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Development of student worksheets based on socio-scientific issues: Its influence on chemical literacy and students' scientific attitudes

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Abstract. Based on the needs analysis, it is indicated that students' chemical literacy and scientific attitudes at SMA Negeri 1 Bayung Lencir remain low. The cause was the limited availability of chemistry learning resources that are contextualized to real life. Therefore, this study aimed to know the characteristics, feasibility, and practicality of developing student worksheet products based on Socio-Scientific Issues (SSI) on the chemical bond topic and its influence on students' chemical literacy and scientific attitudes. The type of this study is Research and Development (R&D) with the 4D development model by Thiagarajan. In the *Define* stage, a needs analysis was conducted; in the Design stage, the initial design of the worksheets was created; in the Develop stage, SSI-based student worksheets were produced after undergoing validation; and in the Disseminate stage, the SSI-based student worksheets were distributed to a class of X students at SMA Negeri 1 Bayung Lencir. The results showed that the student worksheet was produced in printed form, was feasible for use, practical, and there was a significant difference in students' chemical literacy. However, no significant difference was observed in students' scientific attitudes. Further research is recommended to develop SSI-based worksheets for other abstract chemistry topics and to explore their influence on students' scientific attitude.

Introduction

The Merdeka Curriculum, which schools in Indonesia still use currently, focuses on designing learning activities that can develop soft skills and student profiles according to the principles of Pancasila. Learning materials emphasize deepening numeracy and literacy skills as basic student abilities. This is relevant to the challenge of the 21st century, a period marked by increasingly complex and evolving aspects of life due to rapid technological advancement, the impact of globalization, and social and environmental changes. Therefore, student as part of society need skills, knowledge, and an understanding of scientific facts and the interactions between science, technology, and culture, so that they can apply their knowledge to solve problems in everyday life (Subiantoro et al., 2021). This ability is referred to as scientific literacy (Bond, 1989).

Science literacy includes chemical literacy, which is important for students to have. Shwartz and colleagues have defined chemical literacy to include content knowledge in chemistry, chemistry in context, higher-order learning skills, and attitudinal aspects. This refers to an individual's ability to understand and explain chemical concepts and phenomena-from the microscopic level (such as molecular structures) to chemistry in everyday life contexts. In addition, individuals can also ask questions, seek information, relate it to prior knowledge, and analyze the benefits/risks in every debate (Sjöström et al., 2024). Wiyarsi et al. (2020) also said that chemical literacy, apart from making students more critical and creative, also helps solve many problems in life based on their knowledge, so that chemical literacy becomes the main goal in chemistry education.

In addition to chemical literacy, there is another aspect that students must master, namely a scientific attitude. This attitude is related to chemical literacy and is part of the other essential skills that students need to possess in the 21st century. Rohaeti et al. (2020) explained that a scientific attitude is a key element of success in chemistry learning. A scientific attitude is an attitude that must be possessed by an academic when dealing with scientific problems. It reflects a tendency to value empirical evidence as the basis for belief in science and refers to the attitude required in one's effort to explore or understand natural phenomena. Students with a good scientific attitude will think fluently and easily, motivating them to continue achieving and fostering a strong commitment to success and excellence (Putri & Aznam, 2024). Therefore, the development of scientific attitudes through an appropriate learning environment is vital, such as through contextual and student-centered learning, which emphasizes the relevance of the material to the real world and students' experiences (Shanderi & Suwardi, 2023; Sugrah et al., 2023; Suryaningsih et al., 2025).

The importance of chemical literacy and scientific attitudes necessitates that students develop these competencies within themselves as essential provisions for the future. However, in reality, many students are still unaware of this condition, which means they lack mastery or even a deficiency in 21st-century competencies. Specifically in chemistry learning, which is part of science, many students still face difficulties in learning chemistry materials and are unable to understand chemical concepts well (Djalil et al., 2023; Nababan, 2023; Sari et al., 2024), connecting chemical concepts with everyday life and making decisions related to social issues involving chemistry remain challenging (Cigdemoglu & Geban, 2015; Wiyarsi et al., 2020). Several contributing factors include the inherent complexity of chemistry, its abstract concepts, and a lack of interest in learning the subject. This is further compounded by unengaging teaching methods and learning materials that are not sufficiently adapted to students' context or needs, thereby affecting the effectiveness of chemistry learning (Astafani et al., 2024; Purnadewi & Widana, 2023).

This is also in line with what occurs at SMA Negeri 1 Bayung Lencir. Based on observations and interviews with the chemistry teacher, it was found that students' scores on assignments, daily tests, their ability to understand and solve problems during exercises, and discussion in chemistry subjects are mostly very low, and this has continued over several academic years. It was also revealed that students have minimal learning resources, such as modules or student worksheets, especially for chemistry subjects. Chemistry requires a high level of literacy that must be supported by various learning resources to help students explore their competencies. In addition to the use of teaching materials, the implementation of contextual learning is still rarely carried out and remains suboptimal. The low learning outcomes of the students indicate that their chemistry literacy and scientific attitudes are also low.

Several other research findings regarding chemical literacy and scientific attitudes in schools support the issues occurring at SMA Negeri 1 Bayung Lencir. Among them, students in Indonesia have a level of scientific and chemical literacy that falls into the low category (Fitriyani et al., 2022; Haetami et al., 2023). A study by Sumarni et al. (2023) also shows that students' chemical literacy is still low, particularly in their conceptual understanding of phenomena, which remains poor. This is due to their limited understanding of chemical materials. Other contributing factors include the inaccurate use of learning models, strategies, approaches, and teaching methods applied by teachers in the classroom (Novita et al., 2021; Widana et al., 2023). Regarding scientific attitudes, in reality, not all students can apply scientific attitudes properly, so students' scientific attitudes tend to be less than optimal (Amaliyah et al., 2024). This is supported by research from Fahmidani & Rohaeti (2020), which shows that students' scientific attitudes in terms of curiosity are very low. This means that students' interest in learning chemistry is still very low. The low scientific attitude is caused by several problems in chemistry learning, such as a lack of student learning experience, a lack of curiosity, a lack of a critical attitude, and a lack of intention or enthusiasm in learning chemistry (Waruwu & Purba, 2022).

To overcome some of the problems in chemistry learning mentioned above, the role of teachers in schools is crucial in creating learning experiences that positively impact students' chemical literacy and scientific attitudes. Teachers must also be more creative and innovative in creating a conducive learning environment and in selecting appropriate methods, strategies, and learning materials that suit students' needs, such as student worksheets. Student worksheets are one of the commonly used learning tools in the instructional process (Kurniasih et al., 2020; Evi Yupani & Widana, 2023). Nugraha et al. (2024) stated that the currently available learning tools, especially student worksheets, are not yet optimal, as they mainly contain evaluation questions that make it difficult for students to connect scientific knowledge with real-life problems in their environment. Therefore, it is necessary to develop chemistry student worksheets that can help students understand issues and phenomena in their surroundings, in order to meet the demands of contextual learning characteristics and goals (Sukendra et al., 2024). One of the contextual learning approaches that can integrate chemistry content with its social and ecological nature is through the contextualization of chemistry in authentic, relevant, and controversial socio-scientific issues (SSI), which can serve as a bridge for students' learning processes (Stolz et al., 2013). This can serve as a reference for teachers in choosing learning strategies. SSI-based learning can be integrated into student worksheets, as Socio-Scientific Issues contain scientific topics that require students to be involved in a dialogue, discussion, and debate.

Research on Socio-Scientific Issues-based learning has been conducted by previous researchers with several school levels, learning models, different dependent variables, and different science materials including chemistry (Rahayu et al., 2022; Husniyyah et al., 2023; Steube et al. (2024). However, previous studies have mainly focused on discussion-based learning strategies, student profiles, and the development of assessment instruments. At the same time, printed teaching materials, especially for abstract chemistry content, have rarely been addressed. In addition, empirical study that measures the effectiveness of SSI on chemical literacy and scientific attitudes as part of the affective domain through the use of quantitative teaching materials are still limited, particularly on the topic of chemical bonding. The novelty or finding of this study is the development of SSI-based student worksheets specifically designed for the topic of chemical bonding, which has not been widely explored before. Chemical bonding is a highly abstract topic that involves atoms of elements bonding to form molecules with specific properties. However, this material can be connected to real-life contexts to make it more engaging and meaningful for students, for example, the habit of excessive salt and sugar consumption.

This study was implemented in the chemistry learning process to identify its contribution or influence on students' chemical literacy and scientific attitudes simultaneously through the use of Socio-Scientific Issues-based student worksheets on the topic of chemical bonding. This research seeks to answer the following questions: (1) What are the characteristics, feasibility, and practicality of the SSI-based student worksheets product?; (2) Is there a significant difference in chemical literacy and scientific attitudes between students who learn with and without the SSI-based student worksheet on the chemical bonding topic, and what is the practical contribution?. Therefore, this study is expected to effectively have a positive impact on high school students' chemical literacy and scientific attitudes after using the SSI-based student worksheets; to increase students' understanding of the importance of chemistry concepts; and to serve as a reference for teachers in designing appropriate teaching materials and instructional strategies for their students.

Method

Type of Research and Development Model

This type of research is Research and Development (R&D). The development model used is the 4D instructional development model developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I, which consists of 4 main stages, namely Define, Design, Develop, and Disseminate (Thiagarajan et al., 1974). The student worksheet developed in this research is based on Socio-Scientific Issues (SSI) on the Chemical Bond topic, and the learning steps use the Socio-Scientific Issues approach combined with the Problem-Based Learning (PBL) model.

Development Procedures

Define

The definition stage is carried out to determine the objectives and constraints of the need to develop an SSI-based student worksheet. The stage consists of initial analysis, student analysis, task and concept analysis, and formulation of learning objectives.

Design

The design stage aims to create an initial design of the student worksheets (Draft I) and the construction of a criterion-referenced test.

Develop

This stage involves the assessment of the product and research instruments by a subject matter expert lecturer and a media expert lecturer, chemistry teachers. Revisions are made to produce Draft II, followed by a readability test with 32 students of grade XI IPA 1.

Disseminate

This stage involves the large-scale implementation/effectiveness testing of the student worksheets product with students at SMA Negeri 1 Bayung Lencir.

Product Trial Design

Consists of two activities: (1) A limited trial, to test the readability of the student worksheets product and conduct empirical testing of the chemical literacy test instruments and scientific attitude questionnaire, administered to 97 students of grade XI IPA; (2) A field trial, using a quasi-experiment with a posttest-only control group design on the experimental and control classes. The field trial design in this study is presented in Table 1 (Creswell & Creswell, 2018).

Table 1. The Field Trial Design

Group	Treatment	Post Test
Experimental	X	Y_1, Y_2
Control	-	Y_1, Y_2

Description:

X : chemistry learning using SSI-based student worksheets
- : chemistry learning without using SSI-based student worksheets
Y_1 : test instrument to measure students' chemical literacy
Y_2 : test instrument to measure students' scientific attitude

Trial Subject
The sample in this study consisted of 69 students from SMA Negeri 1 Bayung Lencir, selected using cluster random sampling. Class X.3 was assigned as the experimental group and Class X.4 as the control group.

Data Collection Techniques and Instruments
The techniques used were interviews, non-tests, and tests. The data collection instruments included: interview guidelines, student needs analysis questionnaires, validation sheets by subject matter experts and media expert, product assessment sheets by practitioners, student response questionnaire, chemical literacy test instrument, and scientific attitude questionnaire instrument.

Data Analysis Techniques
The data analysis techniques used in this research are descriptive, qualitative, and quantitative.

Interview Data Analysis
The results of the chemistry teacher interview were analyzed descriptively and used as the basis for developing the SSI-based student worksheets.

Feasibility Analysis of the SSI-Based Student Worksheets
Quantitative data is in the form of assessment scores using a Likert scale of 1-5, converted into category values, then described again as qualitative data.

Test Item Analysis
The validity and reliability of the chemical literacy and scientific attitude test items were analyzed using the QUEST application. The validity test is based on the value of the infit Mean of Square (infit MNSQ) and Outfit T. The infit MNSQ value considered to fit the Rasch model ranges from 0.77 to 1.33, while the Outfit T value that fits the model is below 2.00. Then the reliability test is based on the reliability of the estimated value using Cronbach's Alpha calculation.

Analysis of Differences in Students' Chemical Literacy and Scientific Attitudes
The analysis of the results from the implementation of the developed student worksheet teaching materials on students' chemical literacy and scientific attitudes was conducted using the Multivariate Analysis of Variance (MANOVA) test and its assumptions. Finally, the eta-squared test is used to calculate the percentage of the effective contribution of using an SSI-based student worksheet on the chemical bond topic.

Results and Discussion

The product resulting from this Research and Development is a student worksheet on the Chemical Bond topic. The student worksheet was developed based on Socio-Scientific Issues (SSI), with learning steps consisting of: introduction to socio-scientific issues, problem exploration, issue clarification, discussion and decision-making, as well as reflection/evaluation. The development of these SSI-based student worksheets was carried out using the 4D development model, which includes the stages of Define, Design, Develop, and Disseminate.

Results of the Define Stage
The initial analysis indicated that the curriculum used is the independent curriculum; the learning resources used are still limited, and there is still rare use of other learning resource materials such as worksheets or modules; contextual-based learning is still rarely implemented, such as Socio-Scientific Issues-based chemistry learning, which is something new for the students. The analysis of students' characteristics revealed that they were less enthusiastic and struggled to understand

chemistry learning concepts, necessitating the use of alternative learning media. Consequently, they agreed to the development of a student worksheet incorporating socio-scientific issues relevant to everyday life. Task and concept analysis involves examining both learning outcomes and chemical bond topic concepts, specifically tailoring them to the SSI context. The final analysis in the define stage is the formulation of learning objectives, aimed at determining the indicators of achievement as a benchmark for the success of the learning process.

Results of the Design Stage

The test construction was carried out to construct a questionnaire instrument that would be used as a reference for assessing the product's feasibility based on expert validation, practicality testing, and readability testing. In addition, a questionnaire instrument was constructed to measure students' scientific attitudes, comprising 30 items of both positive and negative statements. The test instrument consists of 14 essay questions designed to assess students' chemical literacy and socio-scientific issues-based knowledge. In selecting the media and format for the development of the student worksheet, the Canva website was used as the design platform, and the presentation format was chosen to suit the characteristics of the students and the student worksheet being developed. The initial design of the developed student worksheets product consists of the cover, foreword, table of contents, student worksheets user guide, student worksheets identity, learning achievements and objectives, concept map, learning materials, learning activities on chemical bond, glossary, evaluation questions, bibliography, and author profile. The learning activities consist of two parts: the first part is atomic stability and ionic bonds; the second part is covalent bonds and metallic bonds.

Results of the Develop Stage

The third development stage is 'Develop'. This stage aims to produce a chemistry student worksheet teaching material based on Socio-Scientific Issues that is feasible and usable in chemistry learning. The process involves validation by subject matter experts and media experts, chemistry teachers as practitioners, and students for the product's readability testing. The validation of the SSI-based student worksheets product by the subject matter expert is based on four aspects: content feasibility, material presentation, the uniqueness of the student worksheets product, and language. The results of the subject matter expert validation are presented in Table 2.

Table 2. The Result of the Subject Matter Expert Validation

Aspect	Number of Indicator	Average score	Ideal Percentage	Category
Content feasibility	9	38.50	85.56%	Very Good
Material presentation	8	35.50	88.75%	Very Good
Uniqueness of the student worksheets product	3	12.00	80.00%	Good
Language	5	20.50	82.00%	Good
Total score	25	106.50	84.08%	Very Good

Based on the data in Table 2, the average product assessment score by the subject matter expert is 106.50, with an ideal percentage of 84.08%, falling into the "very good" category. The subsequent assessment by the media expert lecturer, which considers three aspects: appearance, content, and writing of the student worksheets product, is presented in Table 3.

Table 3. The Result of the Subject Media Expert Validation

Aspect	Number of Indicator	Average score	Ideal Percentage	Category
Appearance	4	16.00	80.00%	Good
Content	6	26.00	86.67%	Very Good
Writing style	4	17.00	85.00%	Very Good
Total score	14	59.00	83.89%	Very Good

Based on the data in Table 3, the average product assessment score by the subject media expert is 59.00, with an ideal percentage of 83.89%, falling into the "very good" category. The validation results from expert lecturers show that the SSI-based student worksheets product is suitable for use according to the revisions provided.

Next, the revised student worksheets product will be assessed for its practicality by two chemistry teachers from SMA Negeri 1 Bayung Lencir. The student worksheets product, revised based on expert and chemistry teacher suggestions, was tested for readability on a limited scale by 34 students from Class XI Science 3. This test aimed to gauge the responses of students who had studied the chemical bond topic to the developed product. The results of the practicality test by the chemistry teacher are presented in Table 4.

Table 4. Product Practicality Test Results

Aspect	Number of Indicator	Average score	Ideal Percentage	Category
Material	8	37.00	92.50%	Very Good
Uniqueness of the LKPD product	7	32.50	92.86%	Very Good
Language	3	12.50	83.33%	Good
Media	5	21.50	86.00%	Very Good
Total score	23	103.50	88.67%	Very Good

Based on the data in Table 1, the average score of all aspects of the student worksheet product practicality test is 103.50 out of a maximum score of 115, with an ideal percentage of 88.67%, and the product can be categorized as Very Good for use in the learning process. Meanwhile, the results of the readability test of the student worksheets produced by 34 students are presented in Table 5.

Table 5. Product Readability Test Results

Aspect	Number of Indicator	Average score	Ideal Percentage	Category
Ease of understanding the student worksheets	8	36.31	90.78%	Very Good
The appeal of the student worksheets media	2	9.22	92.22%	Very Good
Total score	10	45.53	91.49%	Very Good

Based on the readability assessment by students in Table 2, the average score of the four assessment aspects given by the students was 45.53 out of a maximum score of 50, with an ideal percentage of 91.49%, and the product can be categorized as Very Good for use in the learning process. Some responses from a student participant during the product readability test stated:

"Overall, the LKPD is very good and easy to understand for readers; the material is arranged in a logical sequence. Even though I do not usually enjoy chemistry, I became interested. The worksheets that were developed are elementary to understand and interesting to discuss. My suggestion is that the material or learning activities should not have overly long explanations, so that students do not take too much time reading them. "The worksheets are excellent. However, the material is still difficult to understand".

The final student worksheets product is in printed form using A4 paper size; the Chemical Bond topic covered in each learning activity is supported by Socio-Scientific Issues that are relevant to everyday life. The SSIs and their relevance to the chemical bond material are presented in Table 6.

Table 6. Integration of SSI Discourse into the Concept of Chemical Bond Topic

Chemical Bond Concept	Integration of Socio-Scientific Issues
Atomic stability and Ionic Bonds	Sea salt and Himalayan salt issues
Covalent Bonds and their Properties	Wrong tea serving
Coordinate covalent and Lewis structures.	Global warming is getting worse.
Metallic Bonds	Electric vehicle issues

The issue regarding sea and Himalayan salt was chosen because their constituent elements consist of positively and negatively charged ions, namely Na and Cl, which are related to ionic bonding. The technique of tea serving is also chosen as the context because the sugar and water compounds used in making tea, with the chemical formulas CH_2O and H_2O, respectively, when broken down, are classified as covalent bond substances. In addition, the phenomenon of global warming occurring in many regions is also an unresolved issue. Gases resulting from the combustion of fossil fuels that accumulate in the atmosphere consist of CO_2, CO, and SO_x. These waste gases can be related to the subtopic of covalent bonding. The last issue chosen is the issue of electric vehicles as one of the ways to address global warming, which remains controversial. Electric vehicle use Lithium metal batteries, and this is related to the subtopic of metallic bonding. The cover page appearance of this SSI-based student worksheet is presented in Image 1.

Image 1. Student Worksheet Cover Page

This cover page contains the student worksheet title, logo, student identity section, name of the student worksheet author, grade level, and an image to attract students' interest. Several learning activities are presented in Image 2.

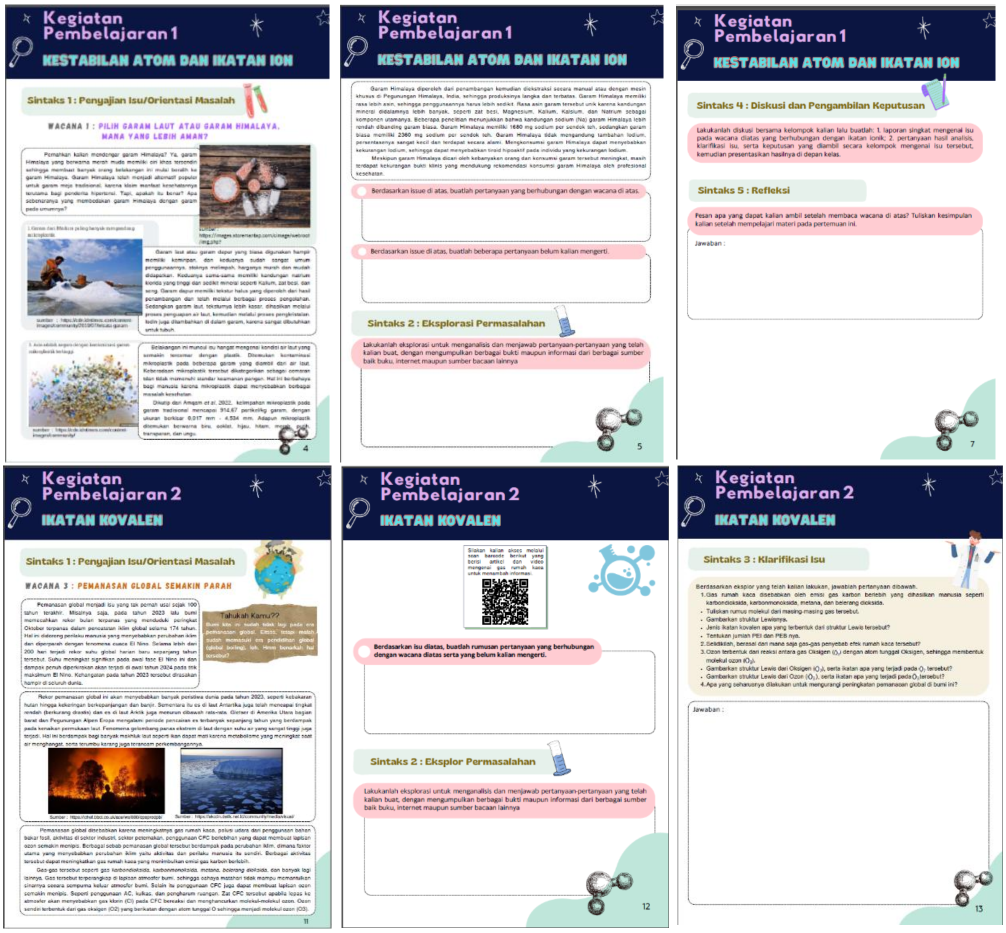

Image 2. Learning Activities

The learning activities include sub-materials supplemented with SSI discourse in the first syntax, namely the presentation of the issue/problem orientation. Learning Activity 1 contains material on atomic stability and ionic bonds; Learning Activity 2 covers covalent bonds; and Learning Activity 3 discusses metallic bonds. Each learning activity is equipped with Problem-Based Learning syntax adapted to the Socio-Scientific Issues approach.

In addition to the student worksheets and products that were assessed, the chemical literacy test instruments and scientific attitude questionnaires were also tested for validity and reliability. In the validity test, the results showed that for the chemical literacy questions, the average MNSQ infit value was 1.007 and the average Outfit-T value was below 2.00; while for the scientific attitude questionnaire statement items, the average MNSQ infit value was 0.998 and the average Outfit-T value was below 2.00. This means that all chemical literacy descriptive questions and scientific attitude questionnaires are declared valid for use in the implementation of the research because they are in accordance with the Rasch model. In the reliability test of the chemical literacy items, the reliability coefficient in the Summary of Item Estimates was 0.49, which falls into the "moderate" category, while the coefficient in the Summary of Case Estimates was 0.74, which falls into the "high" category. This indicates that the post-test items for chemical literacy are sufficiently reliable and the students' responses are consistent. In the reliability test of the scientific attitude questionnaire items, the reliability coefficient in the Summary of Item Estimates was 0.00, which falls into the "very low" category, while the coefficient in the Summary of Case Estimates was 0.87, which falls into the "very high" category.

Results of the Disseminate Stage

At this stage, product effectiveness testing (large-scale trial) was conducted at SMA Negeri 1 Bayung Lencir, involving two class groups: X.3 as the experimental class and X.4 as the control class. Subsequently, the product was disseminated by handing over the SSI-based LKPD to the chemistry teacher at the school.

Product Trial Results

The average post-test scores for chemical literacy and scientific attitudes of students in the experimental and control classes are presented in Table 7.

Table 7. Posttest Score of Experimental and Control Classes

Class	Chemical Literacy post-test	Scientific Attitude Questionnaire
Experimental (N = 34)	76.44	90.88
Control (N = 35)	54.83	86.67

Based on the data in Table 7, the average scores for chemical literacy and scientific attitude of students in the experimental class were higher than those in the control class, indicating that the use of the Socio-Scientific Issues-based student worksheet on the chemical bond topic had a significant effect on students' chemical literacy and scientific attitudes.

MANOVA Assumption Test

To see the influence of differences in chemical literacy and scientific attitudes of students in the experimental class and control class, the Multivariate Analysis of Variance (MANOVA) test and its assumptions were carried out using IBM SPSS Statistics 27. The assumptions test for MANOVA includes: 1) there are two dependent variables, namely students' chemical literacy and scientific attitude; 2) there are two independent variables, namely chemistry learning on Chemical Bonding material in classes using SSI-based worksheets and classes not using the worksheets; 3) has observational independence; 4) an adequate research sample size, namely 34 students in the experimental class and 35 students in the control class; 5) no univariate or multivariate outliers; 6) the relationship between variables in the experimental and control class follow a multivariate normal distribution; 7) there is a linear relationship between the independent and dependent variables, both within and between groups; 8) the data comes from a population with a homogeneous variance-covariance matrix; 9) there is no indication of multicollinearity among the independent variables.

Hypothesis Test Results

The MANOVA test was then conducted using IBM SPSS to determine the influence of differences between the experimental and control groups. The simultaneous test results using Hotelling's Trace showed a significance value of <0.001 and a practical contribution of 0.442, indicating that there was a highly significant difference in chemical literacy and scientific attitudes simultaneously between students who used and did not use the student worksheets.

The results of the test of between-subject effects for chemical literacy showed a significance value of <0.001, with a practical contribution of 0.441. This indicates that there was a highly significant difference in chemical literacy between the class using SSI-based student worksheets and the one that did not. The higher chemical literacy ability of students in the experimental class compared to the control class was also evidenced by the average chemical literacy scores. These results are consistent with the findings of other relevant studies (Pambudi et al., 2018; Hisyam & Handayani, 2024; Qalfin et al., 2024), which show that contextual learning involving socio-scientific issues, either independently or when integrated into student worksheets during the learning process, is effective and has a significant influence on students' chemical literacy skills. The influence can be seen in several aspects, including students' ability to understand chemical concepts well, explain chemical phenomena at the microscopic level in everyday life, comprehend texts or articles and analyze information related to chemical issues through discussions during the learning process, as well as their ability to make informed decisions in socio-scientific debates concerning issues related to chemical bonding topics.

As for the results of the test of between-subject effects for scientific attitude, the significance value was 0,102, which is greater than 0.05, with a practical contribution of 0.040. This indicates that there was no significant difference or learning in the experimental class that used SSI-based student worksheets, and the control class, which did not use them, did not have a large influence on the scientific attitude variable. The absence of a significant difference in the scientific attitude variable suggests that other variables, such as the improvement in students' chemistry literacy, have a more significant influence on learning using SSI-based worksheets. Another contributing factor is that the average scientific attitude scores of the experimental and control classes were not substantially different, as well as the lack of reliable instruments for measuring scientific attitude. This is evidenced by the reliability test results, where the Reliability of Item Estimate was 0.00. However, in terms of validity, the instrument was valid, as shown by the infit MNSQ values falling within the acceptable range of 0.77 to 1.33. Another factor is that a scientific attitude is an aspect of attitude that is not always clearly observable in research actions, but rather serves more as a foundational basis for conducting research.

The strength of this study lies in the use of SSI-based student worksheets for the topic of chemical bonding, which is highly abstract. This approach has been proven to enhance students' chemical literacy significantly. Moreover, this study makes an important contribution to the development of contextual teaching materials that are relevant to students' real-life experiences. Unlike previous studies that focused on only a single variable and did not involve the development of instructional materials, this research comprehensively examines two aspects: chemical literacy and scientific attitudes, thus providing a more holistic view of the impact of SSI-based learning.

A limitation of this study is that the SSI discourse in the worksheets served primarily as a reference and a source of learning inspiration to prevent students from becoming disengaged with abstract chemistry content. However, the limited relevance of the issues to the topic of chemical bonding posed a challenge for the researcher in helping students fully understand the material, despite the contextual issues presented. Another limitation is the possibility that some students completed the scientific attitude questionnaire without adequate seriousness or did not fully reflect their proper attitudes, which may have contributed to the absence of a significant difference between the experimental and control groups.

Conclusion

The product developed in this study is a student worksheet characterized by the use of Socio-Scientific Issues (SSI) in the chemical bonding topic in Grade 10 of the independent curriculum. The product is deemed feasible and practical for use in classroom chemistry learning after undergoing an assessment process. Simultaneously, there is a statistically significant difference in students' chemical literacy and scientific attitudes between those who received instruction using the SSI-based student worksheet and those who did not. The results of the Test of Between-Subject Effects indicate that there is a highly significant difference in students' chemistry literacy. However, there is no significant difference in students' scientific attitudes. Therefore, further research is needed on the effect of using Socio-Scientific Issues-based student worksheets on students' scientific attitudes, particularly in chemistry topics that are highly abstract. In addition, the use of language that students easily understand is crucial when constructing scientific social discourse or issues, both in the development of products and in research instruments.

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