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Implementation of project-based learning in developing a human anatomy and physiology practical guidebook with analysis of the nutritional content of local NTT ingredients

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Abstract

Practical learning that is relevant to local potential is needed so that students understand human physiology concepts theoretically and are able to relate them to real life. This can support the improvement of 21st century skills while also supporting the utilization of local resources in education and community empowerment. This study aims to develop a practical guidebook for the Human Anatomy and Physiology course based on Project-Based Learning (PJBL) with the integration of nutritional content analysis of local food ingredients from East Nusa Tenggara (NTT). The problem faced is the limited availability of practical teaching materials that are relevant to local conditions, specifically linking anatomy and physiology topics with an understanding of the nutritional content of local food ingredients. The method used is research and development with the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The results of the study show that the developed practical guidebook is relevant and effective in enhancing students' understanding of human anatomy and physiology concepts and the nutritional content of local food ingredients. Evaluation of the product indicates positive responses from students, with improvements in active involvement, critical thinking skills, and significant learning outcomes. This guidebook also helps students to better understand scientific concepts in the context of everyday life. In conclusion, the application of PJBL with a focus on local food ingredients from NTT proves to be effective in improving students' understanding and 21st-century skills.

Abstrak. *Pembelajaran praktikum yang relevan dengan potensi lokal dibutuhkan agar mahasiswa memahami konsep fisiologi manusia secara teoritis dan mampu mengaitkan dengan kehidupan nyata. Hal ini dapat mendukung peningkatan keterampilan abad ke-21 sekaligus mendukung pemanfaatan sumber daya lokal dalam pendidikan dan pemberdayaan masyarakat. Penelitian ini bertujuan untuk mengembangkan buku petunjuk praktikum mata kuliah Anatomi dan Fisiologi Manusia berbasis Project-Based Learning (PJBL) dengan integrasi analisis kandungan gizi bahan pangan lokal Nusa Tenggara Timur (NTT). Permasalahan yang dihadapi adalah terbatasnya ketersediaan bahan ajar praktikum yang relevan dengan kondisi lokal, khususnya yang mengaitkan topik anatomi dan fisiologi dengan pemahaman kandungan gizi bahan pangan lokal. Metode yang digunakan adalah penelitian dan pengembangan dengan model ADDIE, yang terdiri dari lima tahap yaitu analisis, desain, pengembangan, implementasi, dan evaluasi. Hasil penelitian menunjukkan bahwa buku penuntun praktikum yang dikembangkan relevan dan efektif untuk meningkatkan pemahaman mahasiswa terhadap konsep anatomi dan fisiologi manusia serta kandungan gizi bahan pangan lokal. Evaluasi terhadap produk menunjukkan adanya respon positif dari mahasiswa, dengan peningkatan keterlibatan aktif, kemampuan berpikir kritis, dan hasil belajar yang signifikan. Buku panduan ini juga membantu mahasiswa untuk lebih memahami konsep-konsep ilmiah dalam konteks kehidupan sehari-hari. Kesimpulannya, penerapan PJBL dengan fokus pada bahan pangan lokal NTT terbukti efektif dalam meningkatkan pemahaman dan keterampilan abad ke-21 mahasiswa.*

A. Introduction

Practical learning in higher education has an important role in improving students' understanding of the theoretical concepts being studied (Ali et al., 2024; Hockham & Wallis, 2024; Kilpeläinen-Pettersson et al., 2025). The Human Anatomy and Physiology course, as one of the fundamental courses in biology education, requires students to understand various aspects of human body physiology, including its relation to the consumption of healthy and nutritious food (Ramadhani & Widyaningrum, 2022; Yusrifan et al., 2021). However, one of the main obstacles in the practice is the limited teaching materials that are relevant and contextual to local conditions, especially in areas such as NTT (Hamaisa et al., 2022; Putri et al., 2025; Thompson & Lake, 2023).

The preliminary study showed that 88% of students stated that practical activities tended to be procedural and did not provide space for creativity or in-depth exploration, while 65% of students preferred using common materials such as rice or bread rather than local food, since they were rarely guided to test typical NTT ingredients. This condition resulted in low interest in practical exploration and limited students' abilities to relate physiological concepts to everyday realities. Therefore, it is necessary to develop teaching materials that do not only support conceptual understanding but also utilize the potential of local resources.

NTT has a wealth of diverse local food ingredients, such as *jagung bose* (Kupang corn soup), *jagung katemak* (a local specialty dish made of corn and papaya), nuabosi cassava, moringa, salted anchovies, salted fish, sorghum, chub mackerels, peanuts, papaya flowers, papaya fruit, papaya leaves, jagung titi (local corn chips), dried cassava, taro, purple sweet potato, yellow sweet potato, yellow cassava, cassava leaves, spinach, carrots, tofu, tempeh, bean sprouts, boiled corn, tomatoes, *rebok* (local snacks), boiled bananas, *kaparak* (specialty dish of Southwest Sumba), coconut oil, dragon fruit, beranga banana, lady finger banana, *ubi manusia* (large yam from NTT), avocado, and sorghum which have high nutritional values (Ersozlu et al., 2024; Mursanto et al., 2023; Prastowo et al., 2023). The use of local food ingredients in practical learning remains limited. Most existing practical guidebooks still rely on general food ingredients that do not reflect the unique characteristics of the local area. Therefore, the development of a project-based practical guidebook focusing on the analysis of the nutritional content of local food ingredients represents a strategic solution to enhance the relevance of learning to the surrounding environment. This approach is also aligned with the learning outcomes of the Human Anatomy and Physiology course, which require students to connect the concepts of human anatomy and physiology with real-life applications, including the consumption of nutritious foods based on local potential. The urgency of this research lies in the importance of integrating the PJBL learning method with local materials that have diverse nutritional content.

By developing a PJBL-based practical guidebook that tests the nutritional content of local NTT food ingredients, it is expected that learning materials can be produced which not only enhance students' understanding of human anatomy and physiology but also provide deeper insights into e potential of local food ingredients as sources of nutrition. Project-Based Learning has been proven effective in connecting theory with practice through active student engagement in contextual projects, thereby fostering critical thinking, collaboration, and scientific literacy (Wibowo et al., 2024; Astartia et al., 2024). This approach also enables students to construct more meaningful understanding by relating scientific concepts to real-life situations within their own environment (Suseno et al., 2022). This is also in line with efforts to support the use of local natural resources to improve the welfare of the surrounding community.

This research is different from previous research which generally only focused on the development of human anatomy and physiology teaching materials without integrating aspects of project-based practical work or the use of local materials.

Previous studies on the development of teaching materials for the Human Anatomy and Physiology course have generally focused on theoretical content or the use of digital learning media, without integrating the local context into practical learning. Ramadhani & Widyaningrum (2022) developed a comprehensive textbook covering basic anatomy and physiology concepts, but it lacked practical activities that connect theory with local resources. Putri et al. (2025) designed an interactive virtual laboratory for ear anatomy, which enhanced visualization and student engagement, yet did not incorporate real-life local material analysis. Meanwhile, Hamaisa et al. (2022) examined the physicochemical characteristics of *jagung bose*, a traditional food from NTT, but their work was limited to food science and not linked to anatomy and physiology education. This situation reveals a research gap: there is no existing work that combines a PJBL approach with hands-on nutritional content analysis of diverse local NTT food ingredients as part of a human anatomy and physiology practicum.

The novelty of this study lies in the integration of PJBL with the analysis of nutritional content from local NTT food ingredients within a practical guidebook for the Human Anatomy and Physiology course. This approach does not only bridge theoretical understanding with practical applications

in a culturally relevant context but also promotes 21st-century skills such as collaboration, critical thinking, and scientific literacy. By connecting scientific concepts with students' everyday experiences and local cultural resources, this research produces an innovative and contextually meaningful learning tool that can enhance both conceptual mastery and practical competence.

This study aims to develop a PJBL practical guidebook for Human Anatomy and Physiology incorporating the nutritional analysis of local NTT food resources, evaluates its effectiveness in enhancing students' conceptual understanding of the human digestive system, and assessing its impact on students' collaboration, critical thinking, and motivation.

B. Material and method

This research was conducted during the odd semester of the 2024/2025 academic year at the Biology Education Study Program, Faculty of Teacher Training and Education, Widya Mandira Catholic University, Kupang, East Nusa Tenggara.

This research is development research (Research and Development) to develop a practical guidebook for the Human Anatomy Physiology course based on PJBL with the integration of nutritional content analysis from local materials from NTT. The development model used is the ADDIE model which consists of five stages, namely Analysis, Design, Development, Implementation, and Evaluation (Suseno et al., 2022) Figure 1.

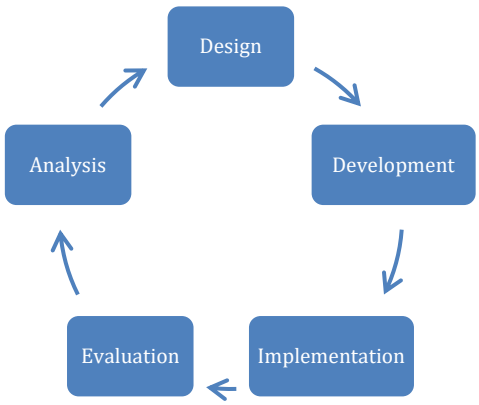

Figure 1 ADDIE development steps

Figure 1 shows the ADDIE model with the first step, namely Analysis, which aims to identify the need for developing a practical guidebook including curriculum analysis (Course Learning Outcomesanatomy and physiology materials, and their relationship to practical teaching materials), Analysis of student characteristics as users, Initial study of existing guidebooks, and identification of local potential of NTT (especially local food ingredients) that are relevant to analyze their nutritional content in practical work. The second step is Design. At this stage, the planning of the guidebook structure and the design of PJBL-based practical tools are carried out, including: compiling a guidebook framework containing PJBL steps, designing a practical activity format, including simple nutritional analysis instruments (for example, a mini laboratory approach or digital tools), and determining product success indicators. The third step is development. This stage includes making an initial draft of the guidebook and validation by experts, by writing a practical guidebook according to the design that has been designed, involving material experts, learning media experts, and nutritionists to validate content and feasibility, revisions based on input from experts and readability tests and limited field tests (limited trials to a number of students). The fourth is implementation which is carried out on a small scale in groups of students taking the Human Anatomy Physiology course, including the use of guidebooks in real practical activities, students working on projects analyzing local materials in terms of anatomy and physiology and nutritional content, and Observation of PJBL processes. The fifth stage is evaluation which is carried out formatively and summatively to assess the effectiveness of the product. Assessments are carried out on the quality of the guidebook (based on expert validation and trial results), student responses to the use of the guidebook (through questionnaires and interviews), student learning outcomes (through learning outcome tests and project assessment rubrics) and final product revisions based on field evaluations.

The subjects of this study were fourth-semester students of the Biology Education Study Program, Faculty of Teacher Training and Education, Widya Mandira Catholic University. Fourth-semester students were selected because they have completed the foundational courses in biology and are currently enrolled in the Human Anatomy and Physiology course, making them suitable for implementing the PJBL approach. The population of this study included all fourth-semester students enrolled in the program, while the sample was determined based on specific criteria, e.g., willingness to participate, enrollment in the relevant practical course, or availability during the study period. The object of this study was the Human Anatomy and Physiology Practical Guidebook, which incorporates PJBL with nutritional analysis of local NTT materials. Data were collected through observation of practical activities, student interviews, expert validation questionnaires, learning outcome tests, and documentation of the development and implementation processes. A checklist was used to observe students' practical performance, while semi-structured interviews captured their feedback and experiences. Expert validation questionnaires assessed the quality and suitability of the practical guidebook. Learning outcomes were measured using

structured tests, and the development and implementation stages were documented with photos and written records.

The data collected in this study consisted of both qualitative and quantitative data. Qualitative data included expert feedback, student interviews, and observations of practical activities, while quantitative data consisted of expert validation scores, student responses, and learning outcome test results. Qualitative data were analyzed using descriptive techniques, which involved a thorough examination of expert inputs, interview transcripts, and observation notes to identify patterns, themes, and suggestions for improvement. Quantitative data were analyzed using descriptive statistics, including the calculation of averages and percentages to summarize expert validation results, student responses, and product assessment categories. In addition, the effectiveness of the PJBL-based practical guidebook was evaluated using normalized gain (N-gain) analysis on pre-test and post-test scores. The N-gain was calculated using the Formula 1.

$$\text{N} - \text{gain} = \frac{\text{Post-test score} - \text{Pre-test score}}{\text{Maximum score} - \text{Pre-test score}} \text{....Formula 1}$$

The resulting N-gain values were then categorized as high (≥ 0.7), moderate (0.3–0.7), or low (< 0.3), allowing the researchers to determine the degree of improvement in student learning outcomes after the implementation of the practical guidebook.

C. Results and discussion

This study produced a human anatomy and physiology practicum guidebook based on PJBL with the integration of nutritional content analysis of local food ingredients in NTT. The development process followed the ADDIE stages: Analysis, Design, Development, Implementation, and Evaluation. Needs analysis was conducted through observation and interviews with students of the Biology Education Study Program at Widya Mandira Catholic University and obtained data that 88% of students stated that practicum activities tended to be procedural and did not provide space for creativity or in-depth exploration, besides that there was no practicum guidebook based on the PJBL approach and integrating local materials as objects of analysis. Local NTT food ingredients such as *jagung bose* (Kupang corn soup), *jagung katemak* (a local specialty dish made of corn and papaya), nuabosi cassava, moringa, salted anchovies, salted fish, sorghum, chub mackerels, peanuts, papaya flowers, papaya fruit, papaya leaves, jagung titi (local corn chips), dried cassava, taro, purple sweet potato, yellow sweet potato, yellow cassava, cassava leaves, spinach, carrots, tofu, tempeh, bean sprouts, boiled corn, tomatoes, rebok (local snacks), boiled bananas, kaparak (specialty dish of Southwest Sumba), coconut oil, dragon fruit, beranga banana, lady finger banana, *ubi manusia* (large yam from NTT), avocado, and sorghum have high potentials for use in anatomy and physiology practicum because they have nutritional value that is relevant to the topic of learning the material on the human digestive system. The urgent need to develop a practicum guidebook is to encourage 21st century skills (collaboration, communication, critical thinking), contextual, based on local wisdom, and integrating science, nutrition, and human physiology in one project scenario.

Based on the analysis results, a practical guidebook was designed with a PJBL approach with a guidebook structure that contains a project description of the topic, objectives, and relevance to real life, PJBL steps starting from essential questions, planning, implementation, reflection, to project evaluation, practical activities with a series of anatomical and physiological experiments, nutritional content tests of food using local NTT food ingredients, simple nutritional content analysis using simple laboratory equipment along with individual and group assessment rubrics based on the process and results of the project. The book format is designed visually, interactively, and encourages independent learning.

Product development is carried out through drafting, where the research team compiles an initial draft based on the design results. The product is compiled using the teaching material development guidelines and is equipped with nutritional table visualizations, anatomical illustrations, and Figure 2 worksheets. Validation was conducted by three experts, namely Anatomy Physiology Lecturer Material Expert who assessed the achievement of CPMK and material accuracy, learning media expert who assessed instructional design, layout, and readability, and Nutritionist who assessed the accuracy of local ingredient nutritional content data. Validation results are presented in Table 1.

Figure 2
Design of practical guidelines for testing the nutritional content of local NTT food ingredients (in Indonesian)

Table 1 Expert validation results for the development of a PJBL-based practical guidebook by testing the nutritional content of local NTT food

Aspect	Total score	Percentage of each aspect (%)	Category
Practical guide size	5	100%	Very good
Practical guide cover design	56	93%	Very good
Design of the contents of the practical guide	82	91%	Very good
Material	105	100%	Very good
Nutritional suitability	2	91%	Very good

Based on the validation results in Table 1, it shows that the practicum guidebook developed based on PJBL by testing the nutritional content of local NTT food received a very good assessment from experts in all aspects being assessed. The highest score was achieved in the material aspect, which shows that the contents of the practicum guide material are very relevant and of high quality to support PJBL that emphasizes active student involvement in the learning process (Putri et al., 2024). The cover design and contents of the practicum guide also received very good assessments, with a slight decrease in the cover design (93%) and content design (91%). This shows that although there is room for improvement, the overall design of the guide is still well received by experts. In this context, the design of visual learning materials is very important to increase students' interest and understanding (Wirani et al., 2023). Nutritional suitability also managed to meet the expected standards, with the nutritional content of local NTT food in accordance with the guidelines set out in the book. Compiling teaching materials that include nutritional content is very important to ensure holistic and contextual learning for students, especially those related to local foods that are rich in nutritional value. Overall, this practical guidebook is successful in presenting PJBL-based practical materials that are not only in-depth and substantial, but also pay attention to attractive design aspects and are in accordance with users' needs, especially in the context of testing the nutritional content of local foods.

The results of the readability test and initial student responses conducted on 15 students obtained data that 91.7% of students stated that the developed practicum guidebook was easy to understand, the material in the book successfully communicated information in a clear and easy-to-understand manner for students. An easy-to-understand book allows students to follow the learning flow more easily and understand the presented concepts, thereby increasing the effectiveness of learning. Furthermore, 83.3% of students felt that project activities made them more active. Project-Based Learning approach encourages student involvement in the learning process. Project-Based Learning has been proven effective in improving student skills, such as critical thinking, collaboration, and communication skills (Wibowo et al., 2024). Therefore, this positive response shows that the approach applied in the practicum guidebook has succeeded in activating student participation in practicum activities. Furthermore, 100% of students stated that the local material theme was very interesting and relevant. The development of local food-based themes, especially those focusing on local materials from NTT, was able to attract interest and relevance among students. Involving local materials in learning not only introduces the diversity of Indonesia's natural resources, but also provides a context that is closer to students' daily lives, which can enrich their learning experiences.

Project-Based Learning practicum guidebook was implemented for 3 weeks in an experimental class consisting of 20 students, and divided into 5 groups. Project activities were carried out in three main stages, namely project planning, experimentation and evaluation. In the planning stage, students choose local food ingredients, namely *jagung bose* (Kupang corn soup), *jagung katemak* (a local specialty dish made of corn and papaya), nuabosi cassava, moringa, salted anchovies, salted fish, sorghum, chub mackerels, peanuts, papaya flowers, papaya fruit, papaya leaves, jagung titi (local corn chips), dried cassava, taro, purple sweet potato, yellow sweet potato, yellow cassava, cassava leaves, spinach, carrots, tofu, tempeh, bean sprouts, boiled corn, tomatoes, *rebok* (local snacks), boiled bananas, *kaparak* (specialty dish of Southwest Sumba), coconut oil, dragon fruit, beranga banana, lady finger banana, *ubi manusia* (large yam from NTT), avocado, and sorghum, while the analysis of the nutritional content tested is the Lugol Test (Carbohydrates), Biuret Test (Protein), Sudan III Test (Fat), Benedict Test (Sugar).

The second stage is the Experimental stage, which involves the practicum of analyzing the nutritional content of selected food ingredients. In the experimental stage, the developed PJBL practicum guidebook was implemented for 3 weeks in an experimental class consisting of 20 students, and divided into 5 groups. Project activities were carried out in three main stages, project planning, at this stage students chose local food ingredients, namely *jagung bose* (Kupang corn soup), *jagung katemak* (a local specialty dish made of corn and papaya), nuabosi cassava, moringa, salted anchovies, salted fish, sorghum, chub mackerels, peanuts, papaya flowers, papaya fruit, papaya leaves, *jagung titi* (local corn chips), dried cassava, taro, purple sweet potato, yellow sweet potato, yellow cassava, cassava leaves,

spinach, carrots, tofu, tempeh, bean sprouts, boiled corn, tomatoes, *rebok* (local snacks), boiled bananas, *kaparak* (specialty dish of Southwest Sumba), coconut oil, dragon fruit, beranga bananas, lady finger bananas, *ubi manusia* (large yam from NTT), avocado, and sorghum. The nutritional content tests used in this study were the Lugol Test (Carbohydrate), Biuret Test (Protein), Sudan III Test (Fat), Benedict Test (Sugar). The second stage is the Experimental stage, which involves the practicum of analyzing the nutritional content of selected food ingredients. The results of the nutritional content test experiment on 35 types of local food in NTT showed that a number of food ingredients contain carbohydrates, which were detected through the Lugol test.

Lugol test is one of the chemical methods to detect the presence of carbohydrates, especially starch, which will show a color change to blue or purple when the food being tested contains starch. in this experiment, the food ingredients that show a color change in the Lugol test are cassava, boiled corn, *jagung titi*, boiled bananas, peanuts, taro, yellow sweet potatoes, purple sweet potatoes, kaparak,rebok, ubi manusia, jagung katemak, jagung bose, sorghum, yellow cassava, nuabosi cassavas and cassava leaves, figure 3.

Carbohydrates are one of the important macronutrients that function as the main source of energy for the human body. Carbohydrates contained in local NTT food are in the form of starch, which is the main source of energy for the body (Naisali et al., 2023). Sweet potatoes are known to contain quite high amounts of starch, which can provide sustainable energy for the body (Lamusu, 2018). Sorghum is rich in starch and can help meet energy needs (Puspita et al., 2018). Peanuts, although better known for their fat and protein content, also contain enough carbohydrates to be used as an energy source. Carbohydrates function as the main source of energy, especially for the brain and nervous system, and are also important for the body's metabolic processes, such as the formation of glucose stored in the liver and muscles in the form of glycogen (Azhari et al., 2022).

The results of the nutritional content test experiment on 35 types of local food from NTT showed that avocado, bean sprouts, cassava, dried fish, tofu, tempeh, carrots, anchovies, coconut oil, and steamed *kombong* fish contain protein, which was detected using the Biuret test (Figure 4). These results are supported by research conducted by (Lapinangga & Lopez, 2018) which states that fish, tempeh, tofu, and bean sprouts are good sources of protein from both plant and animal sources. Processed cassava products such as *gaplek* can contribute protein, although in smaller amounts (Mundita, 2013).

Figure 3 Results of carbohydrate tests on 35 local NTT foods

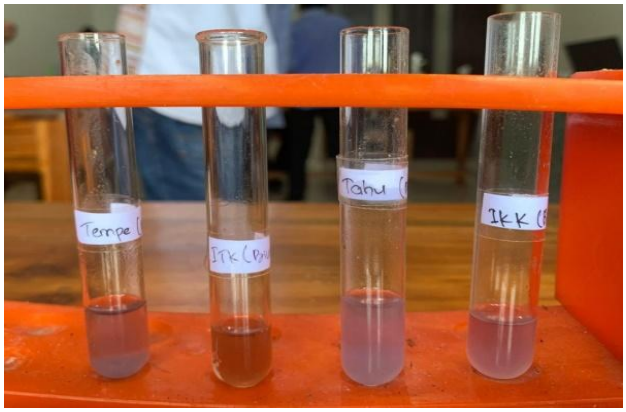

Figure 4 Results of protein content using Biuret solution

The Biuret test is a chemical method for detecting the presence of peptide bonds in protein molecules. If protein is present, the Biuret solution will turn purple, as a positive indication of protein content (Syarfaini et al., 2017). Protein is an important component in human nutrition, which plays a role in various body functions, including the formation and repair of body tissues, the formation of enzymes and hormones, and as a source of reserve energy (Puspita et al., 2018).

Local food ingredients identified as containing fat based on the results of experiments using avocado, tofu, tempeh, peanuts, coconut oil, anchovies, dried fish, *kaparak*, *rebok*, and steamed cubs' mackerel. The Sudan III test was used to detect the presence of fat in food samples, which showed that fat was visible in most of the tested samples (Figure 5). Avocado contains high unsaturated fats, especially oleic acid, which plays a role in increasing good cholesterol (HDL) levels and reducing the risk of heart disease (Mundita, 2013). Puspita et al. (2018) revealed that tofu and tempeh have quite high fat content, although most of it is healthier unsaturated fat (Naisali et al., 2023) found that local fish such as *kaparak*, *rebok*, and cubs mackerels are rich in protein and healthy fats.

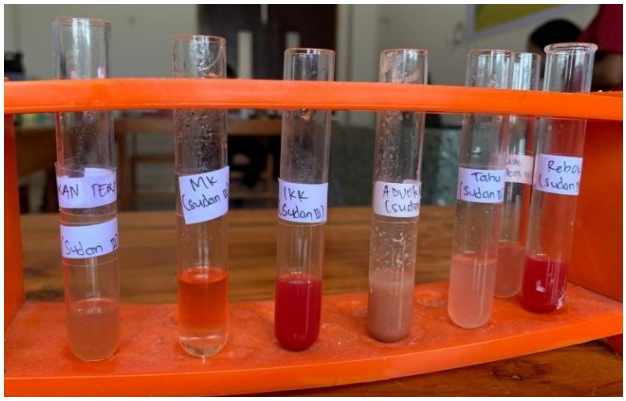

Figure 5 Fat test results using the Sudan III test

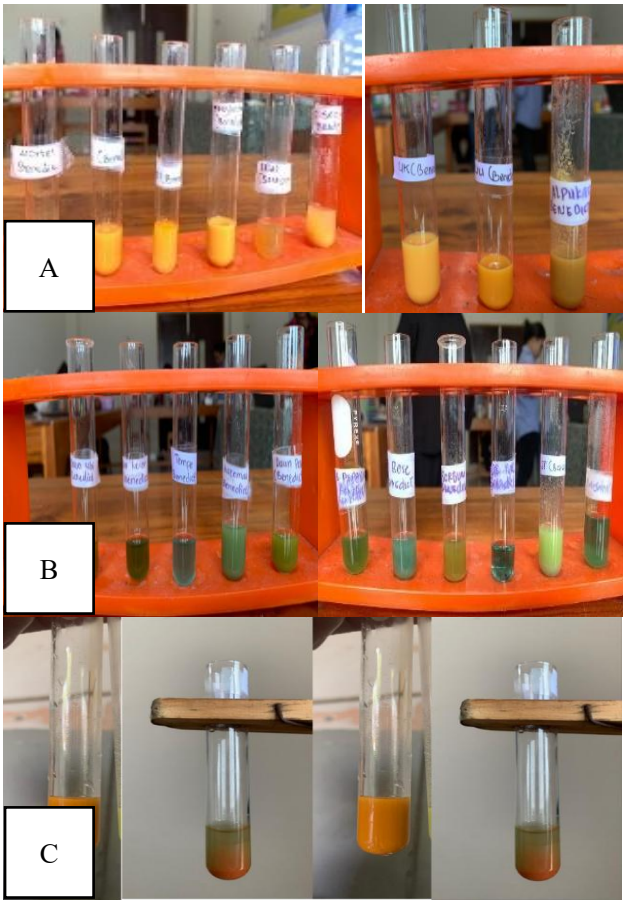

Figure 6
Glucose test results (A) low sugar levels, (B) medium sugar levels, and (C) high sugar levels

The fat contents in local NTT food have the potentials to support the nutritional needs of the community, especially in meeting energy needs. Fat is one of the important macronutrients in the diet, in addition to carbohydrates and proteins, because of its essential function in the metabolic processes of the body, including for the absorption of fat-soluble vitamins (A, D, E, and K) (Rahayu et al., 2018).

Benedict's solution showed that the glucose levels in food ingredients varied as evidenced by three color changes, namely green which indicates that the food ingredients contain low sugar content, namely papaya leaves, titi corn, boiled bananas, moringa leaves, peanuts, taro, purple sweet potatoes, *ubi manusia*, *jagung katemak*, *jagung bose*, papaya flowers, nuabosi cassava, and cassava leaves, yellow color indicates medium sugar content, namely avocado, tempeh, cassava, bean sprouts, tomatoes, spinach, yellow sweet potatoes, papaya fruit, yellow cassava, beranga bananas, and brick red color indicates high sugar content for local foods, namely carrots, bananas, dragon fruit, and apples (Figure 6).

Benedict's test is used to test glucose content because the basic principle of this test is the reaction between reducing sugar and Benedict's solution which results in a color change. Reducing sugar is a type of sugar that can reduce copper ions (Cu^{2+}) in Benedict's solution to copper(I) oxide (Cu_2O), which is brick red or orange (Wilberta et al., 2021).

Research Naisali et al. (2023) shows that taro and purple sweet potatoes have low glucose levels because of their high fiber contents, which can slow the absorption of sugar in the body. Tempeh has a relatively moderate glucose level, which is useful as a source of vegetable protein with minimal effect on blood sugar spikes (Indrawati & Maimaznah, 2020; Rahadiyanti & Mulyati, 2017). Pertiwi (2024) revealed that bananas have a fairly high glucose content, thus providing quick energy. Apples have a relatively high glucose content, and are rich in pectin fiber, thus helping to reduce blood sugar spikes after consumption (Lestari et al., 2023).

Based on the results of observations during the learning process, there was a significant increase in students' collaborative activities, especially in group work and discussion indicators. Students were more active in contributing to groups, putting forward ideas, and building arguments based on the experimental data they had conducted. In addition, the students' involvement was also reflected in their increasingly explorative ability to link experimental results with the concept of human body physiology. This increase is in line with the results of the study, Fatiati (2023) saying that collaborative work encourages students to exchange ideas, deepen their understanding of concepts, and improve learning outcomes. Group discussion activities also help students develop critical thinking skills, because students must evaluate various opinions and find solutions together (Dewanti, 2011; Dwijayanti et al., 2022). The results of group presentations showed an increase in scientific literacy, this was indicated by students' ability to explain scientific phenomena using relevant physiological concepts, interpret experimental data logically, connect experimental results with theoretical concepts, and convey scientific arguments systematically.

Based on the observations during the learning process, there was a significant increase in students' collaborative activities, particularly in group work

and discussions, which reflected greater student involvement in contributing to the group, proposing ideas, and constructing arguments based on the experimental data obtained.

Quantitatively, the collected data showed that 83.3% of students felt more active in project activities compared to previous activities, consistent with the findings reported in Table 3, which indicated that 95.75% of students felt motivated to engage actively in learning. These indicators demonstrate that the implementation of the PJBL approach successfully enhanced students' engagement significantly. In addition, through group discussions, students became more accustomed to linking experimental results with human physiology concepts. For instance, during group presentations, 91.7% of students were able to explain scientific phenomena using relevant physiological concepts, interpret experimental data logically, and present scientific arguments systematically. This indicates a significant improvement in students' scientific literacy skills. A recapitulation of students' collaborative activity observation scores is presented in Figure 7.

Figure 7 shows that students' collaborative activities experienced a consistent increase. This finding is in line with Fatiati (2023), who reported that collaborative work encourages students to exchange ideas, deepen their conceptual understanding, and improve learning outcomes. Engagement in group discussions also helps students develop critical thinking skills, as they are required to evaluate different opinions and find solutions collectively (Dewanti, 2011; Dwijayanti et al., 2022).

According to Mu'minah (2021) Scientific literacy does not only include mastery of facts, but also the ability to use scientific knowledge in making decisions and solving real-world problems. Experimental and collaborative learning approaches have proven effective in improving students' scientific literacy (Sake et al., 2024). Active engagement in scientific activities, including data-based discussions and scientific exploration, is a key factor in developing scientific literacy among students (Rochim et al., 2022).

Project-Based Learning practicum guidebook were conducted through expert validation and limited trials. From this process, several important inputs were obtained related to aspects of visual design, language, and assessment components. In terms of visual design, experts assessed that the appearance of the book needed to be adjusted to be more attractive, consistent, and clarify important information for students. Adjustments include the use of colors, layouts, and selection of images that are more relevant to the content. Good visual design can increase cognitive engagement and facilitate more effective learning through visual information processing (Indrawati & Maimaznah, 2020). In terms of language, input was obtained to simplify several technical terms and clarify practicum instructions so that they are easier for the students to understand. According to (Ilyas et al., 2019), the use of clear, communicative language that is adjusted to the level of learner ability is very important to improve conceptual understanding, especially in PJBL. As for the assessment components, input from experts indicated the need to clarify the assessment indicators in the project rubric, so that the students understand the success criteria more transparently. Fatiati (2023) stated that clarity in formative assessment helps students identifying gaps in their understanding and improving learning achievement.

The results of the summative evaluation showed that the use of project-based guidebooks had a positive impact on learning outcomes, critical thinking skills, active involvements, and student satisfaction. The improvement in students' learning outcomes was measured by conducting pre- and post-learning tests, and analyzed using the N-gain formula. The calculation results can be seen in Table 2.

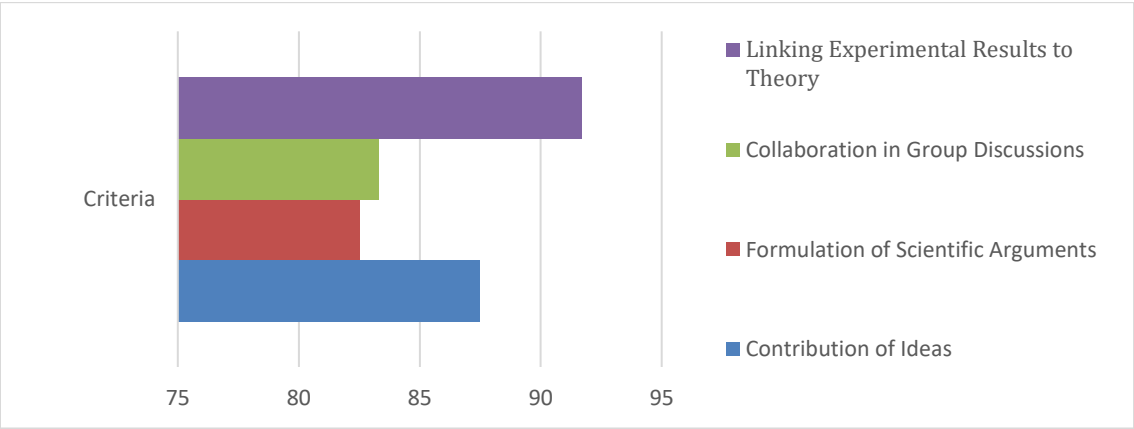

Figure 7
Recapitulation of students' collaborative observation results in group discussions

Table 2 Recapitulation of student learning outcomes using the PJBL-based practical guidebook by testing the nutritional content of local NTT food

Descriptive statistics	Mark	
	Pretest	Posttest
Number of samples	20	20
Average	36.7	68.65
Improvement	10.31	
N-Gain	0.51	
N-Gain category	Currently	
The highest score	57	93
Lowest value	17	47

Table 3 Recapitulation of student responses to the practical guidebook

No	Aspect	Total score	Percentage
1	Practical guidebook improves conceptual understanding	460	92%
2	Practical guidebook helps develop critical thinking skills	756	94.5%
3	The practical guidebook motivates active involvement in learning.	383	95.75%
4	Easy to use and attractive practical guide book	378	94.5%

Table 2 shows that the PJBL method has proven effective in improving students' understanding of the nutritional content of local NTT food. The significant increase in average pretest and posttest scores, along with the N-Gain value categorized as moderate, indicates that PjBL provides students with a deeper and more practical learning experience. This result is consistent with the research objectives stated in the introduction, namely to enhance students' understanding not only in anatomy and physiology but also in real-life applications through the nutritional analysis of local foods relevant to daily life.

More specifically, the application of PjBL allows students not only to learn theory but also to connect it with hands-on practice through experiments focusing on local foods. By engaging students in projects that require them to collect data, analyze findings, and construct scientific arguments based on practical evidence, PjBL has successfully enhanced critical thinking and collaboration skills, which are essential components of 21st-century education.

As highlighted by Astartia et al. (2024), PJBL increases student engagement in the learning process by emphasizing the application of knowledge in real-world contexts. In this study, the implementation of PjBL not only supported students in understanding human physiology concepts related to nutrition but also deepened their awareness of the relationship between local food consumption and human health.

The moderate N-Gain improvement, with relatively low pretest scores and significantly higher posttest scores, suggests that although there was meaningful progress in understanding, there remains room for further improvement, particularly in integrating broader aspects of practical analysis and more in-depth evaluation in future experiments. As stated by Suseno et al. (2022), PjBL holds great potential to continuously enhance student engagement and activeness, but this requires adjustments in evaluation methods as well as further development in PJBL design.

Furthermore, PjBL has also proven effective in enhancing students' critical thinking skills. Fatiati (2023) noted that collaboration within projects provides opportunities for students to exchange ideas, evaluate different perspectives, and work together to find solutions, thereby contributing to the development of analytical abilities and the synthesis of scientific information.

Project-Based Learning focuses on developing students' skills through real projects that are relevant to life, for example by testing the nutritional content of local food. Project-Based Learning makes students more active in participating and applying the theories they have learned, so that they can improve their understanding of the topics being taught. The students' Responses to the Guidebook are presented in Table 3.

Table 3 shows very positive response to the use of the practicum guidebook. This response supports the research by Astartia et al. (2024), finding that systematically designed PJBL media can improve students' conceptual understanding, critical thinking skills, and intrinsic motivation. In addition, Sholeh et al. (2024) it also reveals that contextual and PJBL materials can increase students' active involvement in the learning process.

The results of the student project assessment using the project assessment rubric showed that there were 4 groups that scored 98 with a very good category while 1 group scored 83 with a good category. These results indicate that most students are able to meet the project assessment indicators very well, and both in terms of understanding concepts, applications in projects, and teamwork skills. Artama et al. (2023) state that project-based evaluation is able to measure content mastery, and 21st century skills such as collaboration, problem solving, and scientific communication.

This study concludes that the application of PJBL in developing a Human Anatomy and Physiology practical guidebook with the integration of local NTT food analysis is effective in enhancing students' conceptual understanding, critical thinking, and collaboration. By linking theoretical knowledge with real-life applications, this approach not only makes biology learning more relevant and practical but also supports the development of 21st-century skills and fosters a deeper appreciation of biology in everyday contexts.

D. Conclusion

Project-Based Learning based practical guidebook with a test of the nutritional content of local NTT food has successfully improved scientific literacy, learning outcomes, and collaborative skills of students. The innovation of this research lies in the integration of PJBL with the local context, which enriches the practical experience of the human anatomy and physiology course on the digestive system. Formative evaluation resulted in improvements in the visual, language, and assessment aspects to ensure product effectiveness. It is recommended that similar research be carried out by reviewing the application of this book on a wider scale and integrating the development of students' soft skills in a more structured manner.

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