis stages in the e-worksheet not only present factual knowledge but also emphasize reasoning and evaluation skills and build awareness of the importance of maintaining respiratory health in a social and environmental context.

The integration of interactive features in e-worksheet, such as videos, simulations, and digital worksheets based on Liveworksheets, plays a crucial role in supporting active student engagement (Alfira et al., 2024). These features not only stimulate visual attention but also facilitate exploration and manipulation of concepts through more flexible and independent means. These findings extend Sugianto et al. (2022) work on e-worksheet by demonstrating how SSI integration enhances conventional digital worksheets. Positive responses from students, with 78% stating that the media is easy to use and 85% stating that the issues raised are relevant to their lives, demonstrate that user-centered media design can enhance student learning motivation and understanding (González-Pérez et al., 2021). These findings are reinforced by research (Rahmawati et al., 2022), which shows that cognitive engagement increases when students are confronted with real-world problems that require analysis, reasoning, and decision-making based on scientific data. In this context, SSI is not only content but also a pedagogical strategy that fosters students' scientific literacy and ethical awareness of science and technology issues in society.

In terms of product quality, expert validation showed an increase in scores from 68% to 82% for the language aspect, and from 72% to 86% for the graphics aspect. This improvement indicates that improvements based on expert input are a crucial factor in enhancing the instructional quality of digital media. Changes such as simplifying instructional language, adjusting text colors, and improving concept map layouts have a direct impact on readability and user experience. This aligns with findings (Bian & Ji, 2021; Mohamed, 2025), which emphasize that effective digital media must address the principles of visual clarity, aesthetics, and language comprehensibility to support the learning process. Furthermore, post-trial reflections revealed the importance of integrating local case studies, which increased the relevance of the material by up to 35%. Adding local context provides students with opportunities to connect global issues with their immediate surroundings, deepening their understanding of scientific issues, and increasing their participation in classroom discussions (Dare et al., 2021; Lubis et al., 2022). The 35% relevance increase from local case integration validates Permanasari et al. (2021) assertion about SSI's power to contextualize learning.

Close collaboration between teachers and researchers during product development and revision demonstrates the effectiveness of the DBR approach in producing adaptive and contextually relevant learning innovations. In the DBR approach, the development process goes beyond producing a product, but also builds practical knowledge through a cycle of design, implementation, evaluation, and reflection (Amin et al., 2025; Naser & Harb, 2025). Close teacher-researcher collaboration exemplifies DBR's effectiveness in creating adaptive innovations, addressing implementation gaps identified by Assem et al. (2023) and Kusmawan et al. (2025). This approach also encourages the growth of a reflective culture among educators and opens up space for continuous pedagogical innovation. Thus, e-worksheets is not only a learning medium, but also the result of scientific and practical collaboration that bridges the world of research with the real needs of learning in schools.

Conclusion

The results of this study can be concluded as follows. First, this research successfully designed and refined an SSI-based science e-worksheet through a DBR approach implemented iteratively by involving teachers and students. The development process, which included problem analysis, prototype design, gradual implementation, and reflective evaluation, resulted in a contextual product that was well-suited to the needs of junior high school science learning. Second, the evaluation results showed that the e-worksheet was judged highly appropriate by science education experts and teachers, with content suitability rated at 86% and graphic aspects at 82%. Third, the e-worksheet also received

positive responses from students, with 85% indicating its relevance and 82% noting an increase in their learning engagement. Overall, this research not only produced a valid and practical learning tool, but also demonstrated that the integration of socio-scientific issues into e-worksheets can strengthen the connection between science and real life, enhance students' motivation, and support the development of CTS in junior high school students. This study enriches the body of knowledge on SSI-based learning by providing empirical evidence of how socio-scientific contexts can be effectively embedded into digital teaching materials through a DBR framework. It also offers a practical reference for educators and curriculum developers seeking to design engaging, contextual, and interactive learning media that align with 21st-century learning demands. For future research, it is recommended to conduct large-scale trials across diverse school contexts to test the generalizability of the findings, as well as longitudinal studies to examine the long-term effects of SSI-based e-worksheets on students' scientific literacy and critical thinking development. Further exploration into integrating additional digital features, such as gamification elements or adaptive feedback systems, could also enhance the effectiveness and personalization of SSI-based digital learning tools.

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