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## Development of a Case Based Module to Enhance 4C Skills among Laboratory Management Engineering Students

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### ABSTRACT

The Laboratory Techniques and Management course requires not only a mastery of laboratory concepts and procedures but also critical thinking, creativity, communication, and collaboration skills (4C). However, the current module is dominated by conceptual material and thus does not fully facilitate case-based learning. This study aims to develop a case-based module that is valid, practical, and capable of fostering students' 4C skills. The study employs a Research and Development (R&D) approach using the ADDIE model, comprising the stages of analysis, design, development, implementation, and evaluation. The research subjects included two validators, the course lecturer, and students from the Biology Education Study Program at the Faculty of Teacher Training and Education (FKIP), University of Riau. Research instruments included interview guidelines, a needs analysis questionnaire, validation sheets, a practicality questionnaire, and a 4C skills observation sheet. Data were analyzed descriptively using mean scores and percentages. The results indicate that the module achieved an average validity score of 2.95 (valid), a practicality score of 92.77 (highly practical), and a 4C skills observation score of 85.05 (competent). Consequently, the case-based module is considered valid, highly practical, and suitable for use as teaching material to facilitate students' 4C skills.

## 1. Introduction

Higher education is an educational institution that is expected to produce graduates with strong academic abilities in their respective fields. Therefore, universities must always keep up with the development of science and technology, especially in preparing graduates with qualified skills. Among the competencies required in the 21st century, critical thinking, creativity, communication, and collaboration (often referred to as the 4C) are essential (Barabanova et al., 2019; DwiYama, 2021). These skills do not automatically exist in individuals but must be intentionally trained

through innovative learning strategies (Harjo et al., 2019; Istiyono et al., 2020; Permatasari et al., 2019).

According to Indarta et al., (2022), innovative learning is designed to be more learner-centered, providing students with full opportunities to construct their own thinking. Nurvianti et al., (2025) further explain that, innovative learning is an educational approach oriented toward renewing learning processes, methods, and strategies, designed to enhance the quality of both the learning process and its outcomes. One strategy that can be implemented to realize innovative learning is the development of learning modules capable of facilitating active, independent, and structured learning activities.

Preliminary survey results for the Laboratory Techniques and Management (TML) course within the Biology Education Study Program at the Faculty of Teacher Training and Education (FKIP), University of Riau, indicate that the learning process is still dominated by theoretical explanations. Furthermore, the module-based teaching materials currently in use focus primarily on conveying conceptual and procedural content. Consequently, these modules do not optimally support the development of critical thinking, creativity, communication, and collaboration (4C) skills.

A module is a type of instructional material systematically designed to facilitate independent learning by integrating content presentation, learning activities, and evaluation (Chairunisa & Zamhari, 2022). Various studies indicate that the use of modules has a positive impact on enhancing student competence. Triantoro (2022) reported that, modules can improve students' problem-solving abilities, while Anisa & Wijayanti (2025) demonstrated that, learning modules are effective in stimulating 4C skills through contextual and structured learning stages. These findings indicate that modules are instructional materials with the potential to support student competence development, provided they are designed in alignment with learning needs.

The Laboratory Management Techniques (TML) course emphasizes not only the mastery of concepts regarding laboratory management, but also requires students to possess the ability to analyze problems, make decisions, collaborate, and communicate problem solving outcomes across various practical activities, such as specimen preservation and the use of scientific measuring instruments (Fauziah & Arnentis, 2012). Consequently, the TML course possesses characteristics highly conducive to developing critical thinking, creativity, communication, and collaboration skills (4C). In line with this, Asmawi et al., (2015) explain that developing 21st-century skills within laboratory courses plays a role in shaping students who are more independent, active, and technologically adaptable, as well as capable of collaborative problem solving.

One approach considered capable of facilitating the development of the 4C skills is the case method. According to Andayani et al., (2022), the case method is an instructional approach based on real-world problems whether prepared by the lecturer or introduced by students that are relevant to the course material. This type

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of learning yields alternative recommendations for problem-solving to be implemented in real life contexts, thereby making the learning process more meaningful rather than a mere exercise in rote memorization (Haerullah et al., 2022). Furthermore, the application of the case method in the learning process has been shown to significantly stimulate and enhance students' critical thinking, active communication, collaboration, and creativity (Dipuja et al., 2025).

These studies demonstrate that both learning modules and the application of the case method have the potential to enhance student competencies, particularly 4C skills. However, previous research has generally focused on module development or the application of the case method in isolation, and most studies have been conducted in courses other than Laboratory Techniques and Management (TML). Consequently, there is limited research integrating the case method into TML learning modules to support the development of students' 4C skills. Therefore, this study aims to produce a case-based module that is valid and practical, and capable of facilitating the enhancement of students' 4C skills in the Laboratory Techniques and Management course.

## 2. Methodology

This study employs a Research and Development (R&D) approach using the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation. The ADDIE stages are presented in Figure 1.

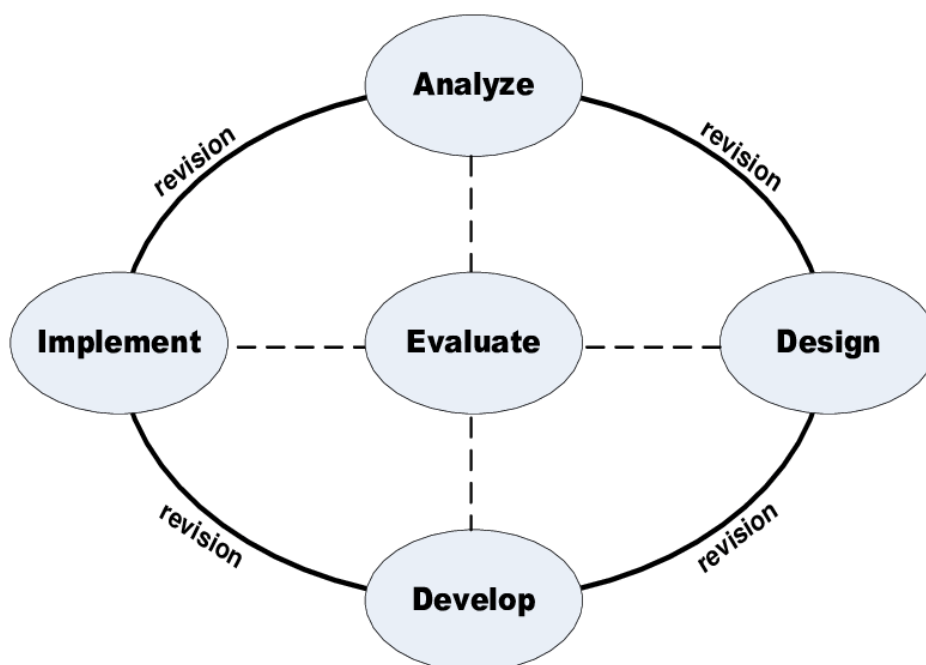


Figure 1. Design of the ADDIE development model (Branch, 2009)

Data from the needs analysis obtained through interviews with lecturers and student questionnaires were analyzed descriptively to identify the learning context and the need for developing a module based on the 4C and the case method. Module

validation data from subject matter and media experts were analyzed using mean scores based on a four point Likert scale. Subsequently, data from module practicality questionnaires and observations of students 4C skills were analyzed descriptively using percentages and categorized according to established criteria. The validation instrument employed a Likert scale with a score range of 1–4. Validation scores were calculated using the following mean formula:

$$M = \frac{\sum fx}{N}$$

Information:

M = Average score

Fx = Score earned

N = Number of validation components

Product validation was conducted by two validators a subject matter expert and a media expert categorized according to Table 1.

Table 1. Validity Category

| Score Interval      | Validity Category |
|---------------------|-------------------|
| $3.25 \leq x < 4$   | Highly Valid      |
| $2.5 \leq x < 3.24$ | Valid             |
| $1.75 \leq x < 2.4$ | Less Valid        |
| $1 \leq x < 1.74$   | Invalid           |

Modification of Sugiyono (2020)

The observation sheet was developed based on critical thinking, creativity, collaboration, and communication skills. The criteria for student skills based on the observation sheet are presented in Table 2.

Table 2. Student Skill Criteria Based on Observation Results

| Interval | Predicate | Category           |
|----------|-----------|--------------------|
| 86 – 100 | A         | Highly Competent   |
| 81 – 85  | B         | Competent          |
| 76 – 80  | C         | Lack of competence |
| < 75     | D         | Incompetent        |

Modification of Purnawirawan (2019)

### 3. Results and Discussion

#### *Analysis*

The analysis phase involves analyzing needs, the curriculum, and the Course Learning Plan (RPS). This analysis aims to identify the alignment of Course Learning Outcomes (CPMK) and Sub-Course Learning Outcomes (Sub-CPMK) with learning conditions, as well as the requirements for teaching materials that support the development of 4C skills.

### ***Needs Analysis***

A needs analysis conducted through interviews with the lecturer of the Laboratory Techniques and Management (TML) course within the Biology Education Study Program at the Faculty of Teacher Training and Education (FKIP), University of Riau reveals that although the instruction utilizes modules, the material presented focuses primarily on conceptual and procedural aspects and is dominated by theoretical explanations. This approach has not provided optimal opportunities for students to develop critical thinking, creativity, communication, and collaboration (4C) skills. Consequently, the lecturer identifies a need for a case-based module as an alternative learning resource; such a module can present laboratory-related issues within a contextual framework, thereby encouraging students to play a more active role in analyzing and solving problems, as reported by Yanti et al., (2022).

The results of a needs analysis conducted among students who had taken the TML course indicate that, while the existing module aided in understanding the subject matter, its presentation was dominated by conceptual and procedural content and lacked the integration of case-method-based activities. Students expressed a desire for instructional materials that present real-world problems, encourage group discussion, and facilitate the development of the "4Cs" skills. These findings align with Andayani et al., (2022), who noted that the case method offers students opportunities to analyze real-world problems, engage in collaborative discussion, and develop critical thinking, creativity, communication, and collaboration skills. Therefore, the development of a case-based module is considered to meet student needs and support the achievement of competencies in the TML course.

### ***Curriculum and RPS Analysis***

Curriculum analysis indicates that the Laboratory Techniques and Management course features course learning outcomes (CPMK) that emphasize not only the mastery of concepts regarding laboratory management but also students' abilities to analyze laboratory-related issues, make decisions, collaborate, and communicate problem-solving results (Darmadi et al., 2025). These characteristics suggest that the learning process should be designed contextually to foster the development of critical thinking, creativity, communication, and collaboration skills (4C). Based on this analysis, a mapping of sub-learning outcomes (Sub-CPMK) and core topics was conducted to serve as the foundation for developing a case-based module. The results of the analysis are presented in Table 3.

Table 3. Results of Curriculum and RPS Analysis as a Basis for Module Development

| <b>No.</b> | <b>Sub-CPMK</b>                                                          | <b>Subject matter</b>                       | <b>Module</b>                                         |
|------------|--------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------|
| 1          | Analyze the function, layout, and equipment of the laboratory            | Laboratory, functions, layout and equipment | Module 1. Laboratories, Their Functions and Equipment |
| 2          | Analyze the organization, management, and administration of laboratories | Laboratory organization and management      | Module 2. Laboratory Organization and Management      |

| No. | Sub-CPMK                                                                                     | Subject matter                                                                                      | Module                                          |
|-----|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-------------------------------------------------|
| 3   | Analyzing occupational safety and health (K3) in the laboratory                              | Laboratory work safety                                                                              | Module 3. Occupational safety in the laboratory |
| 4   | Explaining the use of microscopes, glassware, and non-glassware and their functions          | Microscope, glassware, measuring instruments, centrifuge, spectrophotometer, respirometer, quadrant | Module 4. Laboratory Equipment                  |
| 5   | Analyzing the properties and grouping of chemicals and solutions                             | Introduction to Chemicals                                                                           | Module 5. Chemicals                             |
|     |                                                                                              | Introduction and preparation of solutions                                                           | Module 6. Solution                              |
| 6   | Explaining the function and making herbariums, insectariums, and taxidermy as learning media | Making herbarium, insectarium, and taxidermy                                                        | Module 7. Simple Teaching Aids                  |

Based on Table 3, the analysis results indicate that all course content for Laboratory Techniques and Management has been mapped into seven case-method-based learning modules. The material was grouped based on an analysis of the Sub-Course Learning Outcomes (Sub-CPMK) and core topics outlined in the Semester Learning Plan (RPS), ensuring that each module comprises interconnected content that supports the achievement of the Sub-CPMK. This aligns with Syahrir et al., (2025), who state that the analysis of learning competencies serves as the foundation for developing module content, ensuring alignment with the prevailing curriculum. According to Trisnawati et al., (2024), innovatively developed and relevant learning materials positively impact the quality of education within educational institutions. This mapping serves as a reference for the module design phase, ensuring alignment with course learning outcomes and facilitating the development of students' 4Cs skills.

### Design

The design phase resulted in a preliminary draft of a case-based module, developed based on the findings of needs, curriculum, and course syllabus (RPS) analyses. This aligns with Sari et al., (2026), who stated that the module design phase is conducted based on needs analysis results to produce a learning structure that suits user characteristics and supports the development of 21st-century skills. The module design encompasses the module structure, content presentation, learning activities, and evaluation all integrated with the case method framework to foster critical thinking, creativity, communication, and collaboration (4C) skills. The components of the designed module are presented in Table 4.

Table 4. Module Components Based on 4C and Case Method

| Module Components  | Description                                                                              |
|--------------------|------------------------------------------------------------------------------------------|
| Module cover       | Contains the module identity, course, and compiler identity.                             |
| Foreword           | Contains a foreword by the author.                                                       |
| List of contents   | Contains the components of the material to be studied.                                   |
| Learning outcomes  | Contains course descriptions and sub-CPMK learning competency standards for each module. |
| Learning materials | Presenting material according to Sub-CPMK.                                               |

| Module Components           | Description                                                                       |
|-----------------------------|-----------------------------------------------------------------------------------|
| Case study                  | Presenting real cases according to the material to be studied.                    |
| Problem solving activities  | Students analyze and solve cases in groups.                                       |
| Presentation and discussion | Students present the results of solving cases and discuss them with other groups. |
| Reflection                  | Students draw conclusions based on the results of the discussion.                 |
| Competency test/Evaluation  | Measuring competency achievement after learning.                                  |

Based on the results of the analysis and design stages, seven learning modules were developed in accordance with the Sub-CPMKs of the Laboratory Engineering and Management course. Each module has a different identity and content; however, all modules follow the same format, structure, and case method syntax. The cover designs of the seven developed modules are presented in Figure 2.



Figure 2. Cover of the 4C and Case Method-based module

Figure 2 displays the cover designs of the seven developed modules. While the content of each module is tailored to specific Sub-Course Learning Outcomes (Sub-CPMK), the presentation structure remains consistent across all modules to facilitate the students' learning process. The module structure is arranged referring to the case method syntax which includes determining the case, students analyzing the case together in groups, formulating problem solutions by collecting ideas, collecting literature data, supporting evidence, discussion results and new knowledge information as they need, students making answer hypotheses together in groups, each group presenting the results of the analysis of the case given by the lecturer, the results of the presentation are then collected and each group disseminates new information. (Fembriani et al., 2025). Each stage in the module is designed to ensure students not only understand the concepts but also analyze

laboratory problems, collaborate in groups, communicate discussion results, and formulate solutions to given cases. Therefore, the integration of case method syntax into the module is expected to facilitate the development of students' critical thinking, creativity, communication, and collaboration (4C) skills.

### **Development**

The module, having been outlined during the design phase, was subsequently developed into a complete product in accordance with the planned structure. The resulting product was then validated by subject matter and media experts to determine its validity prior to implementation with students. The validation results are presented in Table 5.

Table 5. Module Validation Results

| Aspects                    | Average | Category   |
|----------------------------|---------|------------|
| Module and Graphic Formats | 3.60    | Very Valid |
| Content Aspects            | 2.62    | Valid      |
| Language Aspects           | 2.65    | Valid      |
| Average                    | 2.95    | Valid      |

Based on Table 5, the case-based module achieved an average score of 2.95, falling into the "valid" category. These results indicate that the module met the feasibility criteria as a teaching resource for the Laboratory Techniques and Management course following revisions made in accordance with the validators' suggestions. The module format and graphics aspect received the highest score 3.60 placing it in the highly valid category. This score indicates that the module's visual presentation met feasibility criteria. The high score in this aspect is attributed to a systematic layout, consistent typography, relevant illustrations, and a coherent presentation of module components, all of which facilitate the students' learning process. These findings align with Putra (2024), who stated that the quality of the graphic aspect is influenced by cover design, layout, typography, illustrations, and presentation consistency factors that enhance the readability and appeal of teaching materials.

The content aspect achieved an average score of 2.62, falling into the valid category. This indicates that the presented material aligns with the Course Learning Outcomes (CPMK) for Laboratory Techniques and Management and is integrated with the case method framework through case presentations, group discussions, problem solving analysis, presentations, and evaluations. However, the validators suggested presenting the module's 4C skills components in a more contextual manner to provide a more meaningful learning experience for students. According to Febriana et al., (2024), the content feasibility of teaching materials is determined by the alignment of material with learning outcomes, conceptual accuracy, systematic presentation, and the connection between learning activities and the intended objectives.

The language aspect received an average score of 2.65, falling into the valid category. This indicates that the language used was communicative and easily

understood by students. However, the validator provided suggestions for improving the writing style to ensure the presentation of information was clearer, more consistent, and aligned with proper Indonesian language standards. This aligns with the findings of Charty & Syofyan (2024), who stated that linguistic suitability is a crucial component of module development; the use of clear, communicative, and accessible language facilitates independent learning and enhances the effectiveness of the learning process.

Based on these validation results, the module was refined in accordance with the validator's feedback. Revisions focused on improving the writing style and the presentation of the 4C skills components to better align them with the learning activities in the Laboratory Techniques and Management course. The results of the module revisions are presented in Table 6.

Table 6. Results of Module Development Improvements

| Improvement Suggestions                                                                                   | Improvement Results                                                                 |
|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|                                                                                                           | Before                                                                              |
| Cover section, adjust the spelling of the word "Management" to the correct spelling in KBBI.              |   |
|                                                                                                           | After                                                                               |
| Cover section, adjust the spelling of the word "Management" to the correct spelling in KBBI.              |  |
| Page 6 of module 1, the spelling error for the word "Laboratory" is adjusted to the correct word.         |  |
|                                                                                                           | After                                                                               |
|                                                                                                           |  |
| Case method syntax in module 4. Provide a more contextual introduction, inserting images would be better. |  |
|                                                                                                           | After                                                                               |
|                                                                                                           |  |

Table 6 shows the results of the module revisions based on validator input. The revisions focused on improving the formatting and refining the 4C skills component to make learning activities more contextual. The revisions resulted in an improved module ready for use in the implementation phase.

### **Implementation**

Implementation was carried out after the module was declared valid and revised based on feedback from the validators. During implementation, the lecturer used the module as instructional material in the learning process and subsequently assessed the module's practicality as well as the students' 4C skills. Assessments of practicality were conducted by both the lecturer and the students to determine the ease of using the module during the learning process; these assessments covered planning, content suitability, and pedagogical aspects. The results of the practicality assessment for the case-based module are presented in Table 7.

Table 7. Results of the Module Practicality Questionnaire

| Aspects                        | Average | Category         |
|--------------------------------|---------|------------------|
| Eligibility Aspects of Content | 95,83   | Highly Practical |
| Planning Aspects               | 87,5    | Highly Practical |
| Pedagogic Aspects              | 95      | Highly Practical |
| Average                        | 92,77   | Highly Practical |

Based on Table 7, the module achieved an average score of 92.77, falling into the highly practical category. These results indicate that the module is easy to use during the learning process and supports the implementation of the course in alignment with the designed learning objectives. This finding aligns with Rafi'y & Qalbi (2023), who stated that a practical module is characterized by ease of use, time efficiency, and utility in supporting the learning process. The content feasibility aspect received the highest score 95.83 placing it in the highly practical category. This result demonstrates that the presented material aligns with the learning outcomes of the Laboratory Engineering and Management course and integrates the case method framework through case presentations, discussion activities, presentations, and learning evaluations. The systematic presentation of material makes it easier for lecturers to guide students in analyzing laboratory issues within a contextual framework.

This result is consistent with research by Wahyuni et al., (2025), which showed that systematically organized modules with sound designs and clear instructional frameworks elicit excellent user responses, thereby supporting the implementation of learning activities. The pedagogical aspect scored 95.00, falling into the highly practical category. This score indicates that the module facilitates student centered learning through activities such as case analysis, group discussions, results presentations, and reflection. These activities encourage active student participation while fostering critical thinking, communication, collaboration, and problem-solving skills. This aligns with Razak et al., (2022), who stated that implementing the case method fosters learning that is more active, collaborative, and contextual, thereby enhancing student engagement in the learning process.

Meanwhile, the planning aspect scored 87.50, placing it in the highly practical category. This result indicates that the module's usage instructions, material presentation sequence, and instructional steps are systematically organized, making it easier for lecturers to implement the module during course activities. In addition to assessing the module's practicality, the study also measured students' 4C skills while participating in learning activities using the case-method and 4C based module. Observations were conducted using an observation sheet, and the results are presented in Table 8.

Table 8. Results of Observations of Students' 4C Skills

| 4Cs Skills     | Class B | Category         |
|----------------|---------|------------------|
| Think Critical | 83.11   | Competent        |
| Communication  | 87.25   | Highly Competent |
| Collaboration  | 86.40   | Highly Competent |
| Creative       | 84.22   | Competent        |
| Average        | 85.05   | Competent        |

Based on Table 8, the observation results indicate that the students' 4C skills achieved an average score of 85.05, placing them in the competent category. These results indicate that the case method-based module supports the development of students' 4C skills through learning activities centered on case resolution. Communication skills achieved the highest score at 87.25, followed by collaboration at 86.40, while critical thinking scored 83.11, falling into the competent category. These results indicate that the presentation of contextual cases, group discussions, problem analysis, and the presentation of findings provided students with opportunities to exchange ideas, express opinions, defend arguments, and collaborate in resolving laboratory based problems. These findings align with Astriani et al., (2023) who stated that the case method fosters students' critical thinking, communication, collaboration, and creativity skills through contextual case analysis and problem solving activities. Nashiroh et al., (2024) further added that case-method-based learning enables students to actively engage in discussions, present analysis results, and establish more effective communication and collaboration throughout the learning process.

Meanwhile, creativity skills achieved a score of 84.22, placing them in the competent category. These results indicate that students were able to generate various alternative solutions to the problems presented, although this ability could still be enhanced through the use of more diverse and challenging case scenarios. Overall, the observations indicate that the case method-based module supports the development of students' 4C skills through learning activities that foster analysis, discussion, collaboration, and systematic problem solving. These findings are supported by Dipuja & Wahyuni (2025), who reported that case method-based modules are effective in enhancing students' 21st-century skills, including critical thinking, creativity, communication, and collaboration, through case-based learning activities. These results also align with Rukiyah et al., (2025) who stated that implementing the case method in conjunction with group work can increase

active student participation while developing collaboration and problem solving skills during the learning process.

### **Evaluation**

The evaluation phase was conducted formatively at each stage of module development. The evaluation began with expert validation to assess the module's feasibility, followed by revisions based on the validator's suggestions. Once declared valid, the module was implemented in the learning process to determine the level of practicality and students' 4C skills. The evaluation results showed that the module was categorized as valid, highly practical, and able to facilitate the development of students' critical thinking, creativity, communication, and collaboration skills. Therefore, the case method-based module is suitable for use as teaching material in Laboratory Engineering and Management courses.

### **4. Conclusion**

This research produced a case-based module for the Laboratory Engineering and Management course using the ADDIE development model. The module was developed by integrating case-based learning activities to support students in developing critical thinking, creativity, communication, and collaboration skills. The validation results indicate that the developed module meets the feasibility criteria after revisions were made based on expert suggestions. The implementation results also demonstrate that the module is highly practical for use in the learning process and can support the development of students' 4C skills. Thus, the developed module can be used as teaching material to support learning in the Laboratory Engineering and Management course, particularly through learning activities that involve case analysis, discussion, collaboration, presentation, and problem solving. The development process indicates that integrating contextual cases into module activities provides a suitable approach for facilitating students' engagement with learning and the development of 21st-century skills. Further research is needed to examine the effectiveness of the module through comparative or experimental studies involving broader samples and more rigorous measures of 4C skill development.

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