

Development of an E-Module Based on Project-Based Learning (PJBL) and Integrated With Local Wisdom Batak Toba Mardemban on Teaching Reaction Rate Chemistry

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Abstract: The development of Project-Based Learning (PjBL)-based instructional materials integrated with ethnopedagogy represents an innovative approach to supporting the implementation of the Merdeka Curriculum. However, the development of PjBL-based e-modules for the reaction rate chemistry topic integrated with local wisdom remains limited. This study aimed to analyze the initial needs for developing a PjBL-based e-module integrated with ethnopedagogy, determine its feasibility based on the criteria established by the Indonesian National Education Standards Agency (BSNP), and evaluate teachers' and students' responses to the developed e-module. This study employed the Research and Development (R&D) method using the Four-D (4D) development model, consisting of the Define, Design, Develop, and Disseminate stages. The needs analysis revealed that chemistry teachers strongly supported the development of a PjBL-based e-module, while 85.5% of the students expressed interest in an e-module integrated with local wisdom. The expert validation results indicated content and media feasibility scores of 88.1% and 86.8%, respectively, whereas the teachers' validation yielded content and media feasibility scores of 96.7% and 94.3%, respectively. All validation results were categorized as highly feasible. Furthermore, the teachers' response score reached 94.6%, while the students' response scores were 89.7% at the research site and 89.9% outside the research site, all of which were classified as very high. Therefore, the developed PjBL-based e-module integrated with ethnopedagogy is considered highly feasible for chemistry instruction and demonstrates positive potential for enhancing students' engagement in the learning process.

Keywords: e-module development; reaction rates; Project-Based Learning (PjBL); ethnopedagogy; local wisdom; Indonesian National Education Standards Agency (BSNP).

1. INTRODUCTION

Education aims to develop students' knowledge, intellectual abilities, and character through the collaboration of the government and teachers. The government is responsible for establishing educational policies, developing curricula, enhancing teacher professionalism, and providing adequate educational facilities, while teachers implement the curriculum according to students' characteristics and the needs of educational institutions. In response to the rapid advancement of technology in the Industrial Revolution 4.0 era and the demands of 21st-century learning, the Indonesian government has introduced the Merdeka Curriculum, which emphasizes character development, essential learning content, project-based learning, and greater school autonomy through the *Projek Penguatan Profil Pelajar Pancasila* (P5), a program that promotes contextual, student-centered learning [1], [2], [3], [4]. In chemistry education, particularly in the topic of reaction rates, students often experience learning difficulties because the concepts are abstract, involve mathematical calculations, and are constrained by limited laboratory facilities [5]. Therefore, innovative instructional media such as Project-Based Learning (PjBL)-based e-

modules are needed to enhance students' engagement, critical thinking, creativity, collaboration, and learning motivation [6], [7]. To create more meaningful learning experiences, the e-module integrates an ethnopedagogical approach by incorporating local wisdom, including the *mardemban* and *marsukkil* traditions of North Sumatra and the *menginang* tradition in Papua, which are closely related to the concept of reaction rates and enable students to understand chemical concepts while fostering appreciation for local culture [7], [8], [9], [10]. Previous studies have reported positive student responses toward ethnosience-based teaching materials, although their effectiveness in improving learning outcomes requires further investigation [11], [12]. Furthermore, needs analysis has revealed that chemistry instruction is still dominated by conventional teaching materials and teacher-centered approaches, while the existing teaching materials have not integrated innovative learning models or local wisdom. Consequently, there is a need to develop more contextual, practical, and engaging instructional materials that can improve students' conceptual understanding and active participation in the learning process [13]. Based on these findings, this study aims to develop a Project-Based Learning (PjBL)-based chemistry e-module integrated with

ethnopedagogy for the reaction rate topic, analyze the needs of teachers and students as well as the suitability of the currently used teaching materials, and conduct a limited trial involving Grade XI students to evaluate teachers' and students' responses to the developed e-module.

2. RESEARCH METHODS

This study employed the Research and Development (R&D) method to develop and evaluate the quality of an instructional product. The development of the Project-Based Learning (PjBL)-based e-module integrated with local wisdom followed the Four-D (4D) model proposed by Thiagarajan, Semmel, and Semmel (1974), which consists of four stages: ****Define, Design, Develop, and Disseminate****. The study was conducted at SMA Negeri 2 Percut Sei Tuan, Medan, Indonesia. The preliminary stage involved observations and interviews with several chemistry teachers and Grade XI-C students. The interviews were conducted to identify the instructional strategies and teaching methods implemented by teachers, evaluate the alignment of classroom instruction with the current curriculum, and examine the teaching materials used during the learning process. Meanwhile, classroom observations were carried out to investigate students' learning activities, the availability and utilization of learning facilities, students' characteristics, challenges encountered during the learning process, and the need for instructional media based on the objectives of the study.

2.1 Research Procedure

This study adopted the Four-D (4D) development model proposed by Thiagarajan, Semmel, and Semmel (1974), which consists of four sequential stages: (1) Define – This stage aims to identify learning needs, existing problems, and instructional requirements through a preliminary analysis; (2) Design – This stage involves designing the product by developing the initial draft or prototype of the Project-Based Learning (PjBL)-based e-module integrated with local wisdom; (3) Develop – This stage includes expert validation, product revision based on reviewers' feedback, and refinement of the developed e-module to ensure its validity and feasibility; (4) Disseminate – This final stage focuses on implementing and disseminating the validated e-module for use in the learning process.

2.2 Data Collection and Analysis

Four data collection methods were employed in this study. Classroom observations were conducted to analyze learning needs, while a literature review was carried out to examine the curriculum, syllabus, and existing teaching materials. Questionnaires were administered to collect teachers' and students' responses regarding the content and media aspects of the developed instructional materials. In addition, validation sheets were completed by expert validators based on the assessment criteria established by the Indonesian National Education Standards Agency (BSNP). The collected data were analyzed using qualitative descriptive methods through two stages: (1) expert evaluation of the developed e-module and (2) analysis of teachers' and students' responses to determine the validity and feasibility of the developed instructional material.

PowerPoint presentations, while interactive and contextual e-modules have not yet been utilized. Furthermore, Project-Based Learning (PjBL) integrated with the local wisdom of the betel-chewing tradition has not been implemented in the learning process. The questionnaire results indicated that most students were interested in the development of a project-based e-module because they believed it could facilitate a more meaningful, independent, and authentic understanding of reaction rate concepts [13].

An analysis of the three chemistry textbooks currently used at the school, based on the Indonesian National Education Standards Agency (BSNP) criteria, showed that all textbooks were classified as highly feasible. However, none of them were designed using the Project-Based Learning (PjBL) approach or integrated local cultural values. Therefore, there is a need to develop a Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition to support more effective, contextual, and meaningful chemistry learning [13].

3.2 Design Stage

The design stage aimed to establish the framework and guidelines for developing the e-module. The e-module was designed using Canva Premium and published through the AnyFlip platform. Canva Premium was used to prepare the instructional content and visual layout of the e-module. The completed design was then converted into PDF format and uploaded to AnyFlip, which provides various features, including customizable themes, templates, and interactive digital displays. The developed e-module consists of several components. The introductory section includes a preface, table of contents, concept map, module identity, the Pancasila Student Profile, a brief description of the learning material, and user guidelines. The main section contains several learning activities covering fundamental concepts of reaction rates, factors affecting reaction rates, and collision theory.

Each learning activity includes learning objectives, content explanations, learning activities, practice exercises, answer keys, and self-assessment. In addition, the e-module integrates an ethnopedagogical approach through the betel-chewing tradition and spiritual values, enabling students to relate reaction rate concepts to local culture and everyday life. The final section of the module contains an evaluation, answer key, glossary, summary, and references to complete the instructional material.



3. RESULTS

3.1 Define Stage

The needs analysis conducted at SMA Negeri 2 Percut Sei Tuan revealed that chemistry instruction on the topic of reaction rates is still dominated by conventional teaching materials, including printed textbooks, worksheets, and



Figure 1. Some views of the content and images in the reaction rate e-module.

3.3 Development Stage

During the development stage, the initial draft of the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic was refined. The developed e-module was subsequently evaluated by media and subject matter experts based on the assessment criteria

established by the Indonesian National Education Standards Agency (BSNP) to determine its validity and feasibility. The content validation was conducted by six expert validators, comprising three chemistry lecturers from Universitas Negeri Medan and three chemistry teachers from SMA Negeri 2 Percut Sei Tuan. The validation instrument was developed based on the BSNP criteria, which include content feasibility, presentation feasibility, and language feasibility. Each assessment item was evaluated using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

a. Results of Material validation by Lecturer Assessment

Lecturers as expert validators of PjBL-based e-module materials that are integrated with ethnopedagogy of spiritual culture and spiritual values can be seen in table 1

Table 1. Results of Material Assessment by Lecturers

No	Assessment component	Percentage Average			Average Assessment (%)
		D1	D2	D3	
1	Content feasibility	80	91,1	90	87.3
2	Contextual assessment	80	91.1	95.5	89.1
3	Presentation Feasibility	80	92.9	91.1	88
Overall average (%)					88.13
Validation Criteria Analysis Percentage					Valid

Information :

D1 : Validator lecturer 1

D2 : Validator lecturer 2

D3 : Validator lecturer 3

Based on Table 1, the results of the expert content validation showed that the content feasibility aspect obtained a score of 87.3%, the contextual feasibility aspect achieved 89.1%, and the presentation feasibility aspect reached 88.0%. Overall, the average validation score across all assessment aspects was 88.13%, indicating that the developed e-module was highly feasible for use in the teaching and learning process. The average results of the expert validation are presented in Figure 2.

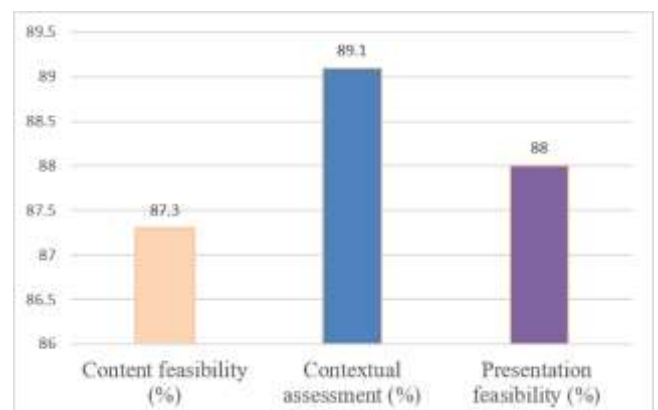


Figure 2. Graph of Material Expert Validation Results by Lecturers

b. Results of Media validation by Lecturer Assessment

The media validation was conducted by three chemistry lecturers from Universitas Negeri Medan based on the assessment criteria established by the Indonesian National Education Standards Agency (BSNP), which include graphical feasibility and language feasibility. Each assessment item was evaluated using a five-point Likert scale ranging from 1 to 5. The results of the media experts' evaluation of the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic are presented in Table 2.

Table 2. . Results of Media Assessment by Lecturers

No	Assessment Component	Percentage Assessment (%)			Average (%)
		D1	D2	D3	
1	Graphic Feasibility	80	92.9	92.9	87.6
2	Language Feasibility	80	90	88.3	86.1
Overall Average (%)					86.8
Validation Criteria Analysis Percentage					Valid

Based on Table 2, the graphical feasibility aspect obtained a score of 87.6%, while the language feasibility aspect achieved 86.1%. The overall average validation score was 86.8%, indicating that the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic was highly feasible for use in the teaching and learning process.

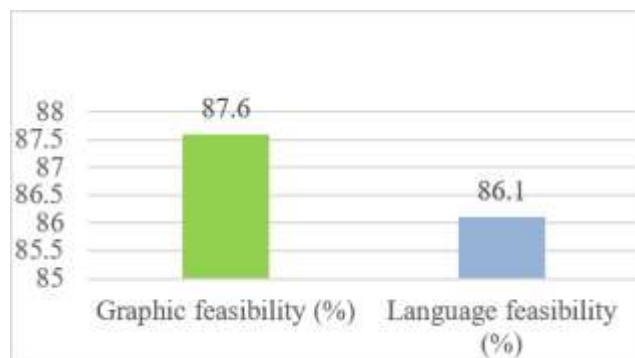


Figure 3. Graph of Media Expert Validation Results by Lecturers

c. Results of Material validation by Teacher Assessment

Content validation was conducted by three chemistry teachers from SMA Negeri 2 Percut Sei Tuan. The validation instrument was developed based on the assessment criteria established by the Indonesian National Education Standards Agency (BSNP), which include **content feasibility**, **contextual feasibility**, and **presentation feasibility**.

Each assessment item was evaluated using a five-point Likert scale ranging from 1 to 5. The results of the teachers' validation of the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic are presented in Table 3.

Table 3. . Results of Material Assessment by Teachers

Assessment component	Percentage Average			Average Assessment (%)
	G1	G2	G3	
Content feasibility	93.8	93.3	96.9	94.6
Contextual assessment	97.7	97.7	97.7	97.7
Presentation Feasibility	98	97.7	98	97.9
Overall average (%)				96.7
Validation Criteria Analysis Percentage				Valid

G1 : Teacher Validator 1

G2 : Teacher Validator 2

G3 : Teacher Validator 3

Based on Table 3, the results of the teacher validation indicated that the content feasibility aspect obtained a score of 94.6%, the contextual feasibility aspect achieved 97.7%, and the presentation feasibility aspect reached 97.9%. Overall, the average validation score was 96.7%, indicating that the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic was highly feasible for use in the teaching and learning process. The average validation results from the three chemistry teachers are presented in Figure 3.

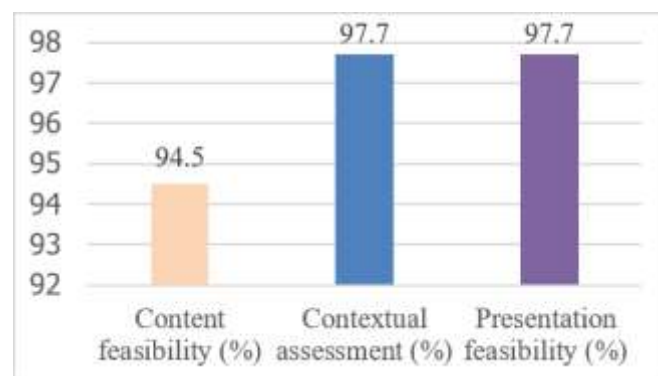


Figure 4. Graph of Material Expert Validation Results by Teachers

d. Results of Media validation by Teacher Assessment

The media validation was conducted by three chemistry teachers from SMA Negeri 2 Percut Sei Tuan. The validation instrument was developed based on the assessment criteria established by the Indonesian National Education Standards

Agency (BSNP), which include graphical feasibility and language feasibility. Each assessment item was evaluated using a five-point Likert scale ranging from 1 to 5. The results of the teachers' media validation of the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic are presented in Table 4.

Table 4. . Results of Media Assessment by Lecturers

No	Assessment Component	Assessment (%)			Average (%)
		G1	G2	G3	
1	Graphics Feasibility	88	98.8	90	92.3
2	Language Feasibility	91.6	98.3	98.3	96.4
Overall average (%)					94.3
Validation Criteria Analysis Percentage					Valid

Based on Table 4, the graphical feasibility aspect obtained a score of 92.3%, while the language feasibility aspect achieved 96.4%. The overall average validation score was 94.3%, indicating that the Project-Based Learning (PjBL)-based e-module integrated with the ethnopedagogical values of the betel-chewing tradition and spiritual values for the reaction rate topic was highly feasible for use in the teaching and learning process. The average media validation results from the three chemistry teachers are presented in Figure 5.

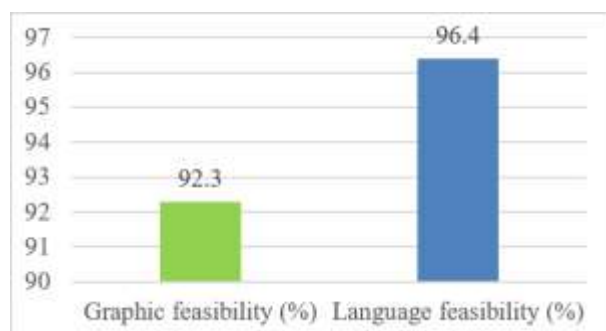


Figure 5. Graph of Media Expert Validation Result by Teachers

3.4 Disseminate Stage

3.4.1. Student respons

a. Analysis of student responses questionnaires at the research location .

During the field trial, the students' response questionnaire was administered to 35 Grade XI students at SMA Negeri 2 Percut Sei Tuan, Medan. The purpose of this trial was to evaluate the feasibility of the developed e-module based on the perceptions of students as its primary users. The students' responses were assessed using the Indonesian National Education Standards Agency (BSNP) criteria, which include three aspects: attractiveness, content, and language. The results of the

students' evaluation of the developed e-module are presented in Table 5.

Table 5. Students' Response Questionnaire at Research Location

No	Assesment Aspect	Percentage(%)
1	Interesting Aspects	91.5
2	Material Aspect	88.8
3	Language	89
Average		89.7
Interpretation of quetionnaire percentage		Very High
Module criteria		Very Interesting

Based on Table 5, the attractiveness aspect obtained a score of 91.5%, the content aspect achieved 88.8%, and the language aspect reached 89.0%. Overall, the average score across all assessment aspects was 89.7%, which falls into the very high category, indicating that the developed e-module was highly attractive to students. The students' responses demonstrated a positive perception of the developed e-module. They reported that the e-module helped them gain a better understanding of reaction rate concepts through a more engaging and meaningful learning experience. Furthermore, the contextual presentation of the learning materials made it easier for students to comprehend the concepts being studied.

b. Analysis of student responses questionnaires at the outside research location.

During the field trial conducted outside the research site, the students' response questionnaire was administered to 34 Grade XI-2 Science students at SMA Negeri 1 Raya, Simalungun Regency, Indonesia. This school was selected because the betel-chewing tradition remains widely practiced within the local community, including among adolescent girls who are still familiar with this cultural practice. The purpose of this trial was to evaluate the suitability and acceptability of the developed e-module based on the perceptions of students as its primary users. The students' responses were assessed using the Indonesian National Education Standards Agency (BSNP) criteria, which include three aspects: attractiveness, content, and language. The results of the students' evaluation of the developed e-module are presented in Table 6.

Table 6. Students' Response Questionnaire Outside the Research location

No	Assesment Aspect	Percentage(%)
1	Interesting Aspects	90
2	Material Aspect	90.7
3	Language	89
Average		89.9
Interpretation of quetionnaire percentage		Very High
Module criteria		Very Interesting

Based on Table 6, the developed e-module obtained a score of 90.0% for the attractiveness aspect, 90.7% for the content aspect, and 89.0% for the language aspect. Overall, the average score across all assessment aspects was 89.9%, which falls into the very high category, indicating that the developed e-module was highly attractive to students. The students' responses were overwhelmingly positive, with participants reporting that they enjoyed learning and exploring reaction rate concepts through the integration of the betel-chewing tradition.

Overall, both students at the research site and those outside the research site expressed positive perceptions of the developed e-module. They reported gaining a better understanding of reaction rate concepts through a more contextual learning approach that was closely connected to their everyday lives. In addition, the integration of spiritual values into the learning materials was perceived as helping students strengthen their awareness of God's greatness while fostering meaningful connections between scientific knowledge and religious values.

3.4.2. Teacher Responses Questionnaire

A teacher response questionnaire was administered to evaluate the developed e-module and to assess its potential for use as instructional material in chemistry learning. The questionnaire was distributed to teachers outside the research site because the chemistry teachers at the research site had already participated as content and media validators during the development process. In this stage, the questionnaire was administered to six chemistry teachers from Medan City and surrounding regions outside Medan. The results of the chemistry teachers' response questionnaire are presented in Table 7.

Table 7. Chemistry Teachers' Response

No	Assesment Aspek	Percentage Assesment (%)						Avarage (%)
		G1	G2	G3	G4	G5	G6	
1.	Content Feasibility Aspect	98	90	98	98.3	93.3	90	94.6
2.	Language Feasibility Aspect	98	82.8	97.1	97.1	97.1	91.4	93.2
3.	Presentation Feasibility Aspect	98	93.3	98.8	96.6	96.6	93.3	96.1
Average (%)								94.6%
Interpretation of questionnaire percentage								very high
Module criteria								very interesting

Based on Table 7, the developed e-module obtained a score of 94.6% for the content feasibility aspect, 93.2% for the language aspect, and 96.1% for the presentation feasibility aspect. Overall, the average score across all assessment aspects was 94.6%, which falls into the very high category, indicating that the developed e-module was highly attractive and well accepted by the teachers. The teachers expressed

positive perceptions of the developed e-module and reported that it effectively presented the reaction rate concepts in a clear, contextual, and engaging manner, making it a valuable instructional resource for chemistry learning.

4. DISCUSSION

This study developed a Project-Based Learning (PjBL)-based e-module integrated with ethnopedagogy for the reaction rate topic using the Four-D (4D) development model, consisting of the Define, Design, Develop, and Disseminate stages. During the Define stage, a needs analysis, curriculum analysis, and content analysis were conducted. The development of the e-module was aligned with the Merdeka Curriculum, which emphasizes the integration of local culture into learning as stated in Government Regulation No. 4 of 2022. Furthermore, the Merdeka Curriculum promotes Project-Based Learning (PjBL) as an approach to developing students' competencies, character, and spiritual values [14], [15], [16]. Preliminary observations at SMA Negeri 2 Percut Sei Tuan revealed that the implementation of culturally integrated PjBL was still limited due to inadequate laboratory facilities and the lack of project examples incorporating local culture. Therefore, an innovative e-module integrating PjBL, the ethnopedagogical values of the betel-chewing tradition, and spiritual values was developed.

One of the main advantages of the developed e-module is its accessibility, as it can be accessed anytime and anywhere using smartphones or laptops, allowing students to learn independently according to their individual learning needs [17], [18], [19]. During the Design stage, the e-module was organized into several components, including user instructions, concept maps, project-based learning activities, evaluations, summaries, and references. The module was designed using Canva and published through the AnyFlip platform to improve accessibility and enhance students' learning experiences.

During the Develop stage, the e-module was validated by three chemistry lecturers and three chemistry teachers based on the Indonesian National Education Standards Agency (BSNP) criteria. The average content validation scores reached 88.1% from the expert lecturers and 96.7% from the chemistry teachers, while the average media validation scores were 86.8% and 94.3%, respectively. These findings indicate that the developed e-module is highly feasible for classroom implementation. Similar findings were reported by Silaban et al. (2025), who obtained content and media feasibility scores of 93.99% and 88.1%, respectively, indicating that integrating local wisdom into chemistry teaching materials provides more contextual and meaningful learning experiences.

After being declared feasible, the e-module entered the Disseminate stage by being published on the AnyFlip platform and introduced to chemistry teachers from several schools, including SMA Negeri 1 Raya, SMA Negeri 5 Medan, Maitreyawira High School, and Sultan Iskandar Muda High School. The teachers' responses were highly positive, with an overall average score of 94.6%, indicating that the e-

module was highly attractive and acceptable for classroom use. This finding supports the study of [10], which states that ethnopedagogy not only integrates culture into education but also revitalizes local wisdom that is gradually declining because of globalization while strengthening students' cultural identity.

Students also responded positively to the developed e-module. The average response scores were 89.7% from 35 Grade XI students at SMA Negeri 2 Percut Sei Tuan and 89.9% from 34 Grade XI students at SMA Negeri 1 Raya, both categorized as very high. Students reported that the e-module was more engaging and helped them understand reaction rate concepts by connecting chemistry with local culture and spiritual values. These findings are consistent [20], [21], who reported that local culture-based instructional materials increase students' engagement because they relate scientific concepts to familiar real-life contexts.

A distinctive feature of the developed e-module is the integration of the betel-chewing tradition into project-based learning activities. The reaction rate topic is presented through cultural practices, including the chemical reaction between tannins in areca nut and the alkaline compounds in slaked lime, which produces the characteristic red color during the betel-chewing process. This cultural phenomenon is used to explain reaction rate concepts such as collision theory, reaction rate equations, reaction order, and factors affecting reaction rates, including temperature, concentration, surface area, and catalysts. Gambier, one of the traditional ingredients, is also introduced as an example of a catalyst in the learning activities. In addition, the e-module integrates spiritual values by relating scientific concepts to students' personal reflections, thereby strengthening the relationship between science learning and character development.

Each learning unit includes project-based student worksheets (LKPD), followed by reflective activities designed to reinforce students' conceptual understanding and learning experiences. According to the participating teachers, these project activities successfully increased students' motivation to learn chemistry while fostering appreciation for the betel-chewing tradition. These findings support [9], who emphasized that integrating local culture into science education enables students to use their prior cultural knowledge to better understand scientific concepts and encourages them to preserve their cultural heritage.

Overall, the findings of this study are consistent with previous research. Silaban et al. (2025) reported that a PjBL-based ethnopedagogical e-module on stoichiometry achieved content and media validation scores of 93.99% and 88.1%, respectively. Similarly, [3], [22] found that integrating local culture into instructional materials enhances students' learning motivation, engagement, and contextual understanding. Furthermore, concluded that meaningful and enjoyable

learning environments increase students' enthusiasm and motivation because they recognize the value and relevance of the learning process.

5. CONCLUSION

Based on the findings of this study, the following conclusions can be drawn:

1. During the Define stage, the results of the observations and interviews indicated the need to develop a Project-Based Learning (PjBL)-based e-module integrated with ethnopedagogy for the reaction rate topic. A total of 85.5% of the students expressed interest in a project-based e-module incorporating local culture. Chemistry teachers also reported that the existing teaching materials had not sufficiently connected chemistry concepts with everyday life and local wisdom, highlighting the need for more contextual and meaningful instructional materials.
2. During the Design stage, the e-module was developed based on the PjBL framework and integrated with the betel-chewing tradition and spiritual values. An analysis of three chemistry textbooks revealed that, although they met the BSNP standards with an average score of 91.7% (highly feasible), they were neither designed as e-modules nor based on Project-Based Learning and did not incorporate local wisdom. Therefore, the developed e-module was designed according to the BSNP criteria, including content, language, presentation, and graphical feasibility.
3. The validation results demonstrated that the developed e-module was highly feasible for classroom implementation. The average content validation score from expert validators was 88.1%, while the average media validation score was 86.8%. Higher scores were obtained from the chemistry teachers, with average content and media validation scores of 96.7% and 94.3%, respectively.
4. Both teachers and students expressed highly positive responses toward the developed e-module. The average response score was 94.6% from the chemistry teachers, while the average student response scores were 89.7% at the research site and 89.9% outside the research site, indicating that the e-module was highly attractive and well accepted as a learning resource.

5.1 Research Limitations

This e-module was designed for Grade XI senior high school students and developed based on the Project-Based Learning (PjBL) approach for chemistry instruction, with reaction rates as the main topic. The study employed the Four-D (4D) development model and integrated local wisdom through the betel-chewing tradition, a cultural practice of the people of North Sumatra. This study was limited to a small-scale field trial, in which teachers' and students' responses were collected to evaluate the feasibility and potential effectiveness of the developed e-module.

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