

Development of Electronic Student Worksheet Based on Project-Based Learning (PjBL) Integrated STEM on Reaction Rate Material For Phase F

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Key Words:

electronic student worksheet
PjBL
STEM
reaction rate

Abstract:

This development research aims to analyze the characteristics, feasibility, practicality, and readability of electronic student worksheet based on Project-Based Learning (PjBL) integrated STEM on reaction rate material for phase F. This research uses the stages of the 4-D model consisting of the Define, Design, Develop, and Disseminate stages. The instruments used to collect data consist of electronic student worksheet feasibility sheets, electronic student worksheet practicality sheets, electronic student worksheet readability sheets, and teacher and learner needs analysis sheets. The results of this study indicate that the characteristics of electronic student worksheet developed can be operated via Android smartphones and laptops, have been adapted to the syntax of the STEM integrated PjBL model, can be used anytime and anywhere, prioritize the demands of using technology in learning, and help reduce the use of paper during the learning process. Electronic student worksheet based on Project Learning (PjBL) integrated STEM on reaction rate material obtained an average feasibility score of 134.5 (very good), practicality of 117.5 (very good), and readability of 66.27 (very good). This means that the electronic worksheets based on Project-Based Learning (PjBL) integrated with STEM on the topic of reaction rates developed can be deemed suitable for use in learning. The implication for the research is that electronic worksheets based on Project-Based Learning (PjBL) integrated STEM on the topic of reaction rates are recommended for use as one of the learning resources used by teachers to make learning more meaningful.

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Introduction

In the current era of globalization, technological development is very rapid (Setyaningsih et al., 2021). Technology is developing rapidly and dominates almost every aspect of life, education needs to be adjusted to be relevant to the ever-changing needs of society and the world of work (Ahyanuardi et al., 2022; Suryati et al., 2023). Technology's rapid development changes how we think, work, and learn. Technological advances change how students learn and their learning outcomes (Haleem et al., 2022), how students communicate, and how they interact with the environment at school and outside school (Setyaningsih et al., 2021). The role of technology has evolved from a tool for learning and inquiry to an integrated approach and use in education. Educators are responsible for guiding their students in using educational technology appropriately and beneficially (Tuma, 2021).

Applying the STEM approach can be integrated with learning models, one of which is Project Based Learning (PjBL). PjBL is one of the student-centered learning that allows students to learn by solving problems and looking for theories to solve them (Darmuki et al., 2023). The PjBL model provides opportunities for teachers to manage learning in the classroom by involving project work (Husna et al., 2019; Suwarno et al., 2020), which contains complex tasks based on given problems that require students to carry out design activities, investigate activities, solve problems, make decisions, and provide opportunities for students to work independently and in groups (Maryati et al., 2022). The application of PjBL provides contextual and authentic experiences necessary for students to learn and build strong and meaningful science, technology, engineering, and math concepts supported by language arts, social sciences, and arts. Implementing STEM-integrated PjBL requires collaboration, peer-to-peer communication, problem-solving, and independent learning while incorporating rigor for all students. STEM-integrated PjBL builds on engineering design as a cornerstone and a foundation where students bring their compartmentalized knowledge of science, technology, and math to solve meaningful real-world problems (Capraro et al., 2013).

The application of the STEM-integrated PjBL model in chemistry learning is to provide the required knowledge and skills. This technique is directly related to real-world problems. Chemistry is a branch of science that studies the composition, structure, properties, and changes of matter (Ebbing & Gammon, 2009; Junejo & Özslan, 2023) developed with scientific methods and based on scientific attitudes (Harahap & Novita, 2021). In studying chemistry, students not only apply or use concepts in chemistry but also understand the nature, meaning, quality, or magnitude of the whole concept (Alam, 2020). Concepts in chemistry are important for students as a strong foundation for further learning (Harahap & Novita, 2021).

One of the topics taught in chemistry at the high school level is reaction rate. Based on a survey conducted at public high schools in Banjarmasin city, it is found that students have difficulty in learning reaction rate material. The difficulty is caused by the number of chemical formulas that must be learned and memorized, the number of formulas used in calculating a chemical reaction, and the difficulty in remembering previous materials related to current learning, especially reaction rate material. According to Sari et al., (2018), the difficulties found by students in reaction rate

material include: (1) students cannot explain the relationship between particle shape, surface area and collisions between particles; (2) students have difficulty in explaining why higher concentrations of reactants can accelerate the reaction rate; (3) students cannot explain why the higher the temperature the faster the reaction rate; and (4) students cannot explain how catalysts can accelerate the reaction rate. Reaction rate is one of the chemistry subjects that contains many concepts that are interconnected with each other, which has the potential to cause misconceptions in students (Harahap & Novita, 2021). The concept of reaction rate is primarily abstract, making the topic difficult for students to understand, so students experience errors in understanding a concept (Jusniar et al., 2020). The reaction rate material includes chemical reactions, collision theory, factors that affect the reaction rate, reaction rate equations, and reaction rates (Silalahi, 2020).

This difficulty can be overcome by using learning media that can attract the attention of students studying chemistry, one of which is using electronic student worksheet in learning activities. However, based on a survey, the use of learning media has several problems. The teaching material is too short and has not been able to make students interested in teaching it, and sometimes the teaching material is forgotten. In addition, some teachers have never used electronic student worksheet. Meanwhile, some other teachers have used electronic student worksheet but have not used the Project Based Learning (PjBL) learning model.

Electronic student worksheet is one of the learning media integrated with technology in its application. Electronic student worksheets are learning media that are systematically arranged to contain learning activities in electronic form. The presentation of student worksheet is integrated with technology to be accessed via smartphones and laptops (Alexon & Handayani, 2024). Student worksheet are guidelines for students in conducting investigations or solving problems in learning. Student worksheet is one of the learning tools that can improve students' abilities. In addition, student worksheet can guide cognitive development and all aspects of learning. Using student worksheet helps students find their concepts from the material taught (Melawati et al., 2022). The content of electronic student worksheet can display text, images, graphics, video, and audio that can foster students' understanding of learning materials. In addition, using electronic student worksheet helps teachers increase students' attention (Sari et al., 2021).

Research on the development of student worksheet has been conducted by Budiarti et al., (2023); Indranuddin et al., (2024); and Sayekti & Suparman, (2020). Research conducted by Sayekti & Suparman, (2020) aims to design PjBL-based LKPD with a STEM approach to improve students' critical thinking skills. According to the validator, the study revealed that the LKPD developed very well. In addition, using Project-Based Learning (PjBL) with a STEM approach improves critical thinking skills. Research conducted by Budiarti et al., (2023) states the feasibility of STEM-based PjBL e-Worksheet for validated character development with media validity of 91.67% and content validity of 88.89%, meeting very valid criteria. Therefore, the PjBL e-Worksheet can be tested on Biology Education students at the Faculty of Teacher Training and Education, Jambi University. Practicality is assessed from the responses of students who use STEM-based PjBL learning media, with 90.83% meeting efficient

criteria. The research conducted by [Indranuddin et al., \(2024\)](#) stated that the STEM-PjBL worksheet obtained a percentage of feasibility from media expert 1 with a total average of 94%, media expert 2 with a total average of 87%, material expert 1 with a total average of 95%, and material expert 2 with a total average of 80% which fell into a very feasible category. The assessment on the practicality test conducted by students, teachers (media), and science teachers obtained consecutive scores of 79% with a practical category, 92% with a convenient category, and 94 with a convenient category.

Based on surveys, theories, and previous research results presented, student worksheet based on PjBL with a STEM approach has been proven to be valid, practical, and effective for use ([Budiarti et al., 2023](#); [Indranuddin et al., 2024](#)) and capable of improving students' critical thinking skills ([Sayekti & Suparman, 2020](#)). However, there has been no research specifically developing an electronic student worksheet based on PjBL integrated STEM on reaction rate material. Reaction rate materials have abstract, mathematical, and multi-representational characteristics ([Sodanango et al., 2021](#)), so there is a need for innovative learning media that can link the concepts of science, technology, engineering, and mathematics in real-world projects. In addition, electronic student worksheet maximizes the use of technology during learning. Technology can be utilized to overcome various existing problems. Learning using the PjBL-STEM model makes learning more meaningful because students not only memorize material, numbers, and formulas but can also apply them in everyday life. Therefore, through the development of electronic student worksheets based on Project Learning (PjBL) Integrated STEM on Reaction Rate Materials, it is hoped that chemistry learning will become more meaningful.

Research Method

This study uses the Research and Development (R&D) method with the 4-D model of define, design, develop, and disseminate stages. The define stage analyzes the problems teachers and students face in learning chemistry, the characteristics of students, the competencies that students must obtain, and the main concepts that must be taught to obtain learning objectives and indicators. At the design stage, the instruments used in the study were compiled, consisting of a needs analysis instrument by teachers and students, a feasibility instrument for the developed electronic student worksheet, a practicality instrument, and a readability instrument. In addition, the manufacture of electronic student worksheet will also be carried out. At the development stage, feasibility testing of the developed electronic student worksheet was carried out by two expert judgments as material and media experts to improve the electronic student worksheet that had been developed based on the suggestions given. In addition, at this stage, a practicality test by a chemistry teacher is carried out, which aims to find out that electronic student worksheet and teaching modules are feasible (practical) to be used in learning, and a readability test by students which aims to obtain students' responses to electronic student worksheet based on Project Based Learning (PjBL) Integrated STEM on reaction rate material that has been developed.

The assessment data obtained in the feasibility test were summed and averaged, and the results were then grouped into assessment criteria. Data analysis in the

feasibility test also applies to the practicality and readability tests. The assessment criteria for interactive learning media can be seen in Table 1.

Table 1. Interactive Learning

Media Assessment Criteria Score Interval	Criteria
$X_i + 1.5 S_{di} \leq X$	Very Good
$X_i + 0.5 S_{di} \leq X < X_i + 1.5 S_{di}$	Good
$X_i - 0.5 S_{di} \leq X < X_i + 0.5 S_{di}$	Quite Good
$X_i - 1.5 S_{di} \leq X < X_i - 0.5 S_{di}$	Not Good
$X < X_i - 1.5 S_{di}$	Very Not Good

Results and Discussion

Define Stage

At the define stage, an initial analysis was carried out in public high schools in Banjarmasin City to discover the problems in chemistry learning. The survey results showed that when using the PjBL model, the teacher felt that the time needed was quite long, and the project work was constrained by the distance of the student's homes, so only some teachers applied the PjBL learning model in chemistry learning. Teachers find it difficult to implement the STEM approach because it considers the readiness of students and the characteristics of the material being taught. This results in teachers who do not use the STEM approach during learning. The most often-used approach is the scientific approach. The learning media teachers use are already diverse, such as books, videos, audio, powerpoint files, answer notes, and student worksheet. However, the learning media teachers use still cannot make students interested in learning the material and is neglected by students and teachers. If teachers do not use learning media during the learning process, this will have a negative impact on students' attention during the learning process ([Hardiansyah & Mulyadi, 2022](#)). In addition, not all teachers have used student worksheet in their teaching. Teachers who have used electronic student worksheet have only used the Problem-Based Learning model in its application in teaching. The limitations of the student worksheet used by teachers are that they only provide brief explanations using textual descriptions and workflows, without accompanying experimental diagrams, so students cannot construct the material initially considered abstract ([Syamsidar et al., 2021](#)). According to research conducted by [Mayasari et al. \(2023\)](#), using Student Worksheet is rare because they are only used for specific practical materials.

Students have difficulty learning chemistry because there is a lot of complex material to learn and remember, and it is difficult to connect the concepts in chemistry, so students do not fully understand the material. This impacts students who have difficulty answering questions or solving problems in chemistry given by teachers during lessons. Students find it difficult to solve problems in reaction rate material because of difficulties in understanding the material and concepts of reaction rate, memorizing formulas, and not understanding the explanations provided. According to [Sari et al. \(2018\)](#), the difficulties encountered by students in reaction rate material include: (1) students cannot explain the relationship between particle shape, surface area, and collisions between particles; (2) students have difficulty explaining why higher reactant concentrations can accelerate the reaction rate; (3) students cannot explain why the higher the temperature, the faster the reaction rate; and (4) students

cannot explain how a catalyst can accelerate the reaction rate. Another study conducted by [Harahap & Novita, \(2021\)](#) states that the most significant misconceptions among students regarding reaction rate material are caused by the belief that one concept is the same as another. This occurs due to similarities in terminology and misunderstandings in the relationships between concepts, causing students to associate one concept with another, which leads to misconceptions.

Design Stage

The design stage aims to obtain a draft of the electronic student worksheet product based on Project-Based Learning (PjBL) integrated with STEM on reaction rates, developed using PowerPoint, iSpring Suite, the 2 APK Builder website, and Canva. Additionally, instruments for the research were created, including an electronic student worksheet feasibility sheet, a practicality sheet, and a readability sheet. The format chosen for the electronic student worksheet, based on Project-Based Learning (PjBL) integrated with STEM, consists of a cover, preface, table of contents, instructions for using the student worksheet, learning objectives, concept map, material, student activities, practice questions, glossary, bibliography, and author biography. The initial design of the student worksheet that was developed can be seen in Figure 1.

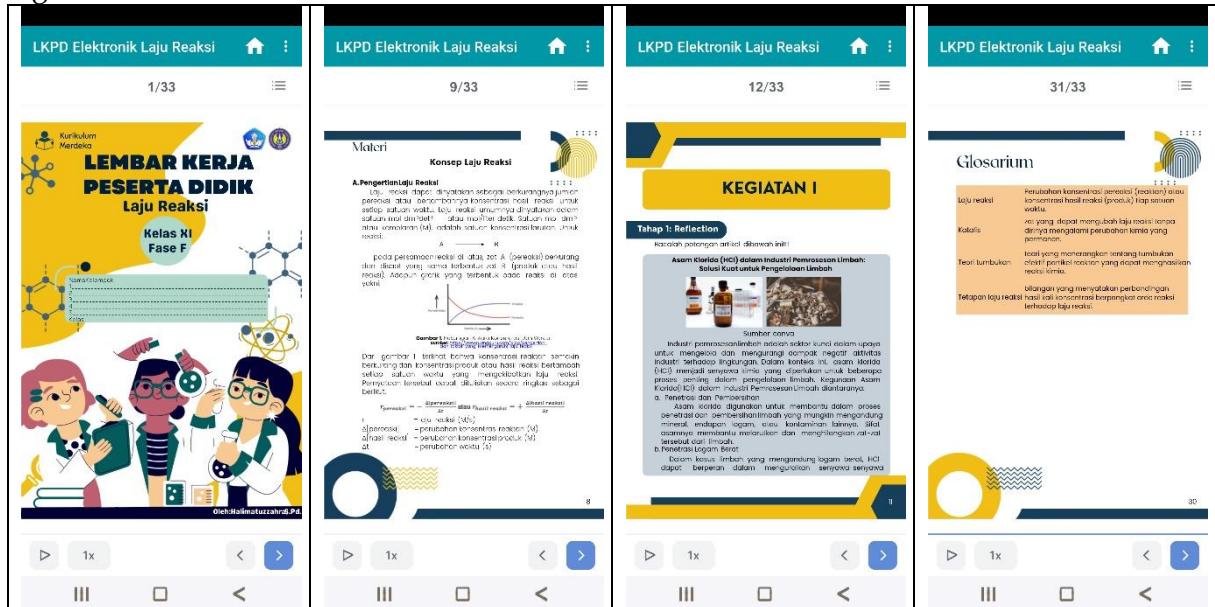


Figure 1. Initial design of the electronic student worksheet developed

According to [Herlina et al., \(2021\)](#), the components of student worksheet consist of a title, learning instructions, basic competencies/core material, supporting information, tasks/work steps, and assessment. Additionally, electronic student worksheet includes images and videos that can enhance students' understanding of the taught material, specifically reaction rate material. Adding images and videos in student worksheet makes the appearance and design of student worksheet more attractive, thereby increasing students' enthusiasm for learning ([Ghaisani & Setyasto, 2023](#)). Furthermore, adding audio, video, and animation in electronic student

worksheet can increase students' interest in learning and independence, influencing their learning outcomes (Alexon & Handayani, 2024).

Develop Stage

Feasibility of Electronic Student Worksheet based on Project Based Learning (PjBL) Integrated STEM on Reaction Rate Material

The feasibility of electronic student worksheet based on Project-Based Learning (PjBL) Integrated STEM on Reaction Rate material was assessed by two expert lecturers. The results of the feasibility assessment of electronic student worksheet based on Project-Based Learning (PjBL) Integrated STEM on Reaction Rate material can be seen in Figure 2.

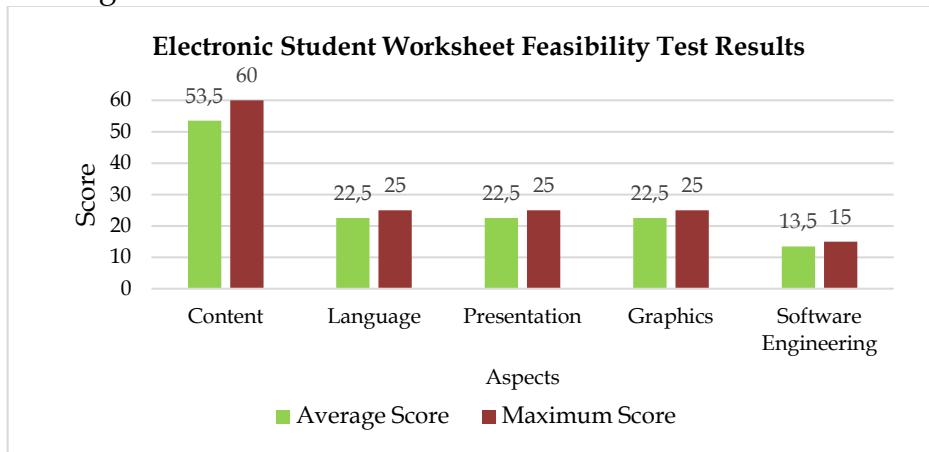


Figure 2. Electronic Student Worksheet Feasibility Test Results

Based on the Figure 2, the average score obtained from the assessment conducted by expert lecturers on each aspect is almost the same as the maximum score. This means that the electronic student worksheet based on project-based learning (PjBL) integrated with STEM on Reaction Rate material gets a "very good" category in all aspects assessed, namely aspects of content, language, presentation, graphics, and software engineering. In addition, the total average score obtained is 134.5 out of a maximum score of 150 and is included in the "very good" category. At this stage, improvements were made to the electronic student worksheet that had been developed, including changing student activities to make them safer to carry out in the material on the concept of reaction rate, adding terms to the glossary, changing images in the material on factors determining reaction rate, improving several sentences to make them easier for students to understand, and improving the electronic student worksheet download process. Several changes to the electronic student worksheet are visible before and after the feasibility test, as shown in Figure 3.

Development of Electronic Student Worksheet Based ...

Before	After	Revision																																																																								
<p>LKPD Elektronik Laju Reaksi</p> <p>12/33</p> <p>KEGIATAN I</p> <p>Tahap 1: Reflection</p> <p>Karakter pokongan artikel dibawah ini!</p> <p>Asam Klorida (HCl) dalam Industri Pengolahan Limbah: Solusi Kunci untuk Pengelolaan Limbah</p> <p></p> <p>Sumber: comca</p> <p>Industri pengolahan limbah adalah sektor iklim ekonomi upaya untuk mengelola dan mengurangi sampah, negara dan daerah Industri pengolahan limbah ini menggunakan asam klorida (HCl) menjadi senyawa kimia yang disebutkan untuk beberapa proses pengolahan pengelolaan limbah. Kegunaan Asam klorida (HCl) dalam pengolahan limbah antara lain:</p> <ol style="list-style-type: none"> a. Penetusan dan Pengolahan b. Pengolahan dan Pengelolaan limbah c. Pengolahan dan Pengelolaan limbah d. Pengolahan dan Pengelolaan limbah <p>Asam klorida (HCl) dapat berperan dalam mengurangi pengelahan dan pengolahan limbah dengan mengikuti reaksi kimia antara senyawa kimia dengan mineral, endapan organik, atau kotoran hewan, atau zat-zat kimia lainnya untuk menurunkan dan menghilangkan zat-zat tersebut dari limbah.</p> <p>b. Pengolahan Logistik</p> <p>Bahan kelas I limbah yang memungkinkan logistik kereta, HCl dapat berperan dalam mengurangi senyawa kimia</p> <p>1x</p> <p>III □ < ></p>	<p>LKPD Elektronik Laju Reaksi</p> <p>15/41</p> <p>KEGIATAN I</p> <p>Tahap 1: Reflection</p> <p>Bacalah potongan artikel dibawah ini!</p> <p>fenomena Reaksi Kimia</p> <p>basa, yaitu abu dan asap yang memenuhi sita sangat berbahaya bagi kesehatan manusia dan pengembangan koyak tidak dapat dilakukan kembali menjadi koyak karena telah menjadi suatu zat yang beracun.</p> <p>5. Pembuatan sayur-sayuran</p> <p></p> <p>Food pembuatan sayur-sayuran di dalamnya berbaga peranannya, seperti buah, wortel, dan rasa. Pembuatan tersebut tentu tidak dapat dikembalikan bentuk semula.</p> <p>6. Pembuatan minuman</p> <p>Minuman adalah minuman yang memiliki rasa tidak terlalu kuat dan tidak berbahaya bagi kesehatan manusia. Minuman ini biasanya dibuat dengan air, gula, dan buah-buahan.</p> <p>7. Pembuatan obat-obatan</p> <p>Obat-obatan yang dibuat dengan menggunakan teknologi kimia dapat membantu mengobati penyakit manusia.</p> <p>1x</p> <p>III □ < ></p>	Changing student activities into safer activities for the reaction rate concept material.																																																																								
<p>LKPD Elektronik Laju Reaksi</p> <p>18/33</p> <p>KEGIATAN I</p> <p>Tahap 4: Application</p> <p>Karakteristik proyek yang telah dilakukan pada tahap tabel dibawah ini</p> <table border="1"> <thead> <tr> <th>No</th> <th>Reagen/reaktor</th> <th>Konsentrasi HCl (M)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Kecap asin</td> <td>getah/gas</td> </tr> <tr> <td>2</td> <td>benzaldehyde</td> <td>getah/gas</td> </tr> <tr> <td>3</td> <td>vitamin C</td> <td></td> </tr> </tbody> </table> <p>Tahap 5: Communication</p> <p>Karakteristik proyek yang telah dilakukan pada tahap tabel dibawah ini</p> <ol style="list-style-type: none"> 1. Tujuan percobaan reaksi dilakukan yang benar ketan saturasi 2. Sifat-sifat hubungan antara senyawa reaksi dengan ikali massa? 3. Bagaimana hubungan antara konsentrasi peleburan HCl yang dibutuhkan dengan waktu? 4. Bagaimana pengaruh senyawa kimia dan reaksi dilaksanakan? 5. Apakah benar bahwa hasil laporan proyek belum dilaksanakan? 6. Apakah benar bahwa hasil laporan proyek belum dilaksanakan? <p>1x</p> <p>III □ < ></p>	No	Reagen/reaktor	Konsentrasi HCl (M)	1	Kecap asin	getah/gas	2	benzaldehyde	getah/gas	3	vitamin C		<p>LKPD Elektronik Laju Reaksi</p> <p>21/39</p> <p>KEGIATAN I</p> <p>Tahap 4: Application</p> <p>Karakteristik proyek yang telah dilakukan pada tahap tabel dibawah ini</p> <p>Table1</p> <table border="1"> <thead> <tr> <th>No</th> <th>Volume HCl 2 M</th> <th>Volume Na₂S₂O₃ 0,2 M</th> <th>Molaritas Na₂S₂O₃</th> <th>Waktu (detik)</th> <th>U/Waktu</th> </tr> </thead> <tbody> <tr> <td>1</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>2</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>3</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>4</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>Table2</p> <table border="1"> <thead> <tr> <th>No</th> <th>Volume HCl 2 M</th> <th>Volume Na₂S₂O₃ 0,2 M</th> <th>Molaritas Na₂S₂O₃</th> <th>Waktu (detik)</th> <th>U/Waktu</th> </tr> </thead> <tbody> <tr> <td>1</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>2</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>3</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>4</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>1x</p> <p>III □ < ></p>	No	Volume HCl 2 M	Volume Na ₂ S ₂ O ₃ 0,2 M	Molaritas Na ₂ S ₂ O ₃	Waktu (detik)	U/Waktu	1						2						3						4						No	Volume HCl 2 M	Volume Na ₂ S ₂ O ₃ 0,2 M	Molaritas Na ₂ S ₂ O ₃	Waktu (detik)	U/Waktu	1						2						3						4						
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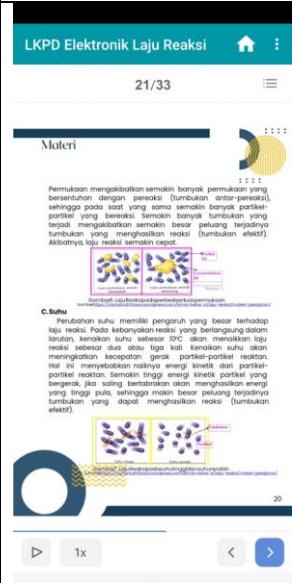
Before	After	Revision
		<p>The image illustrating the factors that determine the reaction rate and its relationship to collision theory is provided below.</p>

Figure 3. Changes to Electronic student worksheet Before and After Revision

In terms of content, it scored 53.5 in the excellent category, indicating that the material presented in the electronic student worksheet aligns with the learning objectives and learning outcomes of the independent curriculum used. In addition, the material presented in the electronic student worksheet is relevant to real life and can be applied in the daily lives of students. student worksheet should emphasize process skills that involve students in systematic and detailed activities related to specific indicators, presenting a variety of activities from simple to complex. This approach encourages students to apply the concepts taught in the lesson material and develop them in their daily lives (Kosasih, 2021). In addition, the electronic student worksheet developed is also in accordance with the PjBL learning model, integrated with the STEM approach, with the level of difficulty of the questions and activities aligned with the students' abilities. PjBL syntax, combined with a STEM approach, further strengthens certain instructional aspects, such as the contextualization of concepts, the clarity of task sequences, and alignment with practical activities (Fajar et al., 2025).

In terms of language, it scored 22.5 in the excellent category, which means that the language used in the electronic student worksheet is easy to understand, interactive, and communicative, the grammar used is in accordance with the rules of proper and correct Indonesian language usage, and there are no words or sentences that offend SARA. student worksheet should use language that is easy to understand (Kosasih, 2021). In addition, the information presented must be accurate, with good, consistent, and effective sentence structure, so that the information conveyed is engaging for users to read (Nurseto, 2012).

In terms of presentation, it scored 22.5 in the excellent category, which means that the instructions for using the electronic student worksheet can be easily understood by users, attract their interest and attention, and the images, graphics, and videos, along with their sources, can be clearly viewed by users. It features attractive illustrations and a well-designed layout, making it engaging and non-boring (Kosasih,

2021). Additionally, the position of the text and images should be placed in a way that is easy to see, allowing users to understand the information presented (Nurseto, 2012).

In terms of graphics, it scored 22.5 in the excellent category, indicating that the layout of the electronic student worksheet is attractive and proportionate, and the font selection, font size, and color are easy to read and understand. According to (Habibi et al., 2018), the graphic aspects of teaching materials include book size, font type, layout, illustrations on the cover, and the use of colors and images. The appearance and design of teaching materials are the first things that people notice and are important criteria for assessing their interest. Additionally, effective display design can enhance reader comprehension (Jaya et al., 2019).

In terms of software engineering, it scored 13.5 in the excellent category, indicating that the electronic student worksheet is easy to access, the navigation buttons function well, and the file size of the electronic student worksheet is neither too large nor too small. The developed electronic student worksheet can be accessed on Android smartphones and laptops. The presentation of the electronic student worksheet makes it easy for users to access the student worksheet quickly and flexibly (Alexon & Handayani, 2024).

Based on the results obtained, it can be concluded that the electronic student worksheet based on Project-Based Learning (PjBL) integrated with STEM on reaction rate material can be declared feasible to be implemented in learning. This is in line with research conducted by Melania et al., (2021); Purnamasari et al., (2025); Silfiyani et al., (2024); and Silvanny & Yerimadesi, (2023) regarding the development of learning media with the PjBL model integrated with STEM which obtained a very feasible category during the feasibility test. Based on these results, the learning media developed is suitable for implementation in learning (Silfiyani et al., 2024). In addition, this also means that the learning media developed is by the learning outcomes, learning objectives, and achievement indicators that students must achieve (Silvanny & Yerimadesi, 2023).

Practicality of Electronic Student Worksheet based on Project Based Learning (PjBL) Integrated STEM on Reaction Rate Material

Peers and chemistry teachers will reassess electronic student worksheet products that have gone through a feasibility assessment to determine the practicality of the Project-Based Learning (PjBL) Integrated STEM-based electronic student worksheet on Reaction Rate material developed. At this stage, improvements were made to the electronic student worksheet based on recommendations provided by teachers, including improving images in the discourse contained in activity 1, adding an apperception video about the concept of reaction rate, correcting overlapping letters, and adding terms to the glossary. The results of the practicality assessment of electronic student worksheet based on Project-Based Learning (PjBL) Integrated STEM on Reaction Rate material can be seen in Figure 4.

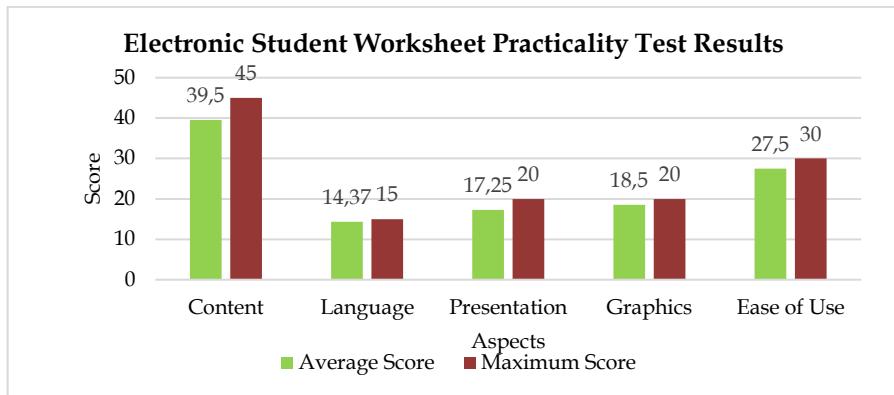


Figure 4. Electronic student worksheet practicality test results

Based on the figure 4, the average score obtained from the assessment conducted by peers and chemistry teachers on each aspect is almost the same as the maximum score. This means that the electronic student worksheet based on Project Based Learning (PjBL) integrated with STEM on Reaction Rate material gets a "very good" category in all aspects assessed, namely aspects of content, language, presentation, graphics, and ease of use. In addition, the total average score obtained is 117.5 out of a maximum score of 130 and is included in the "very good" category. Based on the results obtained, it can be concluded that the electronic student worksheet based on Project-Based Learning (PjBL) integrated with STEM on reaction rate material can be declared practical for use in learning. This is in line with research conducted by [Indranuddin et al., \(2024\)](#) and [Yulkifli et al., \(2022\)](#) regarding the development of learning media with the STEM-integrated PjBL model, which obtained the "very practical" category during the practicality test. This means the E-LKPD developed is practical, feasible, and easy to use in learning ([Silfiyani et al., 2024](#); [Yulkifli et al., 2022](#)). Another study conducted by [Silvanny & Yerimadesi, \(2023\)](#) stated that PjBL-STEM-based electronic teaching materials obtained responses from teachers in the convenient category, which means that the electronic learning media developed are practical to use in terms of ease of use, learning activities, and benefits. The electronic student worksheet contains materials, assignments, and activities that are relevant to the material being taught. The activities contained in the electronic student worksheet are used to help achieve learning objectives ([Erna et al., 2021](#)). Each learning activity in the electronic student worksheet is linked to an active navigation link and is equipped with audio, images, videos, and animations to enhance the learning experience, allowing students to easily understand the material ([Alexon & Handayani, 2024](#)). The use of electronic student worksheet in learning can help teachers provide meaningful information and offer quick and accurate feedback ([Ladamay et al., 2021](#)) and become an alternative and enjoyable learning medium ([Latifah & Luritawaty, 2020](#)).

Readability of Electronic Student Worksheet based on Project Based Learning (PjBL) Integrated STEM on Reaction Rate Material

The readability of electronic student worksheet based on Project-Based Learning (PjBL) Integrated STEM on Reaction Rate material is obtained from the

student assessment. The readability test of electronic student worksheet was conducted on 60 students. The aspects assessed in the readability test consist of material, language presentation, design, and ease of use. The assessment was carried out by providing a readability sheet, and the assessment results were converted into quantitative data. The results of the readability assessment of electronic student worksheet based on Project-Based Learning (PjBL) Integrated STEM on Reaction Rate material can be seen in Figure 5.

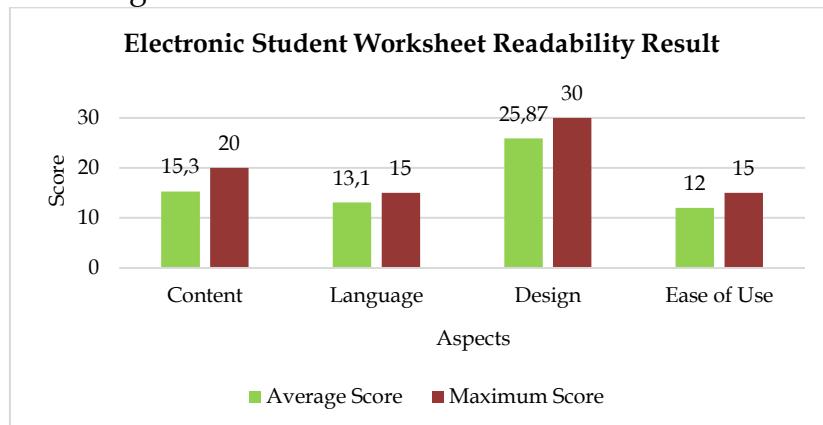


Figure 5. Electronic student worksheet readability test results

Based on the figure 5, the average score obtained from the student's assessment on the material aspect and ease of use obtained a good category. The assessment results obtained in the aspects of language presentation and design obtained a very good category. In addition, the total average score obtained is 66.27 from a maximum score of 80 and is included in the "very good" category. This indicates that students perceive the electronic student worksheet as having clear material, easy-to-understand language, an attractive design, and ease of use. This is in line with research conducted by (Christie & Lestari, 2019), which states the importance of clear and concise language in improving understanding. In addition, findings from research conducted by Budiarti et al., (2023); Silfiyani et al., (2024); and Syukri et al., (2021) indicate that the development of learning media using the STEM-integrated PjBL model received an excellent category in the readability test. This means that electronic learning media makes it easy for students to understand the subject matter provided (Silvanny & Yerimadesi, 2023). In addition, images, videos, and audio on electronic student worksheet facilitate students according to their learning style and make electronic student worksheet attractive (Silfiyani et al., 2024). According to Alexon & Handayani (2024), electronic student worksheets make it easier for users to access student worksheet s quickly and flexibly, increasing students' interest in learning and independence because they contain audio, video, and animation, thereby affecting student learning outcomes. Electronic student worksheets can be designed and developed in accordance with the specific learning needs of students (Alexon & Handayani, 2024). Based on the results obtained, the electronic student worksheet based on Project-Based Learning (PjBL) integrated with STEM on reaction rate material can be declared feasible to be implemented in learning.

Characteristics of Electronic Student Worksheet based on Project Based Learning (PjBL) Integrated STEM on Reaction Rate Material

The product developed in this study is an electronic student worksheet based on Project Based Learning (PjBL) integrated STEM on reaction rate material in html and apk format so that it can be operated via android smartphones and laptops. The electronic student worksheet developed is adapted to the PjBL-STEM syntax, which can guide students in studying the reaction rate material. The stages of the learning model in the developed electronic student worksheet are adjusted to the stages of PjBL-STEM learning according to [Laboy-rush, \(2010\)](#), which consists of reflection, research, discovery, application, and communication stages with STEM aspects consisting of Science, Technology, Engineering, and Mathematics. The contents of the electronic student worksheet product can be seen in Figure 6.

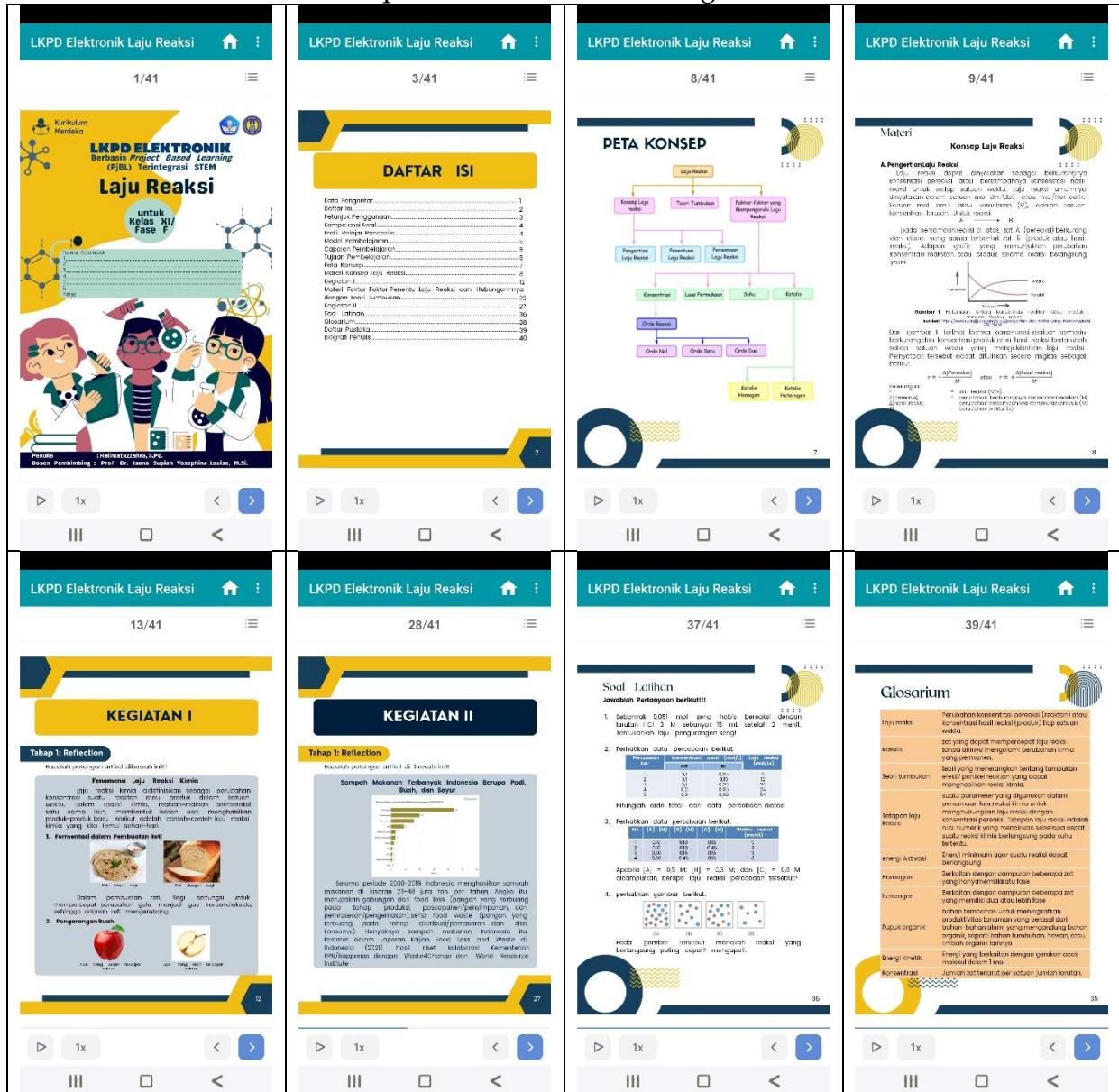


Figure 6. Contents of Electronic Student Worksheet Products

The developed electronic student worksheet products are shared with teachers and learners using a Google Drive storage link. They can be installed on an Android smartphone and operated via a laptop. This can help teachers and learners access electronic student worksheet anytime and anywhere. In addition, this electronic student worksheet prioritizes the demands of using technology in learning. The presentation of electronic student worksheet can be accessed via smartphones and laptops, so that presentation of electronic student worksheet makes it easier for users to access student worksheet quickly and flexibly (Alexon & Handayani, 2024) and makes it easier for students to understand learning materials (Puspita & Dewi, 2021). The use of electronic student worksheet through smartphones and laptops means students do not need to print student worksheet. This helps reduce using paper during learning (Ferdian et al., 2025; Sumanik et al., 2023). Teachers and students can easily share electronic student worksheet if they already have a Google Drive storage link from electronic student worksheet through social media, which makes it more environmentally friendly (Rahmawati et al., 2022). In addition, students get a direct experience of learning using student worksheet by utilizing the technology used by students (Fitriyaningsih et al., 2023; Ghaisani & Setyasto, 2023).

The electronic student worksheet developed using has been adapted to the STEM-integrated PjBL model. The following is a table of learning activities for reaction rate material with STEM-integrated PjBL syntax in the activities in the developed electronic student worksheet. The project carried out by students is the determination of the reaction order based on compounds with specific concentrations and the manufacture of liquid organic fertilizer based on the determinants of the reaction rate.

Table 2. Activities in each STEM-integrated PjBL syntax in the activities of the developed electronic student worksheet.

Syntax PjBL integrated STEM		Activities	
		Reaction Rate Concept (determining the reaction order based on compounds with specific concentrations)	Determinants of Reaction Rate and its Relationship with Collision Theory (making liquid organic fertilizer based on factors determining the reaction rate)
Reflection (STEM Aspect: Science, Technology)	Given a discourse on the phenomenon of reaction rates in everyday life. Learners identify the difference in reaction rates from chemical reactions in everyday life, videos about reaction rates, rate equations and reaction orders, and videos of practicum to determine reaction orders. In addition, learners are asked to conduct a practicum to determine the reaction order with a compound whose concentration has been determined.	A discourse on the most food waste in Indonesia, a video on collision theory and reaction rates, and a video on making liquid organic fertilizer.	
Research (STEM aspect: Science, Technology)	Learners learn and search for more information about determining the reaction order.	Learners study and search for more information about making liquid organic fertilizer and its relationship	

			with the determinants of reaction rate and collision theory.
Discovery (STEM aspect: Science, Technology, engineering, mathematics)	Learners design a project on the given problem of determining the reaction order in compounds with specific concentrations.	Learners design a project on the problem of making liquid organic fertilizer based on the determinants of the reaction rate.	
Application (STEM aspect: Science, Technology, Mathematics)	Learners conduct a project to determine the reaction order in compounds with specific concentrations.	Learners carry out a project on making liquid organic fertilizer based on the factors determining the reaction rate.	
Communication (STEM aspect: Science, Technology)	Learners communicate the project's results on the given problem, determining the reaction order in compounds with specific concentrations.	Learners communicate the project's results on the given problem of making liquid organic fertilizer based on the determinants of the reaction rate.	

Electronic student worksheet is designed to shape the imagination and curiosity of learners, especially in materials that emphasize practical applications and are relevant to everyday life (Sera et al., 2025; Silfiyani et al., 2024). As with STEM-integrated PjBL, it involves learners in interdisciplinary investigations that focus on real-world issues that are highly relevant to the actual collaboration that occurs in STEM fields (Capraro et al., 2013) which encourages innovative thinking, generating ideas, and applying them (Wardana et al., 2024). In addition, STEM-integrated PjBL allows learners to connect the disciplines of science, technology, engineering, and mathematics (Sinurat et al., 2022) through understanding concepts and theories (Science), using and applying technology to help solve problems (Technology), designing Solutions (Engineering), and analyzing data mathematically (Mathematics) (Afrianti & Yerimadesi, 2024). In learning with Project-Based Learning (PjBL) Electronic student worksheet Integrated with STEM, students face phenomena related to real life, such as making liquid organic fertilizer. In this case, in PjBL, students are asked to understand concepts through product creation, while in STEM, there is a design and redesign process that encourages students to create their best products (Wiratman et al., 2023; Yusuf et al., 2023).

Electronic student worksheet can be used as a reference for distance learning, choosing a learning style according to their characteristics (Purwanti & Sholihah, 2021). Electronic student worksheet 's flexibility helps students learn and understand reaction rate material independently. Electronic student worksheet facilitates the learning process independently and forms effective communication between teachers and students (Meilisa et al., 2024; Suparwati et al., 2023). Electronic student worksheet has materials, tasks, and activities relevant to the material being taught so that students can learn independently. Each learning activity in the electronic student worksheet is connected by a link that functions as navigation and is equipped with a presentation of images and videos that make it more interactive (Anwar & Hidayati, 2025) and provide experience to students in learning to more easily understand the material being taught (Alexon & Handayani, 2024).

Conclusion

Based on the research that has been conducted, it can be concluded that the electronic student worksheet developed has characteristics such as being able to be operated via Android smartphones and laptops by the syntax of the STEM-integrated Project-Based Learning (PjBL) model, which can help students understand reaction rate material through projects carried out during learning, can be used flexibly anytime and anywhere, prioritizes the demands of using technology in learning with electronic student worksheet file sizes that are not too large, and helps reduce paper usage during the learning process. The feasibility of electronic student worksheet based on Project Based Learning (PjBL) integrated STEM on reaction rate material obtained an average score of 134.5 with the category "very good" from the assessment conducted by two validators based on aspects of content, language, presentation, graphics, and software engineering. The practicality of the STEM-integrated Project Based Learning (PjBL)-based electronic student worksheet on reaction rate material obtained an average score of 117.5 with an "excellent" category from the assessment conducted by three peers and five chemistry teachers based on aspects of content, language, presentation, graphics, and ease of use. The readability of electronic student worksheet based on Project Based Learning (PjBL) integrated STEM on reaction rate material obtained an average score of 66.27 with the category "very good" from responses made by 60 students based on aspects of the material, language presentation, design, and ease of use. The developed learning media received a "very good" rating regarding feasibility, practicality, and readability. Therefore, the electronic student worksheet based on Project-Based Learning (PjBL) integrated with STEM in the developed reaction rate material can be declared suitable for use in learning. The implication for the research is that electronic worksheets based on Project-Based Learning (PjBL) integrated STEM on the topic of reaction rates are recommended for use as one of the learning resources used by teachers to make learning more meaningful.

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