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A Needs Analysis for the Development of Problem-Based Learning Student Worksheets Integrating Socio-Scientific Issues in the Topic of Reaction Rates to Enhance the Critical Thinking Skills of Senior High School

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Abstract

Instruction on reaction rates continues to face challenges in helping students grasp abstract concepts, link these concepts to real-world phenomena, and develop critical thinking skills. Furthermore, the Student Worksheets (LKM) currently used in schools do not optimally support contextual learning or problem-solving activities. Integrating Problem-Based Learning (PBL) with Socio-Scientific Issues (SSI) into these worksheets offers a relevant approach to introducing real-world problems as learning contexts that foster analysis, argumentation, and scientific decision-making. This study aimed to identify the requirements for developing Student Worksheets that incorporate a PBL model integrated with SSI for the topic of reaction rates. A descriptive method utilizing a survey approach was employed to assess development needs. The study participants consisted of 5 senior high school chemistry teachers and 71 senior high school chemistry students in West Sumatra. Data were collected through teacher interviews and student needs questionnaires using a Likert scale. The findings indicate that the majority of students still struggle to understand reaction rate concepts and relate them to everyday phenomena. Additionally, students require contextually designed worksheets to support their learning, and there was unanimous student support for the development of PBL-SSI integrated worksheets. Students also expressed a need for engaging, contextual teaching materials that facilitate problem-solving activities to hone critical thinking skills. These findings serve as the foundation for developing PBL-SSI integrated worksheets designed to connect reaction rate concepts with contextual issues while simultaneously fostering students' critical thinking skills.

Keywords: Student worksheet, Problem Based Learning, Socio-Scientific Issues, reaction rate, critical thinking

Introduction

Enhancing critical thinking skills is a key aspect of 21st-century science education. These skills enable students to process and analyze information, evaluate problems objectively, and make decisions based on research findings and scientific evidence (Hixson, 2012; Widyawati, et al. 2021). In science education, these skills are essential because the learning process focuses not only on mastering concepts but also on the ability to apply them to solve real-life problems (Facione, 2015).

Chemistry learning has characteristics that are different from other fields of science because it involves three levels of representation: macroscopic, submicroscopic, and symbolic. The relationship between these three representations often poses a challenge for students because many chemical concepts are abstract and require complex thinking skills to understand them (Johnstone's, 2000). Reaction rate is a topic in chemistry instruction that involves a high degree of conceptual abstraction. Discussions on this topic include collision theory, various factors affecting reaction rates, forms of rate equations, and solving calculations that require mastery of concepts and analytical skills Students' difficulties in understanding reaction rate material may arise because they need to connect microscopic concepts with directly observed phenomena (Gilbert & Treagust, 2009). Thus, instruction is needed in order to help students connect chemical concepts with real-world phenomena through meaningful learning activities.

The quality of learning can be improved by providing instructional materials designed with students' characteristics, learning needs, and the current learning situation in consideration. Appropriate instructional materials can help optimize student engagement in the learning process (Perwitasari & Akbar, 2018). One type of instructional material that can be utilized is the student worksheet, which is designed to facilitate guided learning activities through stages of observation, inquiry, and problem-solving (Ika et al., 2020). However, the current use of student worksheet generally still focuses on conveying concepts and providing practice problems, so they are not yet fully capable of supporting the development of higher-order thinking skills, particularly students' critical thinking skills. Meanwhile, high-quality instructional materials should serve as sources of information and encourage students to actively participate in the process of constructing their knowledge and understanding (Berlian et al., 2023). Therefore, it is necessary to develop student worksheets that are integrated with appropriate learning models or approaches to help enhance students' critical thinking skills.

One educational approach that can enhance students' critical thinking skills is problem-based learning (PBL). The PBL model places a problem at the center of the learning process, guiding students to explore information, conduct investigations, connect the concepts they have learned, and generate alternative solutions. Students' active involvement in problem-solving activities within PBL can help develop higher-order thinking skills (Hmelo-Silver, 2004). In addition to the PBL model, the Socio-Scientific Issues (SSI) approach can serve as an alternative for creating chemistry learning experiences relevant to real-life contexts. The SSI approach links scientific concepts to various issues arising in the community, enabling students to see the connections between scientific knowledge, environmental problems, and social aspects (Zeidler et al., 2009). Implementing SSI-based learning has the potential to support the development of students' critical thinking skills through activities such as analyzing issues, expressing opinions based on evidence, and making decisions that take scientific aspects into account (Sadler et al., 2017). With this approach, students not only focus on understanding concepts but also trained to evaluate a problem from various perspectives before formulating a solution.

Many studies have demonstrated that the application of problem-based learning (PBL) can facilitate students' conceptual understanding through conducting investigative activities, discussions, and problem solving, which enhances the development of critical thinking

abilities (Hmelo-Silver, 2004). Moreover, (Gazali & Dasna, 2023) revealed that students' critical thinking skills are boosted when chemistry education is prepared with activities of analyzing, solving problems, and connecting concepts to real life circumstances. In addition, it is said that the use of PBL-based Student Worksheets can increase critical thinking abilities by doing activities such as identifying problems, analyzing material, and finding alternative solutions (Khovivah et al., 2022). Therefore, systematic arrangement of chemistry instructional materials designed to fulfill the needs of learning will be able to improve the conceptual understanding and can support the development of critical thinking abilities (Gazali, Yusmita & Ningsih, 2019). The results indicate that the development of PBL-based instructional materials has the potential to provide a more meaningful chemical learning experience that targets the development of higher-order thinking skills

On the other hand, the Socio-Scientific Issues (SSI) approach can provide a more contextual learning experience by relating scientific concepts to various real-world issues arising in society (Zeidler et al., 2009) .SSI-based learning has been reported to enhance students' ability to argue, think critically, and make scientific decisions through activities that involve analyzing various perspectives on a given problem (Sadler et al., 2017). The integration of Socio-Scientific Issues (SSI) with Problem-Based Learning (PBL) creates more meaningful learning experiences by engaging students with authentic real-world issues that connect scientific concepts to everyday life. Through this approach, students not only develop a deeper understanding of scientific concepts but also integrate scientific knowledge to analyze and solve problems encountered in their surrounding environment (Pernaa & Lizethly, 2021). Thus, the integration of PBL and SSI has the potential to create a learning experience that is oriented not only toward conceptual mastery but also toward the ability to analyze real-world problems and make decisions based on scientific evidence.

Nevertheless, the results of initial interviews with five high school chemistry teachers in West Sumatra indicate that students still struggle to understand the concept of reaction rate, particularly abstract concepts, solving chemical calculations, and connecting the material to everyday phenomena. Teachers also noted that the worksheets used to date have not been effective in fostering the development of critical thinking skills, as they remain dominated by material presentation and practice problems. These findings indicate a need to develop instructional materials that are more contextual, problem-solving oriented, and capable of facilitating higher-order thinking activities. Although numerous studies on PBL and SSI have been conducted, research specifically integrating PBL syntax with the SSI context in the development of worksheets on reaction rate material to train students' critical thinking skills remains limited. This situation forms the basis for the need to conduct this study.

In line with these findings, a review of the literature indicates that although numerous studies have been conducted on the use of PBL and SSI, most still apply these two approaches separately. Furthermore, research specifically aimed at developing learning materials by integrating PBL syntax and SSI context into reaction rate content to foster students' critical thinking skills remains limited. In fact, the characteristics of reaction rate material, which relate to various social and environmental issues, such as the use of food preservatives, corrosion control, and industrial process efficiency, have the potential to be examined through the SSI approach within a problem-based learning framework.

Needs analysis is a crucial step in the process of developing instructional materials that can be tailored to the characteristics of the learning process and the needs of users, including both teachers and students. This study's novelty lies in its needs assessment for developing worksheets that integrate Problem-Based Learning (PBL) with Socio-Scientific Issues (SSI), specifically focusing on reaction rates to foster critical thinking skills among high school students. Thus, this study aims to identify the need for the development of worksheets based

on problem-based learning (PBL) integrated with socio-scientific issues (SSI) regarding reaction rates in order to train students' critical thinking skills.

Method

This study employed a descriptive method using a survey approach to gather information regarding the need to develop Problem-Based Learning (PBL)-based student worksheets integrated with Socio-Scientific Issues (SSI) on the topic of reaction rates as an effort to cultivate students' critical thinking skills. The descriptive method was chosen because this study focuses on describing conditions or phenomena based on data collected from research subjects without the application of any specific treatment. In research on the development of instructional materials, needs analysis is a crucial initial stage for obtaining information regarding user needs before a learning product is developed (Ika et al., 2020).

Research subjects consisted of five high school chemistry teachers and 71 11th-grade senior high school students from several schools in West Sumatra who had studied the topic of reaction rates. The research subjects were selected using purposive sampling, taking into account that the teachers and students had already been involved in learning about reaction rates and were therefore able to provide relevant information regarding the need for the development of worksheets. The selection of research subjects was conducted to obtain information regarding learning conditions, student difficulties, the use of teaching materials, and the need for the development of appropriate worksheets.

The instruments used in this study consist of an interview guide for teachers and a student needs analysis questionnaire. Before being used in the data collection process, all instruments were first validated by three faculty members who are experts in the field of chemistry education. This validation aimed to evaluate the appropriateness of the content, the clarity of the language, and the relevance of the instruments to the research objectives. The validators' assessment results were then used as a reference for refining the instruments to ensure they were suitable for use during the data collection phase.

Interview guidelines were used to collect information on the implementation of chemistry instruction, students' difficulties with reaction rate material, critical thinking skills, the use of worksheets, the application of the PBL model and teachers' understanding of the SSI approach. Interviews were selected because they enable a more thorough examination of respondents' experiences, perceptions and needs (Ika et al., 2020).

A needs assessment questionnaire was administered to 71 students using a five-point Likert scale, as presented in Table 1. The questionnaire was designed to gather data on learning difficulties regarding reaction rate material, the use of learning materials in instruction, the need for contextual learning, the need to develop critical thinking skills, and the need for PBL-based learning materials integrated with SSI. The use of the questionnaire in the needs analysis aimed to obtain an overview of users' needs regarding the teaching materials or learning resources to be developed (Ika et al., 2020).

Tabel 1. Five-point Likert scale

Score	Response Categories	Description
5	Strongly Agree (SA)	Indicates that students strongly need or strongly agree with the given statement
4	Agree (A)	Indicates that the student needs or agrees with the given statement
3	Less Agree (LA)	Indicates whether students find the statement relevant or do not fully agree with it

Score	Response Categories	Description
2	Disagree (D)	Indicates that students have little need for or disagree with the statement
1	Strongly Disagree (SD)	Indicates that the student does not need or strongly disagrees with the statement

Data obtained through interviews were analyzed using qualitative descriptive techniques in several stages: data reduction, data organization or presentation, and the formulation of conclusions. Subsequently, the information from the interviews was categorized based on specific themes related to the needs for student worksheet development. Data from teacher interviews and student needs surveys were analyzed using percentage calculations based on the following formula:

$$P = \frac{f}{N} x\ 100\%$$

Where:
P = Response percentage
f = Total score obtained
N = Maximum possible score

The percentage results are used to illustrate the level of student need for the development of SSI-integrated PBL-based student worksheet. The higher the percentage obtained, the greater the need for the development of the proposed instructional materials.

Results and Discussion

Needs Analysis Based on Teacher Interviews

The initial phase of the needs analysis was conducted through interviews with five high school chemistry teachers in West Sumatra. These interviews aimed to gather information regarding the teaching of the reaction rate topic, challenges faced by students during the learning process, the use of existing instructional materials, the implementation of learning models, and the need to develop student worksheets capable of fostering critical thinking skills.

The interview data were analyzed based on several aspects related to the development needs of the student worksheet. Table 2 presents the percentage for each aspect, calculated based on the number of teachers who provided similar statements out of the total five teachers interviewed.

Table 2. Results of the Needs Analysis Based on Teacher Interviews

No	Aspects Analyzed	%
1	The state of chemistry learning is not yet optimal.	60%
2	Students have difficulty understanding the concept of reaction rate.	100%
3	Students experience difficulties with chemical calculations.	80%
4	Students struggle to connect concepts with everyday life.	80%
5	Students' critical thinking skills still need to be improved.	100%
6	The student worksheets currently in use are not yet capable of optimally fostering critical thinking.	100%
7	The available student worksheets still need to be developed in terms of content and learning activities.	80%
8	Teachers need problem-solving-based student worksheets.	80%
9	The implementation of Problem-Based Learning (PBL) is not yet optimal.	60%

10	The Socio-Scientific Issues (SSI) approach has not yet been specifically implemented.	80%
11	Teachers need student worksheets that are contextual and relevant to students' lives.	100%

Based on the data in Table 2, all responding teachers (100%) indicated that students still face obstacles in understanding the concepts within the reaction rate topic. Furthermore, the majority of teachers (80%) stated that students also encounter difficulties in performing chemical calculations and relating reaction rate concepts to phenomena encountered in daily life. These results demonstrate that learning difficulties regarding reaction rates are influenced not only by calculation-related aspects but also by the ability to grasp concepts in depth. This situation is likely linked to the nature of the reaction rate topic, which requires students to integrate various levels of chemical representation : namely macroscopic, submicroscopic, and symbolic. According to (Johnstone's, 2000), the inability to handle these three representations is a primary cause of difficulties in learning chemistry. Therefore, the developed instructional materials need to incorporate activities that assist students in interpreting and analyzing chemical phenomena.

All responding teachers (100%) also stated that students' critical thinking skills need improvement. Students still struggle to analyze information, evaluate problems, and provide scientific justifications for solutions. This situation indicates that the implemented instructional process has not yet fully engaged students in activities that stimulate higher-order thinking skills. These findings reveal that current learning activities have not sufficiently encouraged students to develop the ability to interpret information, analyze problems, and evaluate concepts or phenomena. This condition aligns with the critical thinking indicators proposed by (Facione, 2015). Therefore, activities within the Student Worksheet need to be designed so that each stage of learning fosters these indicators.

Regarding teaching materials, all teachers (100%) stated that the student worksheets currently in use are not yet optimal for fostering critical thinking skills, while four out of five teachers (80%) indicated that the available worksheets require further development in terms of content and learning activities. The worksheets predominantly consist of material summaries and practice questions, thereby failing to fully provide students with opportunities to analyze problems, evaluate information, and formulate solutions. These findings highlight the need to develop worksheets that serve not only as learning resources but also as tools to facilitate critical thinking activities.

Interview results also revealed that the majority of teachers (80%) expressed a need for problem-solving-based student worksheets, while 80% stated that the SSI approach had not yet been specifically implemented in instruction. These findings indicate a need to integrate problem-based learning with real-world issues relevant to students' lives. According to (Sadler et al., 2017), the SSI approach can help students connect scientific concepts with social and environmental aspects, thereby fostering argumentation skills and evidence-based decision-making. Therefore, integrating PBL and SSI offers a suitable alternative for supporting a more contextual approach to learning about reaction rates.

Needs Analysis Based on Student Questionnaires

A needs analysis was also conducted via a questionnaire administered to 71 high school students in West Sumatra, the results of which are presented in Table 3. The questionnaire aimed to assess the students' learning experiences and their needs regarding the development of Student based on Problem-Based Learning (PBL) and integrated with Socio-Scientific Issues (SSI).

Table 3. Results of the Student Needs Questionnaire

No	Aspects Analyzed	%
1	Difficulty understanding the material on reaction rates.	97,18%
2	Difficulty connecting concepts to real life	95,77%
3	Instruction still focuses on formulas and calculations.	98,59%
4	The topic of reaction rates is difficult to understand.	94,37%
5	The Student Worksheets have not yet fully helped in understanding the material.	77,46%
6	The Worksheets has not yet fostered critical thinking skills.	91,55%
7	Requires engaging and contextual student worksheets.	98,59%
8	Interested in learning using real-world problems.	95,77%
9	Interested in addressing social and environmental issues.	94,37%
10	Requires learning that fosters critical thinking.	97,18%
11	Requires an SSI-based Student Worksheet	95,77%
12	Agreed to the development of PBL-based student worksheets integrated with SSI.	100%

Analysis of the questionnaire results reveals that the majority of students (97.18%) still face challenges in understanding concepts related to reaction rates, while 95.77% struggle to relate these concepts to everyday phenomena. Furthermore, 98.59% of students reported that the learning process remains predominantly focused on the use of formulas and calculation-based problem-solving. These findings indicate that instruction on reaction rates places greater emphasis on procedural mastery than on conceptual understanding or the ability to apply concepts in real-world situations. If this situation persists, students may face obstacles in developing a deeper and more meaningful understanding of the subject matter.

The high percentage of students struggling to grasp the material on reaction rates indicates that instruction has yet to effectively bridge macroscopic, submicroscopic, and symbolic representations. These findings align with (Johnstone's, 2000) view that difficulties in learning chemistry often stem from students' inability to connect these three representations. Consequently, learning activities should be geared toward concept discovery through inquiry. The Problem-Based Learning (PBL) model is well-suited for this purpose, as it uses problems as a starting point for learning, thereby encouraging students to analyze, seek information, and construct solutions (Hmelo-Silver, 2004).

However, the use of PBL alone is insufficient to provide a real-world context for learning. Integrating SSI is necessary to ensure that the problems presented in the student worksheets relate to social and environmental issues relevant to the students' lives. Combining PBL and SSI enables students not only to solve problems conceptually but also to consider impacts, scientific evidence, and diverse perspectives when making decisions (Sadler et al., 2017).

Regarding teaching materials, 91.55% of students stated that the student worksheets currently used were not optimal for fostering critical thinking skills, while 98.59% expressed a need for engaging and contextual worksheets. This indicates that the product to be developed should incorporate features such as the presentation of real-world problems, analytical questions, inquiry-based activities, and reflection on solutions.

All students (100%) expressed agreement with the development of SSI-integrated, PBL-based student worksheets. These findings indicate that students desire learning experiences that are closer to their daily lives and provide opportunities for active engagement in problem-solving. (Hmelo-Silver, 2004) stated that PBL can help students construct knowledge through processes of inquiry and problem-solving, while the SSI approach helps students connect scientific concepts to real-world issues emerging in society (Zeidler et al., 2009).

Synthesis of the Needs Analysis Results for Developing SSI-Integrated, PBL-Based Student Worksheets

Analysis based on teacher interviews and student questionnaires reveals a shared pattern regarding learning needs. Both teachers and students indicated that reaction rates remain a difficult topic to grasp, largely because instruction focuses heavily on solving calculations. Furthermore, the student worksheets currently in use have not effectively fostered critical thinking skills, as most activities consist primarily of content delivery and practice problems. These findings suggest a need for teaching materials that facilitate contextual learning, incorporate problem-solving, and relate to real-life situations relevant to the students' own lives. This aligns with the view (Gazali & Dasna, 2023) that chemistry instruction involving higher-order thinking activities and real-world problem contexts can help enhance students' critical thinking skills. Therefore, the development of SSI-integrated, PBL-based student worksheets is expected to serve as an alternative teaching resource capable of facilitating conceptual understanding while simultaneously fostering students' critical thinking skills.

Based on the needs analysis, the development of Student Worksheets on the topic of reaction rates needs to be designed by integrating the stages of the Problem-Based Learning (PBL) model with the context of Socio-Scientific Issues (SSI). The PBL model is employed because it facilitates students' understanding of problems through inquiry activities, analysis processes, and the formulation of alternative solutions based on the given problems (Hmelo-Silver, 2004). On the other hand, the SSI approach plays a role in introducing real-world issues related to social and environmental life, enabling students to understand chemistry concepts more meaningfully and consider scientific evidence in the decision-making process (Zeidler et al., 2009). Therefore, integrating PBL and SSI serves as a suitable alternative for developing student worksheets, as it addresses the need for learning that is contextual and problem-oriented while supporting the enhancement of students' critical thinking skills.

The needs analysis also indicates that the student worksheet to be developed should possess the following key characteristics: (1) presenting real-world phenomena or issues as a problem orientation; (2) incorporating inquiry activities aligned with the Problem-Based Learning syntax; (3) providing questions that encourage analysis and scientific argumentation; (4) integrating Socio-Scientific Issues (SSI) relevant to the topic of reaction rates; and (5) facilitating reflection and solution evaluation activities. These designed characteristics are expected to support students in understanding the concept of reaction rates more deeply and meaningfully, while simultaneously developing critical thinking skills: encompassing interpretation, analysis, evaluation, inference, explanation, and self-regulation as outlined by Facione (Facione, 2015). Therefore, the development of Student Worksheets based on Problem-Based Learning (PBL) and integrated with Socio-Scientific Issues (SSI) is expected to yield teaching materials that are contextual, innovative, and aligned with the needs of chemistry learning in schools.

Conclusion

A needs analysis indicates that developing Student Worksheets based on Problem-Based Learning (PBL) and integrated with Socio-Scientific Issues (SSI) for the topic of reaction rates is necessary to create more contextual chemistry learning and to foster the development of students' critical thinking skills. The analysis also reveals that students struggle to grasp reaction rate concepts, link chemistry content to real-life phenomena, and develop critical thinking abilities. Furthermore, the worksheets currently in use do not fully support inquiry, analysis, and problem-solving activities. Therefore, the worksheets to be developed must be contextual, grounded in real-world problems, and include activities that cultivate students' critical thinking skills. Integrating PBL and SSI offers a suitable approach, as it guides students to understand chemistry concepts through problem-solving processes and the examination of

real-life issues. Nevertheless, this study was limited to the needs analysis stage and therefore did not include the development, validation, or evaluation of the practicality and effectiveness of the proposed student worksheet. In addition, the study involved only five senior high school chemistry teachers and 71 senior high school students from West Sumatra, Indonesia, limiting the generalizability of the findings to broader educational contexts. Therefore, the findings of this study provide an empirical foundation for future research to develop, validate, and evaluate the practicality and effectiveness of a PBL-based student worksheet integrated with Socio-Scientific Issues (SSI) in improving students' critical thinking skills.

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