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Project-Based Digital Worksheets with Chemoentrepreneurship to Foster Creative Thinking and Entrepreneurial Interest in Reaction Rates

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ABSTRAK

Pembelajaran materi faktor-faktor yang memengaruhi laju reaksi di sekolah menengah atas masih cenderung menekankan aspek konseptual dan belum sepenuhnya mengaitkan konsep kimia dengan konteks kehidupan nyata. Kondisi tersebut menyebabkan kemampuan berpikir kreatif dan minat wirausaha peserta didik belum berkembang secara optimal. Oleh karena itu, diperlukan bahan ajar digital yang mampu memfasilitasi pembelajaran aktif, kontekstual, dan bermakna. Penelitian ini bertujuan untuk mengembangkan serta menguji kelayakan dan keefektifan Lembar Kerja Peserta Didik Elektronik berbasis Project-Based Learning berorientasi Chemoentrepreneurship pada materi faktor-faktor laju reaksi dalam meningkatkan kemampuan berpikir kreatif dan minat wirausaha peserta didik. Penelitian ini menggunakan metode penelitian dan pengembangan dengan model Four-D yang meliputi tahap pendefinisian, perancangan, pengembangan, dan penyebaran. Subjek penelitian adalah peserta didik kelas XI di salah satu sekolah menengah atas negeri yang dibagi ke dalam kelas eksperimen dan kelas kontrol. Data dikumpulkan melalui lembar validasi ahli, tes awal dan tes akhir, lembar observasi kemampuan berpikir kreatif, serta angket minat wirausaha, kemudian dianalisis secara deskriptif dan inferensial. Hasil penelitian menunjukkan bahwa Lembar Kerja Peserta Didik Elektronik yang dikembangkan memenuhi kriteria sangat layak berdasarkan validasi ahli. Selain itu, telah terbukti bahwa penggunaan bahan ajar ini dapat meningkatkan kemampuan berpikir kreatif dan semangat berwirausaha siswa. Ini terbukti dengan peningkatan hasil belajar dan partisipasi siswa pada kelas eksperimen dibandingkan dengan kelas kontrol. Oleh karena itu, lembar kerja peserta didik elektronik yang berorientasi pada kemoentrepreneurship dan menggunakan pendekatan pembelajaran berbasis proyek dapat digunakan sebagai alternatif sumber pendidikan yang mendukung pembelajaran kimia yang kontekstual dan bermakna.

ABSTRACT

The teaching of factors affecting reaction rates in high schools still tends to emphasize conceptual aspects and does not fully relate chemical concepts to real-life contexts. This condition prevents students' creative thinking skills and entrepreneurial interests from developing optimally. Therefore, digital teaching materials that can facilitate active, contextual, and meaningful learning are needed. This study aims to develop and test the feasibility and effectiveness of Chemoentrepreneurship-oriented Project-Based Learning Electronic Student Worksheets on the subject of factors affecting reaction rates in improving students' creative thinking skills and entrepreneurial interest. This study used a research and development method with a Four-D model, which includes the stages of definition, design, development, and dissemination. The research subjects were grade XI students at a public high school, who were divided into an experimental class and a control class. Data were collected through expert validation sheets, pre-tests and post-tests, creative thinking ability observation sheets, and entrepreneurial interest questionnaires, then analyzed descriptively and inferentially. The results showed that the developed Electronic Student Worksheets met the criteria of being highly feasible based on expert validation. In addition, it has been proven that the use of these teaching materials can improve students'.

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INTRODUCTION

Instructional strategies that actively engage students in creating information, applying ideas in practical settings, and developing higher-order thinking skills are essential for learning in the twenty-first century (Muhali, 2019). Modern education places a strong emphasis on student-centered learning that develops creativity, independence, and problem-solving skills in response to these demands. This change is significant in chemistry education because chemical ideas are often abstract but closely related to real-life situations, which requires teaching methods that successfully connect theoretical knowledge with practical applications (Rawung *et al.*, 2021; Mulyani & Haliza, 2021).

Reaction rate is a significant topic in senior high school chemistry with considerable contextual importance. Everyday tasks, such as food processing and fermentation, often involve elements that affect reaction rates, including concentration, temperature, surface area, and catalysts. Learners frequently find it challenging to grasp the principles of reaction rates since they are typically conveyed through theoretical ideas lacking sufficient practical illustrations or experiental learning, leading to perception of the topic as complex (Bahruddin, 2018; Qholby & Lazulva, 2020). As a result, students' creative thinking skills are not optimally developed, and learning tends to focus on understanding formulas rather than generating ideas or applying concepts in meaningful situations.

Several studies have found that traditional or cooperative learning methods in chemistry classes continue to focus on mastering concepts and completing tasks, with few opportunities for students to engage in exploratory and meaningful activities that connect to real-world situations and have economic significance (Sumarti *et al.*, 2015; Sumarti *et al.*, 2018). onsequently, chemistry learning has not optimally facilitated the simultaneous development of students' creative thinking skills and entrepreneurial interest through meaningful learning experiences. This condition is also observed in schools that have adopted the Merdeka Curriculum, as the supply of interactive and project-based teaching resources remains quite limited (Salamah *et al.*, 2023).

Project-Based Learning (PjBL) is a teaching method that involves students participating in real-world projects. This enables them to learn how to solve problems, generate new ideas, and collaborate as a team (Trimawati *et al.*, 2020; Mahmudi *et al.*, 2022). When combined with the Chemoentrepreneurship (CEP) method, studying chemistry enables students to transform chemical concepts into simple, practical, and cost-effective products (Kurnia *et al.*, 2022). Additionally, utilizing E-Worksheet facilitates the setup of project activities, enhances the interest in learning content, and promotes thoughtful reflection, thereby benefiting both individual and group learning (Suryaningsih & Nurlita, 2021; Ayuningtias *et al.*, 2024). Although some earlier research has examined PjBL, CEP, or E- Worksheet individually, combining these methods, particularly when teaching about reaction rates and emphasizing creative thinking and

entrepreneurial interest, has been relatively underexplored (Kurniawati *et al.*, 2021; Prayitno *et al.*, 2024). This study integrates Project-Based Learning, Chemoentrepreneurship orientation, and electronic worksheets into a single instructional design on reaction rate material.

Based on this research gap, this study aims to develop and examine the effectiveness of an E-Worksheet on reaction rate materials, oriented toward Project-Based Learning and Chemoentrepreneurship, to improve students' creative thinking skills and simultaneously foster entrepreneurial interest. The developed E-Worksheet is intended to offer a new and relevant learning tool that connects chemistry ideas with practical tasks, meeting the requirements of the Merdeka Curriculum as mentioned (Arisanti, 2022).

METHODS

This study employed a Research and Development (R&D) approach using the 4D model proposed by Thiagarajan, consisting of the define, design, develop, and disseminate stages. The study aimed to develop a Project-Based Learning (PjBL) E-Student Worksheet oriented toward Chemoentrepreneurship (CEP) on the topic of factors affecting reaction rates, and to examine its feasibility and effectiveness in improving students' creative thinking skills and entrepreneurial interest.

The research was conducted at SMA Negeri 1 Ungaran during the second semester of the 2024/2025 academic year. The participants were grade XI students studying reaction rates. Two classes were involved in the study: one class utilized the newly developed E-Worksheet, while the other class used traditional teaching methods. Each class consisted of 36 students. The study was carried out in the second semester of the 2024-2025 school year at SMA Negeri 1 Ungaran. Students in grade 11 who were learning about reaction rates participated in the study. There were two classes: an experimental class that used the developed E-Worksheet and a control class that received traditional instruction. There were 36 pupils in each class.

The development process followed four stages called 4D. In the define stage, they identified the requirements by conducting interviews with teachers, studying the Merdeka Curriculum, understanding the characteristics of students, and examining factors that affect reaction rates to the material. The design phase involved organizing the E-Worksheet by combining PjBL methods with CEP ideas, ensuring that creative thinking skills and an interest in entrepreneurship were incorporated into the learning tasks and assessments. During the development phase, experts reviewed the materials and media, made adjustments based on their feedback, and conducted limited testing in real classrooms to assess their effectiveness. The dissemination stage was conducted on a limited scale by introducing the finalized E-Worksheet to chemistry teachers and registering the product for intellectual property rights.

Data were collected using expert validation sheets, pre- and posttest instruments, creative thinking observation sheets, and entrepreneurial interest questionnaires. Expert validation sheets were used to assess the feasibility of the E-Worksheet in terms of content and media. Pretest and posttest instruments measured learning outcomes, while observation sheets and questionnaires assessed students' creative thinking skills and entrepreneurial interest during and after the learning process. Instrument validity was examined through expert judgment, and the reliability of test instruments was analyzed statistically. Only instruments that met the validity and reliability criteria were used in the field.

Data analysis involved descriptive and inferential techniques. The feasibility of the E-Worksheet was determined based on the percentage of expert validation scores. Learning effectiveness was assessed using normalized gain, which helps indicate the extent to which students improved in their learning. The difference between the two groups of students one that had the new approach and one that didn't was examined using a test called the Mann-Whitney U test. Information from observing the outcomes and from questionnaires was analyzed by examining the percentage of answers and interpreting them based on established rules.

RESULT AND DISCUSSION

Result

The E-Worksheet was developed using the 4D model, comprising the define, design, develop, and disseminate stages. The define stage revealed that students required digital learning materials that support active learning, contextual problem-solving, and real-life applications of chemistry concepts (Taofek & Agustini, 2020; Rakhmaningtyas, 2022). Existing learning activities on factors affecting reaction rates had not optimally facilitated creative thinking skills and entrepreneurial interest, forming the basis for determining the objectives and design of the E-Worksheet.

At the design stage, the E-Worksheet was structured by integrating the Project-Based Learning (PjBL) syntax with a Chemopreneurship Education approach. The learning activities included identifying contextual problems, planning and conducting experiments, developing chemistry-based products, presenting the products, and reflecting on the learning process. The overall appearance of the developed E-Worksheet, including its cover and Chemopreneurship-oriented PjBL approach, is presented in Figure 1.

The learning activities were organized according to the stages of PjBL, including problem identification, project planning, project implementation, product development, presentation, and evaluation. The sequence of the PjBL syntax incorporated into the E-Worksheet is illustrated in Figure 2. This structure was intended to guide students systematically through the process of investigating factors affecting reaction rates while developing a tangible product.

Chemopreneurship elements were embedded by connecting reaction-rate concepts with the production of economically valuable products. Examples of the Chemopreneurship activities included the production of tape and dodol tape, as shown in Figure 3. Through these activities, students were expected to understand the application of chemistry concepts, modify materials and production procedures, calculate production costs, and identify potential business opportunities.

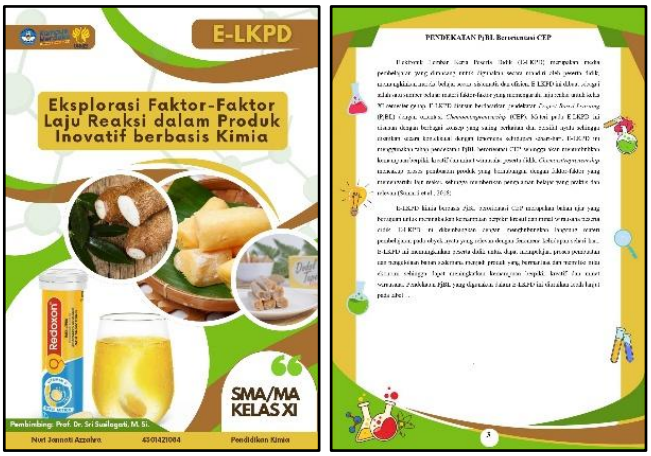

Figure 1. Overview of the Developed PjBL-Based E-Worksheet Oriented toward Chemoentrepreneurship

Figure 2. PjBL Syntax

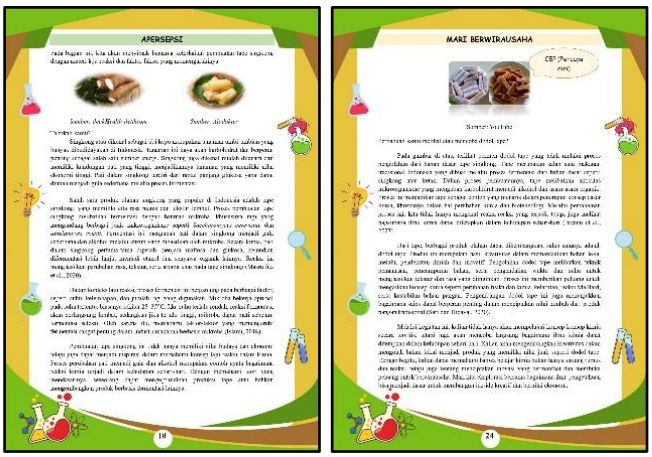

Figure 3. Chemoentrepreneurship (Tape and Dodol Tape)

During the development phase, experts reviewed the content to ensure it was accurate, the instructional approach was well-structured, and the media elements were effectively presented. The E-Worksheet was classified as "very feasible" following some minor adjustments to enhance clarity in instruction and ensure consistency in visual elements, indicating that it is suitable for use in a classroom setting. At the disseminate stage, the finalized E-Worksheet was introduced to chemistry teachers and documented as a learning innovation on a limited scale.

The effectiveness of the developed E-Worksheet in improving students' creative thinking skills was evaluated using pretest and posttest scores. As presented in Table 1, the experimental class obtained a mean N-gain score of 0.7349, which was categorized as high, whereas the control class obtained a mean N-gain score of 0.6243, which was categorized as moderate. These results indicate that both classes experienced improvement, although the improvement in the experimental class was greater than that in the control class.

Table 1. N-gain Results of Creative Thinking Skills in the Experimental and Control Classes

Class	N	Minimum	Maximum	Mean N-gain	Std. Deviation	Category
Control	36	0.20	0.83	0.6243	0.12867	Moderate
Experimental	36	0.50	0.92	0.7349	0.12224	High

Furthermore, the Mann–Whitney U test results presented in Table 2 showed a significant difference between the posttest scores of the experimental and control classes. The experimental class obtained a higher mean rank of 45.82 than the control class, which obtained a mean rank of 27.18. The resulting significance value was less than 0.001, indicating that the null hypothesis was rejected. Therefore, the implementation of the Chemopreneurship-oriented PjBL E-Worksheet had a statistically significant effect on students' creative thinking skills.

Table 2. Mann Whitney U Test Results

Group	N	Mean Rank	Asymp. Sig. (2-tailed)	Decision
Control Class	36	27.18	0.000	Ho accepted
Experimental Class	36	45.82	0.000	Ho accepted

The observational findings supported the results of the statistical analysis. As shown in Table 3, the control class obtained an overall creative thinking score of 79.43%, which was categorized as creative. The scores for fluency, flexibility, originality, and elaboration were 80.79%, 78.82%, 77.78%, and 80.32%, respectively.

Table 3. Observation Results of Creative Thinking Skills in the Control Class

Creative Thinking Aspect	Total Score	Percentage (%)	Category
Fluency	349	80.79	Creative
Flexibility	227	78.82	Creative
Originality	224	77.78	Creative
Elaboration	347	80.32	Creative
Total	1147	79.43	Creative

In comparison, the experimental class obtained an overall creative thinking score of 86.57%, which was categorized as very creative, as presented in Table 4. The experimental class achieved scores of 86.81% for fluency, 87.85% for flexibility, 85.76% for originality, and 85.88% for elaboration. Thus, the experimental class demonstrated consistently higher performance across all creative thinking indicators than the control class.

Table 4. Observation Results of Creative Thinking Skills in the Experimental Class

Creative Thinking Aspect	Total Score	Percentage (%)	Category
Fluency	375	86.81	Very Creative
Flexibility	253	87.85	Very Creative
Originality	247	85.76	Very Creative
Elaboration	371	85.88	Very Creative
Total	1246	86.57	Very Creative

Observational data collected during the project activities also demonstrated differences in students' entrepreneurial interest. As presented in Table 5, the control class obtained an overall entrepreneurial-interest score of 79.54%, which was categorized as strong. The scores for self-confidence, creativity, risk-taking courage, and responsibility were 79.86%, 79.17%, 79.51%, and 79.63%, respectively.

Meanwhile, the experimental class obtained an overall entrepreneurial-interest score of 93.00%, which was categorized as very strong, as shown in Table 6. The experimental class obtained scores of 92.82% for self-confidence, 93.75% for creativity, 91.67% for risk-taking courage, and 93.75% for responsibility. These observational results indicate that students who used the developed E-Worksheet demonstrated greater involvement and more positive entrepreneurial behavior during the project activities than students in the control class.

Table 5. Observation Results of of Entrepreneurial Interest in the Control Class

Entrepreneurial Interest Aspect	Total Score	Percentage (%)	Category
Self-confidence	345	79.86	Strong
Creativity	228	79.17	Strong
Risk-taking courage	229	79.51	Strong
Responsibility	344	79.63	Strong
Total	1146	79.54	Strong

Table 6. Observation Results of of Entrepreneurial Interest in the Experimental Class

Entrepreneurial Interest Aspect	Total Score	Percentage (%)	Category
Self-confidence	401	92.82	Very Strong
Creativity	270	93.75	Very Strong
Risk-taking courage	264	91.67	Very Strong
Responsibility	405	93.75	Very Strong
Total	1340	93	Very Strong

In addition to classroom observations, students' entrepreneurial interest was measured using a post-learning questionnaire. The questionnaire assessed self-confidence, creativity, willingness to take risks, and responsibility. As illustrated in Figure 4, the experimental class

obtained an overall questionnaire score of 81.36%, whereas the control class obtained 74.51%. The experimental class also achieved higher scores for self-confidence (82.11%), creativity (80.83%), courage to take risks (80.28%), and responsibility (82.22%) than the control class, which obtained scores of 74.56%, 75.69%, 73.33%, and 74.44%, respectively. These findings confirm that the Chemopreneurship-oriented PjBL E-Worksheet positively influenced students' entrepreneurial interest.

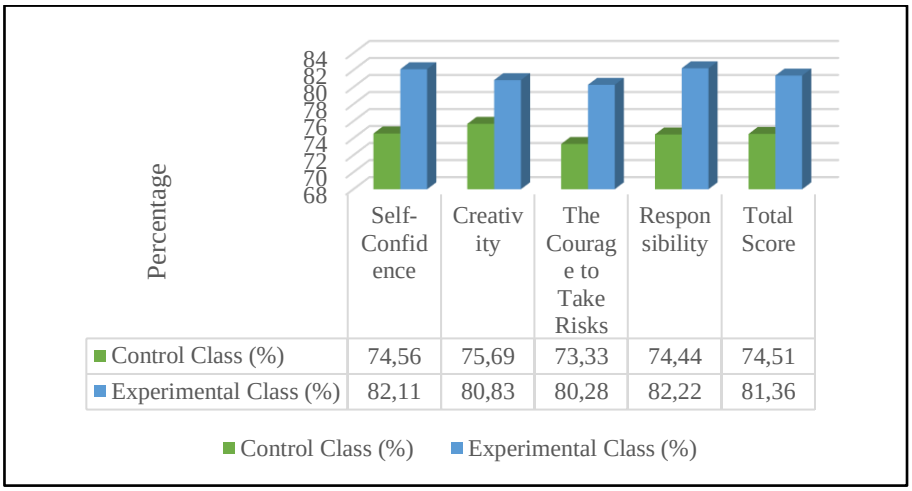

Figure 4. Comparison of Entrepreneurial Interest Scores between the Experimental and Control Classes

Discussion

The findings demonstrate that the Chemopreneurship-oriented PjBL E-Worksheet was effective in improving students' creative thinking skills and entrepreneurial interest. The N-gain results in Table 1 show that the experimental class experienced a higher level of improvement than the control class. This finding was reinforced by the Mann–Whitney U test results in Table 2, which revealed a statistically significant difference between the two classes. Therefore, the improvement was not limited to descriptive score differences but was also supported by inferential statistical evidence.

The improvement in creative thinking skills can be attributed to the characteristics of the developed E-Worksheet, which actively engaged students in structured project-based activities. Through activities that included identifying problems, conducting tests, and creating products based on actual chemical circumstances, students were encouraged to generate their own ideas, investigate various approaches to problem-solving, and discuss their views. By using PjBL, students were able to construct their own knowledge actively, rather than merely listening to their lecturers. This approach helped students become better thinkers by enhancing their ability to generate ideas, think critically, and add more details to their ideas (Munandar, 2021; Mahmudi *et al.*, 2022). The higher scores in the experimental group show that students who use guided exploration with digital tools during learning tend to develop their creative thinking skills more effectively.

In addition, the Chemoentrepreneurship orientation embedded in the E-Worksheet played a significant role in strengthening both creative thinking skills and entrepreneurial interest. By contextualizing chemistry concepts within economically relevant activities, students were challenged to creatively modify materials, procedures, and outcomes as they developed simple chemistry-based products (Sumarti *et al.*, 2018). This contextual learning experience enabled students to perceive chemistry as applicable and meaningful, rather than abstract, which aligns with previous findings that entrepreneurial-based project learning can foster higher-order thinking skills and creativity.

The enhancement of students' entrepreneurial interest was also evident from both the questionnaire and observational data. Students who used the developed E-Worksheet demonstrated higher levels of self-confidence, creativity, bravery in taking risks, and a greater sense of responsibility than students in regular classrooms (Fairusi *et al.*, 2020; Ni'mah & Kamaludin, 2023). Project-based learning provided students with experiences that resembled real entrepreneurial processes, such as planning, experimentation, evaluation, and reflection, which contributed to the development of positive attitudes toward entrepreneurship. These findings indicate that the integration of PjBL and CEP has successfully created an engaging learning environment that supports both affective and cognitive development.

Despite its effectiveness, the developed E-Worksheet has certain limitations. Using project-based learning requires sufficient time for teaching, which can be challenging in classes that lack ample time for learning. Additionally, the E-Worksheet we created only covers the topic of factors that affect reaction speeds, so further work is needed to expand and adapt it for other chemistry subjects. Nevertheless, the findings of this study demonstrate that the Chemoentrepreneurship-oriented PjBL-based E-Worksheet is effective and has strong potential for broader application in chemistry learning, provided that appropriate adjustments are made.

CONCLUSION

This development research resulted in a Project-Based Learning (PjBL) E-Student Worksheet oriented toward Chemoentrepreneurship on the topic of factors affecting reaction rates, which is suitable for use in chemistry learning. Expert validation of content and media confirmed that the developed E-Worksheet meets very feasible criteria for classroom implementation. The E-Worksheet helped students think more creatively and showed they were more interested in starting their own businesses. This was clear from the better results they achieved and the more positive way they acted during learning, compared to students in the control group. These findings indicate that the Chemoentrepreneurship-oriented PjBL-based E-Worksheet can serve as an alternative learning resource to support contextual, active, and meaningful chemistry learning. So, chemistry teachers are encouraged to use this E-Worksheet to help students develop their creative thinking

and interest in entrepreneurship. Additionally, future studies could explore adapting and expanding this tool for other chemistry topics and various learning situations.

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