



Design and Validation of a Contextual Project-Based Organic Chemistry Practicum Module for Undergraduate Learning

Pino Ramadani¹, Maasje Catherine Watulingas¹, Farah Erika¹, Agung Rahmadani^{1,*}, Fitriah Khoirunnisa²

¹ Department of Chemistry Education, Universitas Mulawarman, Kalimantan Timur, Indonesia

² Department of Chemistry Education, Raja Ali Haji Maritime University, Kepulauan Riau, Indonesia

Article Info

Article history:

Received Jan 02, 2026

Revised Feb 15, 2026

Accepted Mar 12, 2026

OnlineFirst Mar 30, 2026

Keywords:

Contextual Approach

Organic Chemistry

Practical Module

Project-Based Learning

ABSTRACT

Purpose of the study: This study aims to design and validate a project-based organic chemistry practicum module that integrates a contextual approach, which is designed to facilitate students' conceptual understanding, practical skills, engagement, learning motivation, and overall learning experience during laboratory practicum activities.

Methodology: This study employed the Research and Development (R&D) method utilizing the ADDIE model specifically for the Analysis, Design, and Development stages. It represents early development phase focused on design and expert validation. Data were collected through interviews and questionnaires. Module validation carried out by subject matter and media validators using Likert scale instruments and Gregory matrix calculations to ensure validity.

Main Findings: This study's project-based, contextually integrated organic chemistry practicum module operationalizes PjBL through structured stages. Contextual learning integrates authentic phenomena with real-world applications. Validation involved two subject matter and two media validators, yielding Gregory coefficients of 1.00 for both. The module is highly valid, and future studies should test its effectiveness and practicality in enhancing conceptual understanding or 21st-century 4C skills.

Novelty/Originality of this study: This study developed an organic chemistry practicum module that systematically integrates contextual phenomena across all PjBL phases. Unlike previous PjBL modules lacking contextual integration or conventional recipe-style modules with limited learning impact. This module addresses gaps in conceptual reasoning, contextual relevance, and competency, while reducing procedural learning and enhancing conceptual understanding, practical skills, 21st-century skills, and integrated science learning.

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Corresponding Author:

Agung Rahmadani,

Department of Chemistry Education, Universitas Mulawarman,

Muara Pahu Road, Samarinda, Kalimantan Timur, 75123, Indonesia

Email: agungrahmadani@fkip.unmul.ac.id

1. INTRODUCTION

Education plays a strategic role in preparing competent, adaptive, and competitive human resources amid rapid global change [1], [2]. The evolving landscape of skills and the rapid pace of contemporary life

demand that education produce graduates ready to meet the complex challenges of the 21st century [3]. Therefore, universities must ensure that the learning process develops critical thinking, creativity, communication, and collaboration (4C) skills as core competencies [4].

In the context of chemistry education, particularly in organic chemistry practicums, learning demands are increasingly high due to the abstract nature of molecular structures, reaction mechanisms, and multistep transformations that require advanced conceptual and analytical skills [5]. Although practicums are intended to deepen conceptual understanding and develop scientific process skills, various obstacles persist in their implementation. Research by Asmussen et al. [6], shows that students experience substantial difficulties in understanding and applying organic reaction mechanisms, particularly in linking mechanistic steps with underlying concepts such as electron movement and structure–reactivity relationships. These difficulties are exacerbated by instructional practices that emphasize memorization rather than mechanistic reasoning.

Similarly, Vaughan et al. [7], report that many chemistry laboratories, including organic chemistry practicums, remain dominated by highly prescribed, “*cookbook-style*” activities in which students follow fixed procedures from conventional modules to obtain expected results with minimal opportunity for decision-making, inquiry, or conceptual reflection. While such laboratory designs may ensure procedural efficiency, they limit students’ engagement in scientific reasoning and reduce the practicum to a technical exercise rather than a meaningful learning experience. Furthermore, Hidayah et al. [8], emphasize that students’ anxiety during organic chemistry practicums is closely related to low self-efficacy, which is often triggered by rigid practicum instructions, fear of making mistakes, and limited conceptual understanding of experimental objectives.

Despite these well-documented challenges, most previous studies focus on identifying students’ difficulties or describing the limitations of conventional practicum designs, without developing a structured organic chemistry practicum module that integrates conceptual reasoning, contextual relevance, and competency-oriented learning outcomes [6]–[8]. This research gap results in the continued use of conventional practicum modules often resembling recipe books focused on procedural compliance that are inadequate for enhancing students’ conceptual understanding, practical skills, and 21st-century skills, particularly critical thinking, creativity, communication, and collaboration.

The limitations of conventional modules highlight the need for more interactive, applicable learning tools that encourage active student engagement [9]. Project-based practicum modules are one solution that offers meaningful learning experiences through project design, investigation, problem-solving, and group collaboration. When combined with a contextual approach, students can relate organic chemistry concepts to real-world phenomena, such as environmental issues, health, or the chemical industry [10], [11]. Research by McLaughlin et al. [12], demonstrates that PjBL significantly enhances students’ conceptual understanding and engagement in chemistry learning by promoting active inquiry and ownership of learning tasks. Similarly, Olii et al. [13], report that the implementation of PjBL in organic chemistry practicum, particularly in synthesis experiments, improves students’ practical skills, conceptual comprehension, and collaborative abilities through authentic laboratory projects.

Aligned with the principles of Outcome-Based Education (OBE), both PjBL and contextual approaches are highly aligned with curriculum demands that emphasize clearly defined learning outcomes, authentic assessment, and holistic competency development, including knowledge, skills, and attitudes [14]. Therefore, the integration of PjBL and contextual learning provides a theoretically grounded and empirically supported solution to address the identified research gap by enhancing students’ conceptual understanding, practical skills, and 21st-century skills, particularly critical thinking, creativity, communication, and collaboration through organic chemistry practicum instruction. Conceptually, this study is grounded in constructivist learning theory as proposed by Piaget and Vygotsky, which posits that knowledge is actively constructed through meaningful experiences, social interaction, and reflective processes [15]. PjBL serves as the pedagogical framework that facilitates inquiry-based and collaborative learning, while the contextual approach functions as a bridge connecting chemical concepts with real-life and interdisciplinary contexts. Together, these frameworks form a coherent theoretical foundation for designing an organic chemistry practicum module that supports integrated science learning, outcome-based education, and the systematic development of 4C skills.

Based on this background, this study developed a project-based organic chemistry practicum module integrated with a contextual approach to support students’ conceptual understanding, learning motivation, practical skills, and the development of critical thinking, creativity, collaboration, and communication skills. The module contributes to Integrated Science Education by contextualizing practicum activities within real-world applications, such as health, environmental sustainability, and industry. Aligned with Outcome-Based Education (OBE), the module integrates learning activities, projects, and assessments with clearly defined learning outcomes, while also fostering 4C skills through collaborative, problem-solving, communicative, and reflective laboratory practices.

2. RESEARCH METHOD

This type of research is Research and Development (R&D) employed a modified ADDIE model. The ADDIE model was chosen as the most suitable for this study because it has a clear, measurable, and flexible structure, making it easier for researchers to develop modules systematically [16]. Although ADDIE generally consists of five stages, namely analysis, design, development, implementation, and evaluation, this study only focused specifically on the first three stages, namely analysis, design, and development. Therefore, effectiveness and practicality testing related to the implementation and evaluation stages were not conducted and are recommended for future research. This limitation was made to suit the scope and objectives of the study. Such modifications can be applied as long as they do not reduce the essence, accuracy, and systematic nature of the research process [17], [18]. Data collection was carried out through questionnaires and interviews, while the main focus of the study was on the design and validity testing of the developed practicum module.

The subjects in this study consisted of two subject matter validators, two media validators, and 78 students from the Chemistry Education Study Program at a public University in East Kalimantan, selected using a purposive sampling technique. Subject matter validators were selected from lecturers or recognized experts in chemistry or chemistry education with relevant academic expertise and prior experience in educational research validation. Media validators were lecturers or experts in computer education or design-related fields with expertise in instructional media design and digital learning development. Student participants were active undergraduate students from the Chemistry Education Study Program, cohorts 2022 and 2023, who had completed organic chemistry practicum courses. The object of this study was a project-based organic chemistry practicum module integrated with a contextual approach, which was developed to improve conceptual understanding, scientific process skills, and student engagement during practicum activities.

This study used both qualitative and quantitative approaches to analyze the data. Qualitative data was processed through descriptive analysis to interpret findings based on interviews, observations, and validator comments. Meanwhile, quantitative data were obtained from validator assessment scores using a Likert scale, which were then analyzed by calculating the content validity coefficient using Gregory's formula. Before calculating the Gregory index, the relevance ratings provided by both validators were organized into a contingency matrix following the procedure detailed by Asril et al. [19], as shown in Table 1.

Table 1. Gregory Index Contingency Table

2x2 Matrix		Validator I	
		Weak (Score 1-2)	Strong (Score 3-5)
Validator II	Weak (Score 1-2)	A (--)	B (+-)
	Strong (Score 3-5)	C (-+)	D (++)

Based on Table 1, Likert scale scores of 1–2 are classified as weak, whereas scores of 3–5 are classified as strong. This classification is consistent with the criteria proposed by Sugiarta et al. [20], which group scale scores into two levels of relevance to facilitate validity analysis. Such categorization simplifies the interpretation of validators' judgments by distinguishing item relevance into two distinct levels and enables each rating to be accurately placed into the appropriate cell of the contingency matrix for subsequent analysis using the Gregory formula.

The contingency table shows that there are four categories of interpretive relationships between validators as described by Asril et al. [19], and these categories shown in Table 2.

Table 2. Gregory Contingency Category Criteria

Category	Explanation
A	When both Validators give the same score, with a score range of 1-2, on the same item, the relevance category is weak-weak, symbolized by A.
B	If Validator 1 rates an item between 3 and 5 while Validator 2 scores it between 1 and 2, the relevance classification is strong-weak, denoted as B.
C	If Validator 1 rates an item between 1 and 2 while Validator 2 scores it between 3 and 5, the relevance classification is weak-strong, denoted as C.
D	When both Validators give the same score for the same item in the range of 3-5, the relevance category is strong-strong, symbolized by D.

Based on Table 2, the contingency matrix classifies the validators' ratings into four cells (A, B, C, and D). These cells represent the levels of agreement and disagreement between the two validators regarding the relevance of each item. This classification serves as the basis for calculating the Gregory content validity coefficient, which indicates the degree of agreement on item relevance [21].

The determination of content validity coefficients based on contingency tables was performed using Gregory's content validity formula described by Dalilah et al. [22], as shown in Formula 1.

$$\text{Content validity} = \frac{D}{A+B+C+D} \dots (1)$$

As shown in Formula 1, the coefficient is calculated by dividing the number of items in cell D, which represents strong agreement between validators, by the total number of items in cells A, B, C, and D. Cell D indicates items rated strong by both validators. This calculation yields a proportional index that reflects the degree of agreement on item relevance. The content validity coefficient is then interpreted into five categories. A module can be considered valid and suitable for use or testing if the minimum level of content validity achieved is in the valid category. The content validity category is expressed in the form of a validity index described by Abadiyah et al. [23], as shown in Table 3.

Table 3. Gregory Validity Index Results

Coefficient	Criteria
0.81-1.00	Highly Valid
0.61-0.80	Valid
0.31-0.60	Moderate Valid
0.21-0.30	Invalid
0.00-0.20	Highly Invalid

Based on Table 3, the validity coefficient is classified into five levels, ranging from highly invalid to highly valid. Each level reflects the degree of content validity achieved by the developed module. This categorization serves as the basis for determining whether the module meets the minimum validity standard required for use or further testing [24].

3. RESULTS AND DISCUSSION

The results of this study are presented in three main stages, namely analysis, design, and development. The development of project-based organic chemistry practicum modules integrated with a contextual approach aims to facilitate students conceptual understanding, enhance learning motivation, practical skills and support the development of critical thinking, creativity, collaboration, and communication skills in completing scientific projects. The preparation of experiment content is carried out through project-based learning to encourage critical thinking, creativity, communication, and collaboration skills. According to Guo et al., [25], project-based learning is able to create meaningful learning experiences because students are actively involved in planning, implementation, and presentation of results, thereby significantly improving their 21st-century skills.

The developed practicum module is integrated with a contextual approach to increase motivation and relevance in learning. According to Ollero & Prudente [26], the contextual approach helps students understand the relationship between concepts and real-life situations, thereby fostering intrinsic motivation and strengthening concept retention. The integration of context in the module makes it easier for students to relate organic chemistry concepts to everyday phenomena such as the environment, health, and industry. In addition, the practicum module is designed with the support of relevant images, videos, and illustrations for each experiment to clarify procedures and facilitate student understanding. According to Ruamba et al., [27], the use of appropriate visual representations in science learning can improve information processing, reduce cognitive load, and help students understand complex concepts more effectively.

3.1. Analysis Stage

In the analysis stage, this study focused on identifying problems and student needs in the practicum process [28]. The analysis stage was conducted through a literature review, material review, and student needs analysis. The literature review was conducted to examine various practicum modules that had been developed previously and to identify weaknesses that were still found. Based on this study, it was found that existing modules tend to still apply conventional learning, have not integrated chemistry concepts with real-life phenomena, have unattractive visual displays, contain too many experiments, and are not equipped with adequate assessment components [29], [30]. These findings formed the basis for designing innovative project-based practical modules integrated with a contextual approach, with more attractive visual designs, a more systematic structure, and relevant illustrations. The material was reviewed to determine the practicum content to be included in the module and to ensure its suitability with the Graduate Learning Outcomes (GLOs) and Course Learning Outcomes (CLOs) Each material was selected based on its relevance to the learning objectives (LOs) and the competency development needs of students in organic chemistry practicums. This stage aims to develop a practicum module that is engaging and aligned with students' needs. Questionnaire results (Figure 1) show that 65.4% of students found organic chemistry practicum material difficult, indicating the need for a more concise, clear, and contextual module. Accordingly, the material was streamlined, emphasizing functional group identification and organic reactions as foundations for subsequent experiments.

The student needs analysis stage was conducted through interviews and questionnaires to identify their preferences regarding the content, design, and characteristics of the expected modules. This stage serves as a crucial foundation to ensure that the developed modules are aligned with students' actual conditions and are able to optimally support the achievement of learning outcomes [31]. The interview results showed that students felt that the previous modules were still too procedural, did not provide enough room for exploration, and did not fully help them understand the differences in organic chemical reaction results in several experiments. The results of the needs analysis were reinforced by the results of the questionnaire given to students, which are presented in Figure 1.

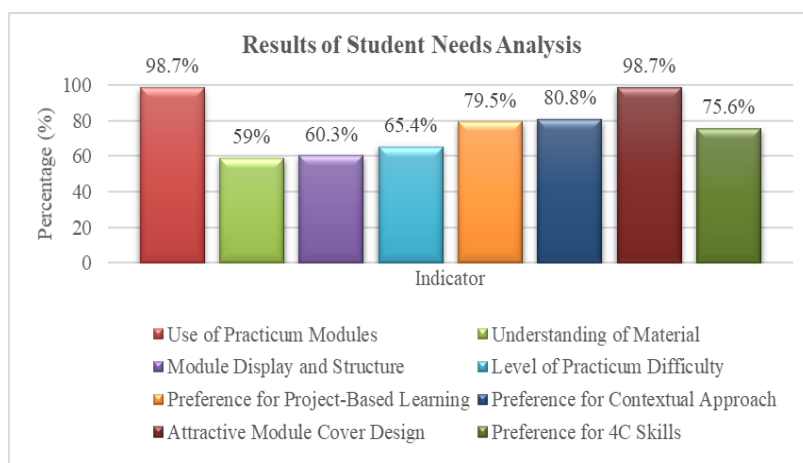


Figure 1. Results of Student Needs Analysis

Based on the need's analysis in Figure 1, it is known that 98.7% of students use modules as their main reference in practical work, but 59% stated that the previous modules were not effective in helping them understand the material. In addition, 60.3% of students considered the appearance and structure of the modules to be unattractive, even though the modules should be designed with better visuals to increase retention and interest in learning [32]. As many as 65.4% of students also felt that the previous organic chemistry practicum was too difficult, requiring simplification of the experiments. Other findings show that 79.5% of students have a high preference for project-based learning, and 80.8% consider that the existing modules are not yet linked to real contexts, thus requiring the integration of a contextual approach. In terms of assessment, 98.7% of students wanted a more detailed rubric, in line with the open-ended and detailed nature of project assessment. In addition, 65.4% of students expected clearer activity syntax, and 80.8% wanted a more attractive module cover design. A total of 75.6% of students also felt that the previous modules had not improved their 4C skills.

The results of this student needs analysis indicate that previous practicum modules were unable to adequately support higher-order thinking skills, lacked visual engagement, and were not integrated with project-based activities or students' real-life contexts. This finding is consistent with Vaughan et al. [7], who report that many chemistry laboratories, including organic chemistry practicums, are still dominated by highly prescribed, "cookbook-style" activities in which students follow fixed procedures to obtain expected results with limited opportunities for inquiry, decision-making, or conceptual reflection. Such conditions restrict the development of critical thinking and meaningful conceptual understanding. These findings emphasize the need to develop practicum modules that are more informative, engaging, adaptive, and authentically connected to real-life contexts. The analysis stage also reveals a clear mismatch between students' learning needs and conventional organic chemistry practicum modules, particularly in terms of contextual relevance, conceptual integration, and the development of 4C skills (critical thinking, creativity, communication, and collaboration). Therefore, redesigning practicum modules through the integration of project-based and contextual approaches becomes a pedagogically justified response to address these gaps.

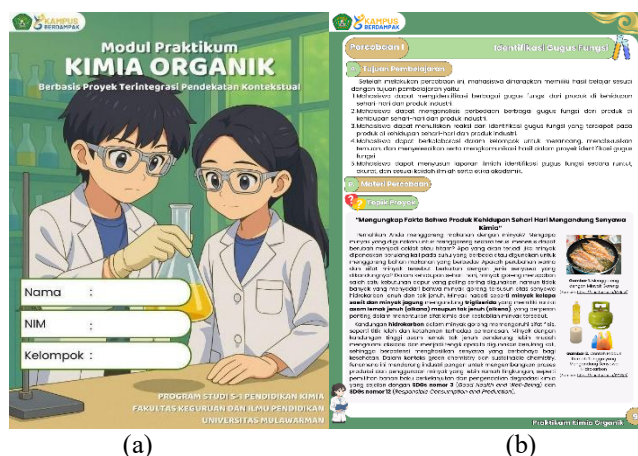
3.2. Design Stage

The results of the analysis in the first stage showed the need to develop practical modules that are able to meet the needs of students, both in terms of clarity of material, visual appearance, and the relevance of content to real-life contexts. Interviews and questionnaires revealed that students expected modules that not only presented material informatively but also facilitated the improvement of critical thinking, creativity, communication, and collaboration skills. In addition, the expected modules needed to support project-based activities, provide structured assessments, and have an attractive and easy-to-understand visual design. Based on these findings, the next step is to implement the design stage as a solution design. This stage begins with content development as the main foundation for module development [33]. At this stage, all practicum materials,

learning objectives (LOs), work procedures, and contextual phenomena are compiled using Microsoft Word to ensure that the substance presented is complete and systematic. The designed content is then developed into a visual design stage that includes color selection, typography, layout, and the addition of illustrations, images, and supporting videos to make the module more attractive and easier for students to understand [34], [35].

The next step is to design the navigation flow to ensure that each part of the module is arranged logically, easy to follow, and supports the learning flow for students from the front cover to the end, as described by Wienand et al. [36]. Once the navigation has been designed, the design stage is completed by creating the module interface using Canva. At this stage, all module components are arranged into their final form, starting from the front cover, introduction, table of contents, usage guidelines, practicum rules, work safety instructions, substance symbols, learning outcomes, practicum assessments, report writing guidelines, bibliography and citation writing instructions, glossary, bibliography, author profiles, to the back cover. Figure 2 shows the attractively designed module cover and practicum page that encourage student interest.

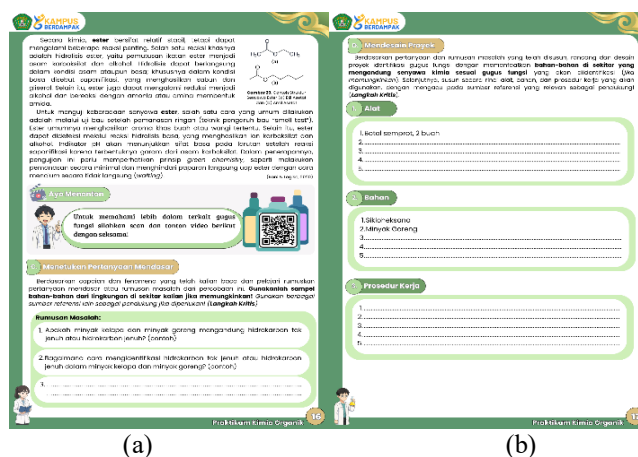
The content of the experiments in the module was designed using project-based learning syntax combined with a contextual approach, as shown in Figures 3 and 4. The syntax used follows the stages described by Rehman et al. [37], namely determining fundamental questions, designing projects, compiling schedules, monitoring projects, presenting results, and evaluating experiences. Pedagogically, this syntax is effective because it positions students as active constructors of knowledge, encourages inquiry and problem solving, and promotes collaboration and reflection, which are core principles of constructivist and project-based learning theory [38]. The integration of the contextual approach is realized through the presentation of real phenomena, the formulation of questions based on everyday life, and the use of practical materials that are familiar to students, as described by Gumay et al. [39], in Figures 5 and 6. This in line with Research from Sari et al. [40], show that contextual elements enhance learning by helping students connect abstract organic chemistry concepts with meaningful real-life situations, thereby strengthening conceptual understanding and learning motivation. The experiment design and module layout were finalized using Canva as a direct implementation of the analysis stage results.



(a)

(b)

Figure 2. a) Module Cover Supporting Visual Engagement b) Practical Experiment Page Ensuring Procedural Clarity



(a)

(b)

Figure 3. a) Fundamental Questions to Promote Inquiry b) Project Design to Support Collaboration

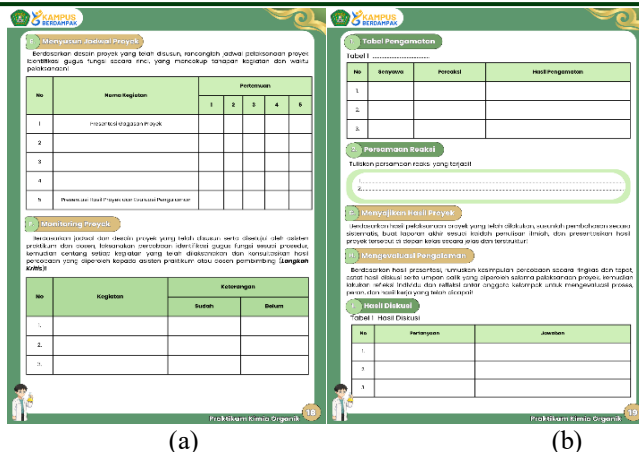


Figure 4. a) Scheduling and Monitoring to Support Responsibility b) Presentation and Reflection to Develop Communication Skills

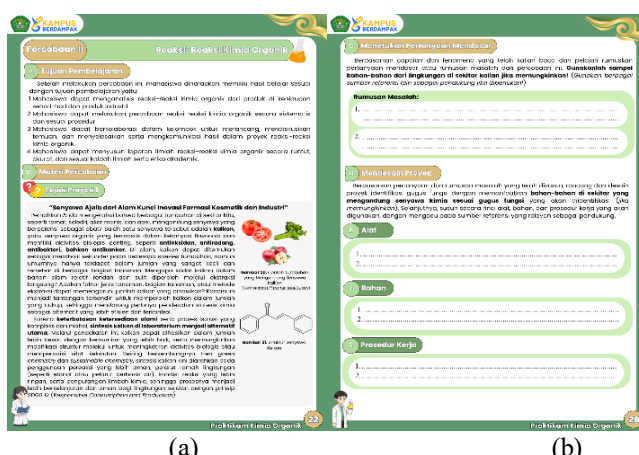


Figure 5. a) Contextual Phenomena Linking Concepts to Real Life b) Contextual Questions to Deepen Understanding

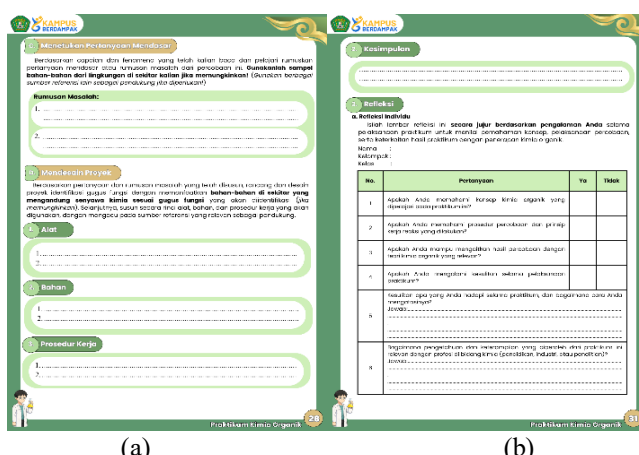


Figure 6. a) Contextual Use of Materials for Applied Learning b) Reflection to Strengthen Conceptual Integration

The visual implementation of these design principles is illustrated in Figures 2 to 6, which demonstrate the module cover and practicum page structure (Figure 2), fundamental questioning and project design (Figure 3), scheduling, monitoring, presentation, and reflection stages (Figure 4), as well as contextual phenomena, questions, material usage, and reflective integration (Figures 5 and 6). These figures collectively show how project-based and contextual components are embedded structurally within the module. This design stage systematically translates student needs into an instructional structure grounded in Project-Based Learning and contextual learning principles. The selection of PjBL syntax and the incorporation of real-life contexts are pedagogically justified, as supported by research from García and Cózar [41], which emphasizes that project-

based approaches foster active inquiry, collaboration, and meaningful learning experiences. This design ensures alignment between learning objectives (LOs), practicum activities, and expected competency development.

3.3. Development Stage

The next stage of development is the phase that processes all design results into a structured initial product [18]. The results of the design stage in this study were developed through two main stages, namely initial product development and validator validation. In the initial development, the previously compiled material content was systematically integrated with visual components, text, and other supporting elements. This integration included the alignment of material, contextual phenomena, and practical procedures with illustrations and videos that served to strengthen students' understanding of the practical concepts. The content of each experiment was formulated sequentially based on project-based learning syntax, thereby helping students follow the practicum process, starting from determining basic questions, designing projects, compiling project schedules, monitoring projects, presenting project results, and evaluating experiences [42].

The initial product that had been developed was then validated to measure its feasibility, evaluate the accuracy of the content, language, visual display quality, and clarity of the module navigation flow [43], [44]. Through validator assessment, the feasibility of the module and aspects that still needed improvement before being used in the implementation stage could be identified. The validation was conducted in two stages to ensure continuous refinement and improvement of the module content based on expert feedback. The validation process was carried out by four validators consisting of two subject matter validators and two media validators. In the subject matter validation, the aspects assessed included content feasibility, characteristics of project-based learning (PjBL) models, characteristics of contextual approaches, module presentation, and language. Content validation aims to ensure that the module content is scientifically accurate, in line with learning outcomes, and capable of supporting the development of students' skills in practical activities [45]. A summary of the results of the first stages of subject matter validators validation is presented in Table 4.

Table 4. First-Stage Material Validation Results

No	Indicator	Tabulation				Gregory Coefficient	Category
		A	B	C	D		
1	Content Feasibility	0	0	0	4	1.00	Highly Valid
2	Characteristics of Project-Based Learning (PjBL) Models	0	0	0	4	1.00	Highly Valid
3	Characteristics of Contextual Approaches	0	0	0	4	1.00	Highly Valid
4	Module Presentation	0	0	0	4	1.00	Highly Valid
5	Language	0	0	0	4	1.00	Highly Valid

Based on the first subject matter validation stage presented in Table 4, all assessed aspects including content feasibility, PjBL characteristics, contextual approach, presentation, and language obtained a Gregory coefficient of 1.00, indicating a highly valid category. This result reflects agreement between validators, showing that the developed module meets expert expectations across multiple pedagogical and linguistic criteria. Furthermore, this outcome suggests that integration of PjBL syntax and contextual elements has been implemented coherently and systematically within the module structure. The results of this first-stage material expert validation were subsequently organized into a contingency table for further analysis, as presented in Table 5.

Table 5. Gregory Contingency of First-Stage Material Validation

2x2 Matrix		Validator I		Gregory Coefficient	Category
		Weak (Score 1-2)	Strong (Score 3-5)		
Validator II	Weak (Score 1-2)	0	0	1.00	Highly Valid
	Strong (Score 3-5)	0	20		

The contingency analysis in Table 5 yielded an overall coefficient of 1.00, indicating a highly valid category. The high validity of the PjBL and contextual approach characteristics indicates strong theoretical alignment between the module design and the principles of project-based and contextual learning, particularly in promoting active inquiry, real-life problem orientation, and collaborative knowledge construction within laboratory settings [46]. During validation, the first subject matter expert provided recommendations mainly related to content validity. Learning objectives (LOs) for CLOs 1 and 2 were considered appropriate, while those for CLOs 3 and 4 particularly scientific writing, collaboration, communication, and presentation skills were deemed insufficient and recommended for inclusion. The validator also suggested improving content emphasis, organizing compound examples, revising usage guidelines into clearer module features with balanced text image

proportions, enhancing image captions and resolution, and refining language use in accordance with Indonesian Spelling (IIS) and General Guidelines for Indonesia Spelling (GGIS).

The second subject matter expert provided recommendations to further strengthen the module, noting that some references and examples insufficiently addressed current chemistry trends such as green and sustainable chemistry and environmentally friendly laboratories. The validator also suggested adding a clear CLOs–experiment–assessment mapping matrix and incorporating up-to-date application examples, including biodiesel production and green synthesis. To enhance project-based learning (PjBL), individual accountability should be strengthened through brief reflections or peer assessments, which can offer more objective feedback on individual participation and learning progress [47].

Regarding the contextual approach, the second subject matter expert validator recommended adding more exploratory questions and a brief guide linking problem formulation, hypotheses, data, and conclusions to structure the inquiry process. For module presentation, the validator suggested including markers for critical practicum steps to prevent misconceptions and procedural errors, as well as adding reaction and mechanism diagrams to clarify reaction flow, structural changes, and relationships between reaction stages [48]. Improvements in visual consistency such as image size, resolution, numbering, and more informative captions were also recommended to enhance professionalism. In terms of language, the validators emphasized the use of clear, specific, and measurable instructional sentences to ensure ease of understanding and minimize ambiguity during practicum implementation. This emphasis is intended to help students accurately interpret instructions, reduce the risk of procedural errors, and support more effective and consistent practicum activities [49].

Although the quantitative validation results indicate that the module is highly valid, qualitative feedback from the validator still revealed several aspects that required improvement. Therefore, the module was improved to enhance its overall quality. This is in line with the view of Perroud et al. [50], arguing that although a developed product has met quantitative validity criteria, qualitative suggestions from expert validators remain essential as a basis for further refinement and optimization of the product. Overall, these validation results are in line with the validators' decision that the practicum module is suitable for testing, with some parts needing improvement.

The identified weaknesses were addressed by incorporating all validators' suggestions. Based on the first subject matter expert's input on content feasibility, learning objectives (LOs) representing CLOs 3 and 4 were added to each experiment to better accommodate scientific writing, collaboration, communication, and presentation skills. The content presentation was also revised by highlighting key concepts in bold and organizing compound examples more clearly and systematically. By using bold formatting, students can more easily identify key information, focus on essential concepts, and improve their understanding during the learning and practicum process [51]. The module usage guidelines were revised into a features section with a better balance of text and visuals, and clearer, more contextual image captions.

Based on the second subject matter expert's recommendations, the module was revised by incorporating up-to-date references and examples related to green and sustainable chemistry and environmentally friendly laboratories, along with a CLOs–experiment–assessment mapping matrix to support CLOs achievement tracking. The module was further enriched with real-world applications such as biodiesel and green synthesis, strengthened PjBL features through reflection and peer assessment, included a one-page PjBL flowchart, and added industry-based case studies supported by recent scientific literature. In terms of the contextual approach, exploratory questions, guidelines on the relationship between problem formulation, hypotheses, data, and conclusions, as well as more focused reflective questions have been added [52]. In terms of presentation, adjustments have been made to the resolution and visual consistency, critical step markers have been added, reaction mechanism diagrams have been included, and image captions have been made more informative [53]. Meanwhile, in terms of language, improvements were made to the use of prepositions and the formulation of instructional sentences that are more specific, clear, and measurable in accordance with IIS/GGIS rules.

The module was revised based on the subject matter expert's suggestions and subsequently revalidated to ensure that all identified weaknesses had been systematically addressed. This iterative revision process strengthened the alignment between conceptual accuracy, pedagogical structure, and linguistic clarity within the module. In the second validation stage presented in Table 6, all aspects content feasibility, PjBL characteristics, contextual approach, presentation, and language again obtained a Gregory coefficient of 1.00, indicating that the module remains in the highly valid category.

Table 6. Second-Stage Material Validation Results

No	Indicator	Tabulation				Gregory Coefficient	Category
		A	B	C	D		
1	Content Feasibility	0	0	0	4	1.00	Highly Valid
2	Characteristics of Project-Based Learning (PjBL) Models	0	0	0	4	1.00	Highly Valid
3	Characteristics of Contextual Approaches	0	0	0	4	1.00	Highly Valid
4	Module Presentation	0	0	0	4	1.00	Highly Valid
5	Language	0	0	0	4	1.00	Highly Valid

Table 6 presents the results of the second-stage content validation, showing sustained and expert agreement even after the revision process. These findings support recent instructional development studies which report that iterative expert-based revisions significantly enhance the stability and consistency of validity coefficients in science learning modules, particularly in project-based and contextual designs. Therefore, the organic chemistry practicum material developed in this study can be interpreted as pedagogically robust, theoretically grounded. The results of this second-stage material expert validation were subsequently organized into a contingency table for further analysis, as presented in Table 7.

Table 7. Gregory Contingency of Second-Stage Material Validation

2x2 Matrix		Validator I		Gregory Coefficient	Category
		Weak (Score 1-2)	Strong (Score 3-5)		
Validator I	Weak (Score 1-2)	0	0	1.00	Highly Valid
Validator II	Strong (Score 3-5)	0	20		

The contingency analysis in Table 7 also produced an overall coefficient of 1.00, classified as highly valid, indicating that the revisions were appropriate and that the practicum module is ready for testing without further improvement. This coefficient reflects consistent agreement between validators in categorizing item relevance after the revision stage. It suggests that the adjustments made were sufficient to address previously identified concerns within the evaluated aspects, and that the module content particularly on functional groups and reactions in organic chemistry has been judged appropriate and aligned with the intended practicum learning objectives. This result is in line with previous study from Acantilado [54], which shows that iterative expert validation in project-based learning modules contributes to higher agreement levels and improved content validity indices. The study also reports that structured revisions based on expert feedback enhance the clarity, alignment, and feasibility of instructional materials. Therefore, the findings of this study are comparable, indicating that the module has met the expected validity standards for proceeding to the next stage of testing.

The initial product developed was then validated by media validators. During media validation, aspects such as graphics, content presentation, typography readability, and effectiveness were assessed. Media validation aims to ensure that the module has a professional appearance, is easily accessible, and is able to provide a comfortable and informative learning experience for users [55]. A summary of the first stage of media validators validation results are presented in Table 8.

Table 8. First-Stage Media Validation Results

No	Indicator	Tabulation				Gregory Coefficient	Category
		A	B	C	D		
1	Graphics	0	1	0	4	0.80	Valid
2	Content Presentation	0	1	0	3	0.75	Valid
3	Typography and Readability	0	0	0	4	1.00	Highly Valid
4	Effectiveness	0	0	0	4	1.00	Highly Valid

Based on the first-stage media validation results presented in Table 8, the Gregory coefficient for the graphics aspect was 0.80, which falls into the valid category. The content presentation aspect obtained a coefficient of 0.75, also categorized as valid. Meanwhile, the typography and readability aspect achieved a coefficient of 1.00, classified as highly valid, and the effectiveness aspect likewise obtained 1.00, indicating a highly valid category. These results indicate that all assessed media aspects have met acceptable validity standards. However, the graphics and content presentation components show relatively lower coefficients compared to the other aspects, suggesting that minor refinements may still be considered to enhance visual clarity and presentation structure. The results of this first-stage media expert validation were subsequently organized into a contingency table for further analysis, as presented in Table 9.

Table 9. Gregory Contingency of First-Stage Media Validation

2x2 Matrix		Validator I		Gregory Coefficient	Category
		Weak (Score 1-2)	Strong (Score 3-5)		
Validator II	Weak (Score 1-2)	0	2	0.88	Very Valid
	Strong (Score 3-5)	0	15		

The contingency analysis in Table 9 yielded an overall Gregory coefficient value of 0.88. Based on the Gregory feasibility index, this value is classified as highly valid. During validation, the first media expert recommended improvements in content presentation, particularly ensuring QR codes are easily scannable and refining the module's initial layout, as well as enhancing graphic consistency in colors, fonts, and image clarity. The second media expert suggested adjusting QR code backgrounds to match the linked content, selecting more proportional fonts, and incorporating more varied interactive images. Overall, both validators concluded that the practicum module is suitable for testing from a media perspective, provided the recommended revisions are implemented.

Once the validation process was complete, various weaknesses in the practicum module were identified. Based on the assessment results and comments from media experts, the module was then revised taking into consideration the weaknesses identified. The improvements began with changing the background of the QR code to match the content of the link displayed, thereby improving readability and ease of scanning. Revisions were also made to the font used Times New Roman font that was previously used was replaced with Poppins. The Poppins font was chosen to provide a more modern, clean, and readable appearance, thereby improving the visual comfort of students when studying the module. In addition, the more proportional characters also create a neater and more professional presentation of information [56]. The module was also improved by adding more varied supporting images and enhancing visual clarity to strengthen students understanding of the material [57].

The module was revised based on suggestions from media expert validators and subsequently revalidated. Based on the second-stage media validation results presented in Table 10, the Gregory coefficient increased in several aspects, with graphics improving from 0.80 to 1.00 (highly valid category) and content presentation from 0.75 to 1.00 (highly valid category). Meanwhile, the typography and readability aspect remained at 1.00 (highly valid), and the effectiveness aspect also reached 1.00, indicating a highly valid category.

Table 10. Second-Stage Media Validation Results

No	Indicator	Tabulation				Gregory Coefficient	Category
		A	B	C	D		
1	Graphics	0	0	0	5	1.00	Highly Valid
2	Content Presentation	0	0	0	4	1.00	Highly Valid
3	Typography and Readability	0	0	0	4	1.00	Highly Valid
4	Effectiveness	0	0	0	4	1.00	Highly Valid

The assessment results from Table 10, were then tabulated into the second stage media validator contingency table as shown in Table 11, resulting in an overall Gregory coefficient value of 1.00. Based on the Gregory feasibility index, this value is classified as highly valid. These improved validation outcomes indicate that the media design of the module is theoretically aligned with Project-Based Learning, contextual learning, and laboratory-based science education, particularly in supporting inquiry-driven activities, contextual meaning-making, and effective laboratory engagement [58].

Table 11. Gregory Contingency of Second-Stage Media Validation

2x2 Matrix		Validator I		Gregory Coefficient	Category
		Weak (Score 1-2)	Strong (Score 3-5)		
Validator II	Weak (Score 1-2)	0	0	1.00	Highly Valid
	Strong (Score 3-5)	0	17		

This finding in Table 11 indicates that the revisions made to the media aspects were aligned with the validator's recommendations and that the module is ready for testing to support students' ease in conducting organic chemistry practicum activities. This result is consistent with research from Subagia & Sudiarmika [59], which shows that contextually integrated PjBL-based chemistry modules demonstrate high validity and promote meaningful real-world learning. It is also supported by findings from Hidayah et al. [60], indicating that PjBL-based instructional materials integrated with contextual and STEM elements enhance students' conceptual understanding and competencies.

Overall, the developed project-based organic chemistry practicum module integrated with a contextual approach demonstrates a highly valid level of material and media validity. Validator feedback confirms that the

module accurately reflects PjBL and contextual learning principles while remaining scientifically sound and pedagogically coherent. The integration of PjBL and contextual learning supports Outcome-Based Education (OBE) by aligning learning outcomes with competency-oriented processes and connecting organic chemistry concepts to real-world and interdisciplinary contexts. The novelty of this study lies in the systematic integration of PjBL syntax and contextual learning specifically within organic chemistry laboratory activities, particularly in practicum topics on functional groups and organic reactions, which are often taught using conventional procedural approaches. This structured integration operationalizes OBE principles directly in hands-on experimental design, linking competency targets with inquiry-based laboratory tasks and reflective components. The module also promotes 21st-century skills critical thinking, creativity, communication, and collaboration through structured laboratory projects and supports conceptual understanding via contextual materials, illustrations, and independent inquiry tasks. However, this study is limited to expert-based validity evidence therefore, future research is recommended to examine the module's effectiveness, practicality and impact on student learning outcomes as well as 21st-century skills through comprehensive implementation and evaluation stages.

4. CONCLUSION

This study developed a project-based organic chemistry practicum module integrated with a contextual approach. The module applies project-based learning through structured stages, from defining fundamental questions to reflecting on learning experiences, while linking organic chemistry concepts to real-world phenomena. Material and media validation results indicate that the module is highly valid, offering practical value for chemistry lecturers and curriculum developers as a reference for designing project-based and contextual laboratory activities aligned with learning outcomes and outcome-based education (OBE). However, the study is limited to development and validation stages, and effectiveness, learning performance, and behavioral impacts were not examined. Therefore, further research is recommended to implement this module through classroom and laboratory interventions to evaluate its effectiveness, practicality, and long-term impact on learning outcomes and 4C skills. The module design also allows for adaptation to other chemistry topics or different educational contexts such as physical chemistry practicums. Overall, this study contributes to chemistry education by providing a valid module for meaningful, relevant, PBL-oriented, and real-world phenomenon-based organic chemistry laboratory learning.

ACKNOWLEDGEMENTS

The author extends heartfelt gratitude to the Chemistry Education students at a public University in East Kalimantan for their participation in this study.

AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft Preparation, & Visualization, Pino Ramadani, Agung Rahmadani; Validation, Farah Erika, Fitriah Khoirunnisa; Writing – Review & Editing, Agung Rahmadani; Supervision & Project Administration, Agung Rahmadani and Maasje Catherine Watulingas.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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