

DEVELOPMENT OF ELECTRONIC STUDENT WORKSHEETS BASED ON PROBLEM-BASED LEARNING USING INTERACTIVE COMICS ON REACTION RATE MATERIAL

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Abstract

This study aims to determine the feasibility of electronic student worksheets (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the material of reaction rate and student responses, and teachers using electronic student worksheets (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the material of reaction rate. This study is a research and development (R&D) project utilizing the ADDIE development model (analysis, design, development, implementation, and evaluation), focusing on the implementation stage, including field trials. The study results were obtained with an average material validation of 75 percent and an average media expert validation of 89.06 percent; through these data, the results of product validation from material and media experts were 82.03 percent, with a very valid category and feasible to use. In the acquisition of field trial data, the average student response was 82.72 percent, with a very positive category for use, and the results of teacher responses were obtained at 96.73 percent, with a very positive category. So, electronic student worksheets (e-SWS) based on Problem-Based Learning, assisted by interactive comic media on reaction rate material, are feasible. They can be used as teaching materials in the learning process.

Keywords: Teaching Materials; e-SWS; Problem-Based Learning; Interactive Comics

doi <https://doi.org/10.24815/jcd.v13i1.45416>

Received: April 7, 2025; **Revised:** May 7, 2025; **Accepted:** May 12, 2025; **Published:** 5 June 2025.

Citation IEEE style: N.S. Rachmi and L. Simatupang, "Development of electronic student worksheets based on problem-based learning using interactive comics on reaction rate material," *Chimica Didactica Acta*, vol. 13, no. 1, pp. 12-20, 2025, doi: 10.24815/jcd.v13i1.45416.

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INTRODUCTION

The *Merdeka Belajar* Curriculum is a curriculum that emphasizes freedom and independence in learning. It allows students to explore their interests, develop their learning paths, and acquire competencies relevant to the 21st century [1]. The *Merdeka Belajar* Curriculum focuses on competency-based learning, where students are encouraged to develop a deep understanding of concepts and skills through active engagement and problem-solving. It promotes using online resources, educational applications, and digital platforms to enhance the learning experience and provide access to various learning materials [2]. In this case, teachers face innovations in teaching materials, including student worksheets.

Generation Z, or Zoomers, is a generation born between 1997 and 2012 and currently taught by teachers [3]. Generation Z is a generation that is closely related to technology in everyday life. Therefore, teaching Generation Z must adapt to technology, and a few students tend to experience a decline in literacy. Students' interest in literacy is another obstacle to achieving a good learning and teaching process. The factor of the lack of interest in student literacy is that in the era of Generation Z, students are

heavily involved with technology, so students often see things that smell of visual or audio content. In Generation Z, they usually multitask, so this is a factor in the lack of student literacy.

Based on data obtained from research by Permatasari [4], the results of both internal and external surveys state that student literacy in Indonesia is still low. This is also supported by PISA 2022 (Program for International Student Assessment) results, which ranked Indonesia 68th out of 81 countries. Indonesia has increased in level compared to 2018, when it was ranked 62nd out of 70 [5]. Thus, student science literacy in Indonesia is still relatively low and requires solutions to improve science literacy, even though it has increased previously. Through these problems, interactive comic media is one solution to good learning media that can improve student literacy [6].

Interactive comic learning media is a method that combines visual and narrative elements of comics with interactivity that allows students to participate in the learning process actively. This media can attract students' attention and make the subject matter more interesting and easier to understand. The development of interactive comic media in a teaching and learning process is one of the

innovations in terms of learning media, where interactive comics contain distinctive images arranged with a mixture of words that are packaged as attractively as possible so that they are expected to be able to improve students' conceptual understanding of the material [7]. Based on this statement, in line with previous research, the results of learning products using expert response comics and students, where comic products are considered very valid to improve the learning and teaching process very well [8]. Other studies show that comic learning media in chemistry subjects can help support students to study chemistry according to the current curriculum [9].

Chemistry is a subject that is very closely related to everyday life, because chemistry represents natural elements and chemical reaction processes that sometimes make it difficult for students to visualize a chemical discussion correctly and adequately. According to Waruwu & Sitinjak [10], many students in schools are less interested in learning chemistry, and students also show a lack of involvement in learning. This is due to the lack of interesting learning media used by teachers, where the learning methods and media used are mostly lecture methods and only use PowerPoint. Through this problem, it is one of the factors that students feel bored and do not even understand the material that will be taught by the teacher, especially the abstract reaction rate material to be understood clearly. So the reaction rate material needs to be visualized so that students can understand the concepts covered in the material.

The Problem-Based Learning (PBL) model involves students in analyzing, diagnosing, formulating, and evaluating a problem presented [11]. Problem-based learning has several advantages. Namely, students are actively engaged in each activity so that the material being studied is well absorbed, students can practice in a group to work together, and students can gain knowledge from various sources [12]. According to Fadila [13], electronic student worksheets (e-SWS) based on Problem-Based Learning can improve scientific literacy skills with a moderate category and a percentage of 82.61%. Problem-based learning can improve students' scientific literacy by connecting scientific concepts with problems that exist in real life. As explained in previous research, using comics in education can increase students' motivation and active participation, improve understanding of scientific concepts and awareness of sustainable development issues [14].

METHOD

This research was conducted at Senior High School 17 Medan, and the research subjects were divided into two parts, namely, the subject of the product design trial or expert test and the subject of the field trial. The subject of the product design trial or expert test was carried out by three people: one person as a material expert, one as a

media expert, and one as a questionnaire validator, who were selected as competent in their respective fields. The subject of the field trial was carried out by testing the learning media in class. The trial was conducted on one of the 11th-grade high school chemistry subjects, the reaction rate material, and three high school chemistry teachers. The object of this study is the development of electronic student worksheets (e-SWS) based on Problem-Based Learning, assisted by interactive comic media on the reaction rate material.

This study's research type is research and development or research and development (R&D). The research and development (R&D) method produces certain products and tests their effectiveness [15]. The product developed by the researcher is an electronic student worksheet (e-SWS) on the reaction rate material for one semester, using interactive comic media based on Problem-Based Learning. The development model used in this study is the ADDIE model, or Analyze, Design, Development, Implementation, and Evaluation, developed by William Lee and Diana Owens. This research model was chosen because it can describe a systematic approach in development, where this process will reach the pre-evaluation stage. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) is a powerful framework for developing educational learning media due to its structured, iterative, and learner-centered approach. It begins with a thorough Analysis of learners' needs, ensuring the product is tailored to their context. The Design phase establishes clear objectives, content scope, and instructional strategies aligned with educational goals. During Development, prototyping and iterative testing refine the media for effectiveness. The Implementation phase ensures smooth deployment in real-world settings, often accompanied by training for instructors. Finally, Evaluation uses both formative and summative assessments to measure effectiveness and guide continuous improvement. This adaptable, evidence-based approach ensures that learning media is purposeful, effective, and responsive to diverse educational needs, making it ideal for traditional and innovative tools like AR-based applications.

The data collection tool in this study uses a questionnaire or checklist. Data collection or research tools are used to measure research variables and find answers to previously formulated problems. The preparation of assessment tools is divided into three types depending on the role and position of the subject in this study, namely: (1) tools for material experts, (2) tools for media experts, and (3) student response questionnaires.

The procedure used in developing electronic student worksheets (e-SWS) based on interactive comics on reaction rate material is adapted from the limited ADDIE development model, according to Lee & Owens [17]. The

development procedure of this model has five stages, which are described in Figure 1.

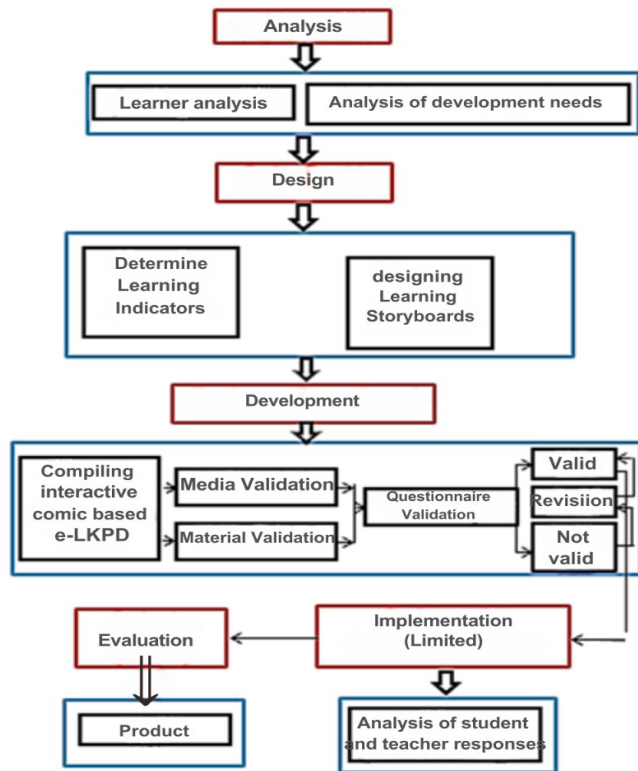


Figure 1. Research Procedure Flowchart

The data analysis technique that the author will use is a quantitative descriptive analysis technique that describes the development carried out. Data analysis was carried out after data were obtained from all research subjects, including material expert validators, media experts, and students. Data analysis was carried out by converting scores obtained from material experts, media experts, and students, initially qualitative data, into quantitative data using the Likert scale rule.

Validity data analysis

The feasibility test of the developed e-SWS was validated using a Likert scale as shown in Table 1 [15].

Table 1. Likert Scale

Category	Score
Very Good	4
Good	3
Quite Good	2
Not Good	1

To determine the average score obtained from the results of the questionnaire data through the questionnaire of material experts, media experts, and student responses, the following formula can be used [16]:

$$\bar{x} = \frac{\sum x}{n}$$

Where, $\bar{x}$ = Average score of each aspect or all aspects, $\sum x$ = The sum of the scores for each aspect or all aspects, and n = number of students or users

The scores obtained from the validation results of the questionnaires of material experts and media experts as users will then be converted into five categories of suitability scales with score intervals, as in Table 2 [18].

Table 2. Score Interpretation Criteria

Percentage	Criteria
81 – 100	Very Valid
61 – 80	Valid
41 – 60	Less Valid
21 – 40	Invalid
0 – 20	Very Invalid

Analysis of student response questionnaire data

The data from the student questionnaire analysis were analyzed using quantitative data to obtain information about student responses to the electronic student worksheet (e-SWS) based on developed interactive comics. The answers to the student response questionnaire were measured using a Likert scale. The percentage results of student responses were calculated using the following formula:

$$P = \frac{\sum X}{N} \times 100\%$$

Where, P = Percentage of student responses, $\sum X$ = The total score for each criterion selected by the student, and N = Maximum or ideal score

The validation criteria for product eligibility based on student responses in the use of electronic student worksheets (e-SWS) based on Problem-Based Learning, assisted by interactive comic media, as in Table 3 [15].

Table 3. Product Eligibility Response Criteria

Score Interval (%)	Category
81-100	Very Positive
61-80	Positive
41-60	Fair
21-40	Negative
0-20	Very Negative

RESULTS AND DISCUSSION

The research was conducted at Senior High School 17 Medan, the data obtained contains the results of the validation of SWS (Student Worksheets) validated by experts and limited product trials (student responses and teacher responses) to e-SWS based on Problem-Based Learning, assisted by interactive comic media on reaction rate material developed. The number of respondents in the

limited product trial was 32 students and three teacher respondents. The selection of the number of respondents in the product trial was chosen to review in more detail and practically on a small scale, as described in the following:

Analysis Stage

The analysis stage is carried out by identifying the main problems. It needs to make e-SWS based on Problem-Based Learning, assisted by interactive comic media on reaction rate material. Furthermore, this stage is divided into two parts, namely:

Analysis of student

In the first stage, the researcher analyzed students as the subject of the product trial through observation and interviews with one of the chemistry teachers to find out the obstacles and constraints faced by students in learning, including media, learning evaluation, and models that are often used.

Development Need Analysis

The researcher conducted a development needs analysis starting with an analysis of the curriculum used at Senior High School 17 Medan, namely the 2013 curriculum for class XII and the independent curriculum for classes X and XI. The researcher analyzed the teaching materials used, namely high school chemistry textbooks. The following analysis, the researcher conducted an analysis of the reaction rate material to include teaching materials that are by the needs of electronic student worksheets (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material through an analysis of the learning objective flow in class XI reaction rate material.

Design Stage

In the second stage, the researcher designed and implemented electronic student worksheets (e-SWS) based on Problem-Based Learning, assisted by interactive comic media, on the reaction rate material. The design was carried out in two stages, starting from determining learning indicators and designing a learning storyboard, which is described as follows:

Determining Learning Indicators

The researcher determined the learning objectives for the reaction rate material for grade XI SMA/Equivalent using the results of the previous analysis of the learning objective flow.

Designing the Learning Storyboard

In the learning storyboard design stage, the researcher designed based on architecture, data structure, and interface design. In the architecture section, the researcher determined an overall picture of the electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material. The architecture focused on the design of the e-

SWS content and the comic storyline. Furthermore, the researcher represented the design in an interface focused on making interactive comic media through a manual storyboard that the researcher drew on a canvas/sketchbook, as in Figure 2.

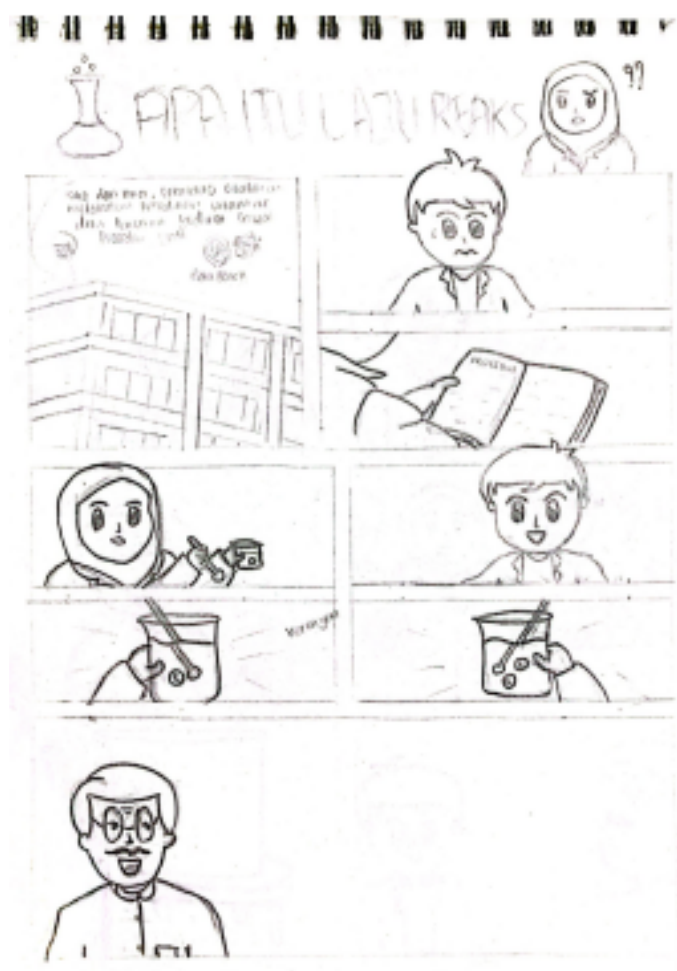


Figure 2. Comic design through sketchbook

Then the researcher integrated the media design with electronic student worksheets based on Problem-Based Learning (PBL) via Canva. The design began using an A4 size of 44 pages. e-SWS was designed to be separated into 3 parts according to the sub-chapter of the reaction rate material, namely the first e-SWS entitled The Concept of reaction rate and collision theory, the second e-SWS entitled factors that affect reaction rate, and the third e-SWS entitled reaction rate equation and reaction order.

Development Stage

The researcher's development stage prepares the design results into products teachers and students can use. Development begins with making comic characters digital using the Ibis Paint X application, as in Figure 3. These characters are then integrated into the design of student worksheets based on Problem-Based Learning (PBL) syntax.

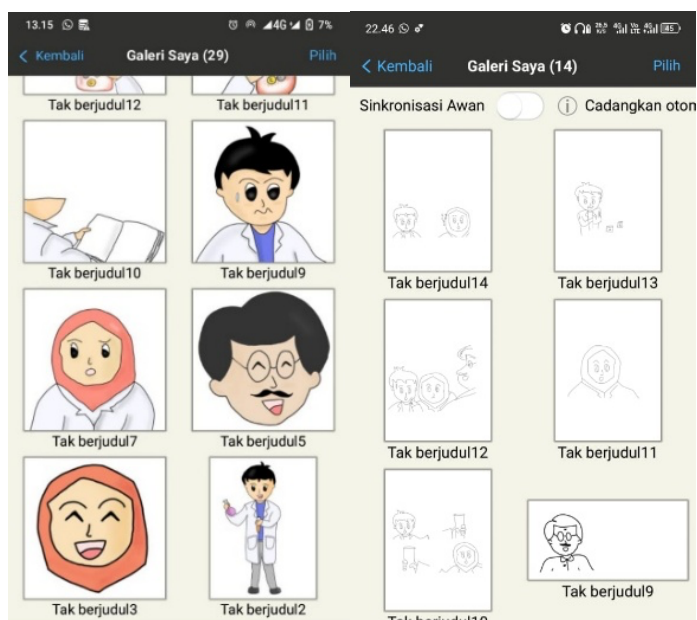


Figure 3. Preparing the Comic Characters Using Ibispaint X Software

Comic media is integrated into the problem-oriented syntax. Comics are arranged according to the storyline and equipped with instructions for use, material summaries, syntax stages, and relevant questions using canvas, as in Figure 4.

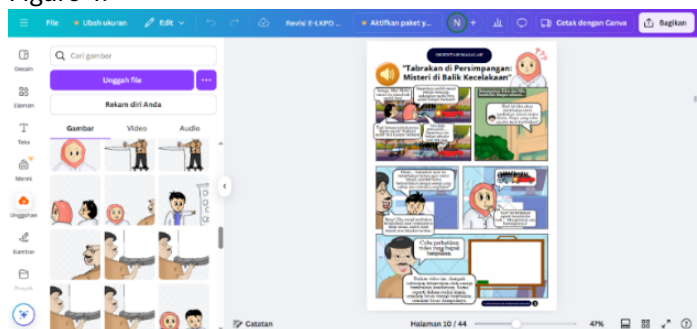


Figure 4. The arrangement of comics in Canva studio

The next stage is when the researcher inputs the electronic student worksheet (e-LSWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material in electronic form on the live worksheet website. This starts with filling in the interactive icons and quizzes that play a role in answering essay test questions and adjusting the layout of the e-SWS that is being developed. Before validating the product to the experts, the researcher validates it to the supervising lecturer first to review the contents of the e-SWS.

The next stage, the researcher validates the product, including validation of the material, media, and questionnaire. This validation is carried out by lecturers who are experts in their respective fields. This stage is carried out to see whether the e-SWS is valid for use or not. The validation sheet and questionnaire were previously validated by instrument experts to be used as valid research instruments. After the researcher obtains the instrument

validation data, it is revised according to the suggestions and input from the validator. The validation sheet of the material expert, media expert, and response questionnaire can be used. The next stage, the e-SWS that has been created, is validated by media and material experts, where the validation is based on BNSP, so that it can be tested on students and teachers at the implementation stage.

The results of the validation percentage of electronic student worksheets (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material consist of 2 aspects, namely the media expert and material expert aspects. The results of the validation percentage can be seen in the Table 4.

Table 4. Final Validation Score of e-SWS Assisted by Interactive Comic as a Learning Media

No.	Validity Aspect	Score (%)
1	Didactic	81.28
2	Construction	90.00
3	Technical	92.86
Mean		89.06

Table 4 shows that the media of comics was valid in each aspect with overall score of 89.06%. In each aspect of the assessment, there was an increase after revisions were made according to the suggestions of the media expert validator. The electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material based on the media perspective is suitable. The results of the material validation at the initial and final stages are shown in Table 5 below:

Table 5. The Content Validity Score of E-SWS Assisted by Interactive Comic Media

No.	Content Aspect	Score (%)
1	Content quality	75.00
2	Conceptual truth	75.00
3	Conceptual suitability	75.00
4	Language	75.00
5	Problem-based learning	75.00
Mean		75.00

In Table 5 above, the validation of the material is 75%. In each aspect of the assessment, there was an increase after revisions were made according to the suggestions of the material expert validator. So, the electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material based on the material perspective is suitable for use. From the data in Tables 4 and 5, it can be presented using the following formula:

$$P = \frac{\sum x}{\sum x} \times 100\%$$

P = percentage (%)

$\sum x$ = total score from the validator

$\sum x$ = total ideal score

The results of the data obtained from the average validation value of media experts and material experts at the final stage are calculated as follows:

$$P = \frac{89.06+75}{2} \times 100\% = 82.03\%$$

The results obtained based on validation by the media and material expert team showed that the electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material to the expert team, then the researcher revised the electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material according to suggestions and input from the validator team. The electronic student worksheet (e-SWS) based on Problem-Based Learning, assisted by interactive comic media on the reaction rate material that had been revised, was validated in the final stage to conduct an assessment. Furthermore, processing data from the results of the validation by media and material experts obtained an average percentage of both validators of 82.03%, with very valid criteria for use in the teaching and learning process at Senior High School 17 Medan.

Implementation Stage

The implementation was carried out after the development stage completed. At this stage, the results of the development that have been validated and revised are tested in a limited trial to determine the responses of the subjects, namely students and teachers, to the electronic student worksheet (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material that researchers have developed. The trial on the electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material was carried out for three meetings in class XI-D at Senior High School 17 Medan with 32 respondents and 3 chemistry teachers, starting from February 10, 2025, to March 7, 2025. At this stage, the researcher distributed e-SWS to each student and chemistry teacher in the form of a link according to the meeting that had been determined to be read. Furthermore, the researcher distributed response questionnaires to students and teachers. In the student response questionnaire, there are 9 statement items and as many as 28 statement items in the teacher response questionnaire consisting of 4 assessment scales, namely 4 (strongly agree), 3 (agree), 2 (less agree), and 1 (disagree) which

include the value of aspects of appearance, language, material to respondent involvement in e-SWS, which can be seen in Table 6.

Table 6. Students' responses toward the quality and the SWS integrated with comics

No	Item	Students' Response
1	The cover is attractive	82.03
2	The material is easy to be mastered	82.81
3	The instruction is easy to be understood	79.69
4	The images used properly	84.38
5	Provision of good answer column	80.47
6	The SWS enhance my knowledge	79.69
7	The SWS enhance my scientific literacy	82.03
8	The comic story is easy to follow	88.28
9	The problem is presented in understandable manner	85.16
Overall		82.72

The data indicates that the comic-integrated problem-based learning (PBL) student worksheet (SWS) is highly effective in engaging students, as shown by the overall positive response score of 82.72%. The strongest aspects include the comic storyline (88.28%), problem presentation (85.16%), and proper use of images (84.38%), all of which suggest that the medium is visually appealing and easy to follow. These strengths highlight the success of using comics to simplify complex concepts and make learning enjoyable. However, areas such as "enhancement of knowledge" and "scientific literacy" received slightly lower scores (79.69%), suggesting that while the worksheet is engaging, it could better support deeper understanding and critical thinking. Similarly, the clarity of instructions (79.69%) could benefit from further refinement to ensure students can navigate the material independently.

The findings imply that comic-integrated SWS is a promising tool for modern classrooms, but there is room for optimization. Strengthening the depth of scientific content and incorporating more thought-provoking problems can enhance knowledge acquisition and literacy. Clearer instructions and a focus on formative feedback mechanisms could improve usability and comprehension. These adjustments, coupled with iterative testing and refinement, would ensure that the SWS not only captivates students but also maximizes their learning outcomes in alignment with PBL objectives. This approach emphasizes the importance of balancing engagement with academic rigor to foster holistic student development.

Thus, the electronic student worksheet (e-SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material received a very positive response from students at Senior High School 17 Medan. This is because the average total score of the results of student responses to the electronic student worksheet (e-

SWS) based on Problem-Based Learning assisted by interactive comic media on the reaction rate material is 82.72% with a very positive category. Based on the research results obtained, according to Hanifa & Susilaningih [19], E-SWS that has been declared valid can be tested in learning. So the next stage in the implementation is to test it on students and teachers to find out the response to the use of electronic student worksheets (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material. Furthermore, the results of the teacher's response can be seen in Figure 5.

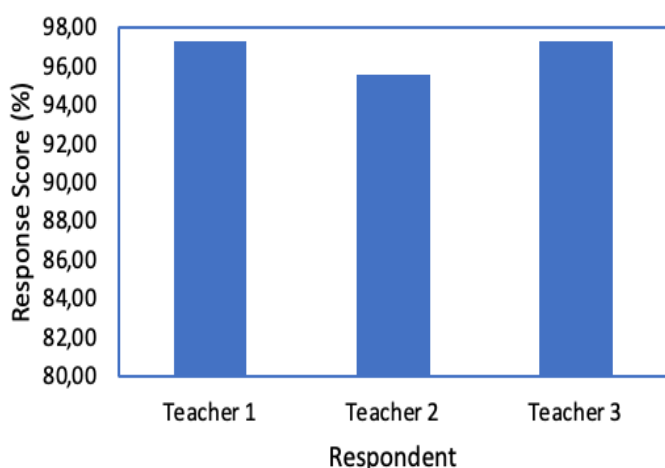


Figure 5. Teachers' responses toward the quality and usability of the SWS integrated with comics

The results obtained from taking student responses were previously tested using electronic student worksheets (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material for 3 meetings and ended with filling out the student response questionnaire, an average value of 82.57% was obtained with a very good category. Based on these data, the electronic student worksheet (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material received a very good response from students in its use. This is influenced by the learning devices used using smartphones will help students more in learning, considering that today's students or generation Z often interact with smartphones, so the response given is very good. The next trial stage was carried out on chemistry teachers at Senior High School 17 Medan as many as 3 teachers gave very good responses and suggestions, the average value data obtained was 96.73% with a very good category. Based on this, it can be concluded that electronic student worksheets (e-SWS) based on Problem Based Learning assisted by interactive comic media on the material on reaction rates can be used as a learning tool that helps the learning process, both in helping teachers in teaching and students in understanding the material on reaction rates.

Evaluation Stage

The evaluation stage is a stage that includes the refinement of the electronic student worksheet (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material obtained from the results of the student and teacher response questionnaire. Based on the evaluation stage, the researcher obtained the results that the electronic student worksheet (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material needed minor revisions to improve the layout, proportion of images and writing to make it attractive in appearance, this was the result of the teacher and student responses in the very positive category towards the electronic student worksheet (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material that the researcher developed.

Based on the research results obtained, it is relevant to the research results of Fadhila [13], who stated that the electronic student worksheet (e-SWS) based on Problem Based Learning can improve students' scientific literacy by connecting scientific concepts and research. Hermawati [20], stated that the results of learning products using expert response comics and students were considered very valid to improve the teaching and learning process which was very good. The learning devices developed by the research with relevant research have similarities, namely connecting learning devices with the Problem Based Learning learning model integrated with scientific literacy, so that the content presented is a socio-scientific issue and uses comic media. One of the main obstacles found was the limited time in the limited implementation stage, namely the trial conducted for 3 meetings, the use of smartphones by students often requires a lot of wasted time to ensure that students can access the learning devices that have been given. Group learning activities in the process of using electronic student worksheets (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material also affect some students' learning difficulties because they are not monitored evenly. With limited time, students need to be given more in-depth learning in accordance with the syntax in the Problem Based Learning learning model. This study explicitly notes that the duration of the research time is limited, so that perhaps only a few students feel the change in the use of electronic student worksheets (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material. So it is suggested to conduct further research to measure the learning outcomes or motivation of students with a longer period of time in more depth to find out the usefulness of the electronic student worksheet product (e-SWS) based on Problem Based Learning assisted by interactive comic media on the reaction rate material that

has been developed. The use of e-SWS based on Problem Based Learning can be easily accessed by students via smartphones, laptops or PC and can be accessed again at home. Through the results of the final review of the product trial by students and teachers, it is recommended that the product be used on a laptop or similar because it has a wide screen so that the visuals and presentations in the comic will look clearer. Use does not require registering an account, so it can be practically done by students.

CONCLUSION

Based on the research that has been conducted, electronic student worksheets (e-SWS) based on Problem-Based Learning assisted by interactive comic media on reaction rate material are feasible to be used in the learning process with a very valid category. The response of students to electronic student worksheets (e-SWS) based on Problem-Based Learning, assisted by interactive comic media, on reaction rate material is very good. The response of teachers to electronic student worksheets (e-SWS) based on Problem-Based Learning, assisted by interactive comic media, on reaction rate material, is also very good. This research has a very valid feasibility, and the responses of students and teachers are very positive, so electronic student worksheets (e-SWS) based on Problem-Based Learning assisted by interactive comic media on reaction rate material are feasible. They can be used as teaching materials in the learning process. The advantages of e-SWS based on Problem Based Learning assisted by interactive comic media are the ease of students in accessing and knowing the right and wrong answers in real time, the ease of teachers in correcting students' answers automatically. In addition to the advantages, the disadvantages are that internet network facilities depend on the location of the school and group work must require extra monitoring from the teacher. This research is not bound to the Merdeka curriculum alone, the products in this development can be applied to other curricula for consolidation or as daily assessments of students.

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