JOURNAL OF BIOLOGY EDUCATION
J O B E
E-ISSN 2656-3436/ P-ISSN 2615-3947
IAIN KUDUS
http://journal.iainkudus.ac.id/index.php/jbe

Development of Research-Based Digestive System Supplementary Materials to Enhance Scientific Literacy and Health Awareness

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ABSTRACT

This study aimed to develop a research-based supplementary teaching material on the human digestive system and to examine its feasibility and effectiveness in improving students' scientific literacy and health-caring attitudes in Biology learning. The study employed a Research and Development (R&D) Borg and Gall model, including problem identification, data collection, product design, expert validation, product revision, and field testing. The feasibility of the developed product was evaluated through material and media expert validation, while its effectiveness was tested using a quasi-experimental with pretest–posttest control group design. Data were collected using scientific literacy tests and health-caring attitude questionnaires and analyzed using N-gain and independent sample t-tests. The results showed that the supplementary teaching material was categorized as very feasible based on material expert validation (93.4%) and feasible based on media expert validation (86.5%). Readability tests also indicated very feasible categories from teachers (93.3%) and students (91.4%). Independent sample t-test results revealed significant differences between experimental and control group ($p < 0.05$). These findings indicate that the developed supplementary teaching material is feasible and effective in supporting Biology learning to improve scientific literacy and health-caring attitudes among Grade XI Madrasah Aliyah students.

Keywords: supplementary teaching material, scientific literacy, health awarness

INTRODUCTION

Twenty-first century learning requires students not only to master factual knowledge but also to develop critical thinking skills, problem-solving abilities, and the capacity to relate scientific concepts to real-life phenomena (OECD, 2024; Lenzer et al., 2024). Furthermore, Suardi (2018) emphasizes that twenty-first century education should encourage students to actively construct knowledge through interaction with their environment and real-world problems.

Meaningful learning should provide contextual learning experiences so that the knowledge acquired by students can be applied in their daily lives (Muharrom et al., 2023). Therefore, biology education in schools needs to deliver meaningful learning and provide contextual learning experiences, enabling students to apply the acquired knowledge in their daily lives and relate scientific concepts to authentic situations encountered in society (OECD, 2023; Lenzer et al., 2024).

In line with these demands, the Indonesian government has implemented the Merdeka Curriculum as a major educational reform aimed at strengthening competencies, character development, and student learning autonomy. The Merdeka Curriculum emphasizes student-centered learning, in which teachers act as facilitators who design meaningful and relevant learning experiences (Muharrom et al., 2023; Malahayati & Zunaidah, 2021). This curriculum requires teachers to be capable of developing contextual and flexible learning materials that align with students' characteristics and learning needs (Marlangen et al., 2021).

In practice, the success of learning is greatly influenced by the availability and quality of teaching materials, which serve as important resources for supporting student engagement and knowledge construction (Marlangen et al., 2021; Muharrom et al., 2023). Teachers are not only responsible for delivering content but also for designing and selecting instructional materials that help transform abstract concepts into concrete and meaningful knowledge that can be easily understood by students (Malahayati & Zunaidah, 2021; Marlangen et al., 2021). Patmawati (2017) states that appropriate teaching materials and instructional approaches play an important role in determining the effectiveness of the learning process and student learning outcomes.

One alternative instructional resource that can support effective learning is supplementary teaching material. Such materials function as enrichment resources that complement the main textbooks in terms of content depth, visualization, and relevance to real-life contexts (Tonda et al., 2023; Malahayati & Zunaidah, 2021). Supplementary materials equipped with colored illustrations, factual data, and research-based information can facilitate students' conceptual understanding and enhance their learning motivation (Depdiknas, 2008; Patmawati, 2017).

In Biology education, particularly on the topic of the digestive system, supplementary teaching materials are highly important because the content is complex, abstract, and closely related to everyday life (Cimer, 2012; Tonda et al., 2023). Without contextual learning resources, students tend to memorize concepts without fully understanding their implications for health and daily behavior. Tonda et al. (2023) reported that limited teaching materials can lead to difficulties in conceptual understanding, low learning motivation, and underdeveloped scientific reasoning skills.

Preliminary observations conducted in senior high schools and Madrasah Aliyah in Kudus indicate that Biology learning on the topic of the digestive system is still dominated by the use of standard textbooks that do not fully accommodate the principles of the Merdeka

Curriculum. Digestive system disorders are generally presented as a list of diseases with brief descriptions, without integration of recent scientific research or current health issues such as obesity. This condition contributes to the low level of students' scientific literacy and the limited development of health-caring attitudes. This condition aligns with the findings of Lenzer et al. (2024), who reported that science learning that lacks meaningful real-world contexts tends to provide limited opportunities for higher-order thinking and does not adequately support the development of students' scientific reasoning skills.

Another challenge in biology education is the need to equip students with scientific literacy (OECD, 2023; Lenzer et al., 2024). Currently, PISA results indicate that the scientific literacy of Indonesian students remains far below the average of other countries (OECD, 2024). Scientific literacy is a fundamental competency that enables students to understand scientific phenomena, identify scientific issues, and use scientific evidence in decision-making processes (Yuliati, 2017). According to PISA, scientific literacy consists of three core competencies: identifying scientific questions, explaining phenomena scientifically, and using scientific evidence (Rini et al., 2021). A low level of scientific literacy indicates the need for innovative learning approaches that integrate scientific concepts with real-life contexts.

Scientific literacy is increasingly recognized as an essential competency for preparing students to face complex challenges in modern society. Students with adequate scientific literacy are better able to evaluate information critically, make evidence-based decisions, and participate responsibly in discussions related to health, science, and environmental issues (OECD, 2023; Lenzer et al., 2024).

In addition to scientific literacy, Biology education plays a strategic role in fostering students' health-caring attitudes. Understanding digestive system functions, healthy eating habits, and obesity-related health risks can encourage students to make informed decisions regarding their personal health. Health literacy has been recognized as a key determinant of adolescents' health behavior because it enables individuals to access, understand, evaluate, and apply health information in daily life (Bröder et al., 2022; World Health Organization, 2024). Furthermore, contextual learning that integrates authentic health issues into science instruction can strengthen students' awareness of the relationship between biological concepts and healthy lifestyle practices. Therefore, research-based learning materials that incorporate current health issues, such as obesity, have the potential not only to improve scientific literacy but also to foster sustainable health-caring attitudes among students.

Based on these considerations, it is necessary to develop research-based supplementary teaching materials on the digestive system that not only present biological concepts but also integrate recent scientific findings related to obesity and digestive health disorders. These materials are expected to improve students' scientific literacy while fostering health-caring attitudes among Madrasah Aliyah students. Therefore, this study focuses on the development of research-based supplementary teaching materials on the

digestive system to enhance scientific literacy and health-caring attitudes among Madrasah Aliyah students.

Although previous studies have demonstrated that contextual teaching materials and problem-based learning can improve students' learning outcomes, conceptual understanding, and scientific literacy, most of these studies have focused primarily on cognitive achievement. Research examining the simultaneous development of scientific literacy and health-caring attitudes remains limited, particularly in Biology learning on the digestive system topic. Furthermore, the integration of current scientific research findings, especially those related to obesity and digestive health, into supplementary teaching materials has not been widely implemented in a systematic manner at the Madrasah Aliyah level. Obesity represents a relevant socioscientific issue because it connects biological concepts with real-world health challenges that require evidence-based reasoning and informed decision-making (Sadler & Zeidler, 2005; Zeidler et al., 2005). Therefore, this study aims to develop research-based supplementary teaching materials integrating obesity-related scientific findings into digestive system learning to enhance students' scientific literacy and foster health-caring attitudes simultaneously.

METHOD

This study employs a Research and Development (R&D) approach aimed at developing research-based supplementary teaching materials on the human digestive system and examining their feasibility and effectiveness in improving students' scientific literacy and health-caring attitudes. The research procedure is adapted from the R&D model by Borg and Gall, which emphasizes a systematic process from identifying educational problems to producing a feasible instructional product (Sugiyono, 2015).

The stages of the research and development process were modified to align with the scope and objectives of the study. A schematic representation of the modified R&D procedure is presented in Figure 1.

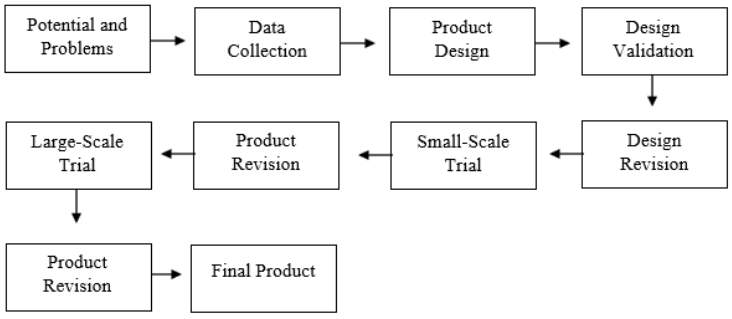


Figure 1. Research and development procedure of research-based supplementary teaching materials

The research procedure was adapted from Borg and Gall Research and Development (R&D) model. Not all stages of the original model were implemented. This study was limited to product development, feasibility validation, readability testing, and effectiveness testing in a school setting. Therefore, the mass production stage was not conducted because the objective of this research was to produce and evaluate a feasible and effective supplementary teaching material rather than to distribute the product on a large scale.

Table 1. Comparison between the borg and gall model and the stages applied in this study

Borg and Gall R&D Stage	**Stage Applied in This Study**	**Description**
Potential and Problems	Applied	Identification of learning problems and needs through classroom observations and questionnaires
Data Collection	Applied	Collection of supporting information through literature review, interviews, and questionnaires.
Product Design	Applied	Development of research-based supplementary teaching materials integrating digestive system concepts and obesity-related issues.
Design Validation	Applied	Validation by material experts and media experts.
Design Revision	Applied	Revision based on suggestions from expert validators.
Small-Scale Trial	Applied	Readability and practicality testing involving students and teachers.
Product Revision	Applied	Revision based on the results of the small-scale trial.
Large-Scale Trial	Applied	Field testing to determine the effectiveness of the supplementary teaching material.
Product Revision	Applied	Final revision based on the results of the large-scale trial.
Final Product	Applied	Production of the final version of the supplementary teaching material.

As shown in Figure 1 and Table X, all stages of the modified R&D procedure were implemented in this study, beginning with the identification of potential and problems and ending with the production of the final product. The procedure was adapted from Borg and Gall R&D model to suit the objectives of developing, validating, and testing the effectiveness of research-based supplementary teaching materials on the digestive system.

As shown in Figure 1, the study began with the identification of potentials and problems through classroom observations and needs analysis questionnaires administered to both teachers and students. This stage was followed by data collection through literature reviews, interviews, and questionnaires, which served as the basis for designing the supplementary teaching materials. The product design stage involved organizing the content, integrating relevant research findings, and developing visual components to support students' understanding.

The designed product was then validated by subject-matter experts and media experts to assess its feasibility in terms of content accuracy, language clarity, presentation, and graphical quality. Feedback from these experts was used to revise the product before it was implemented in a limited-scale trial. Subsequently, a field trial was conducted to evaluate the effectiveness of the developed product before it was finalized as a research-based supplementary teaching material for biology learning.

The field trial employed a quasi-experimental using a pretest–posttest control group design. The participants consisted of 67 grade XI students, divided into an experimental group and a control group, as shown in Figure 2.

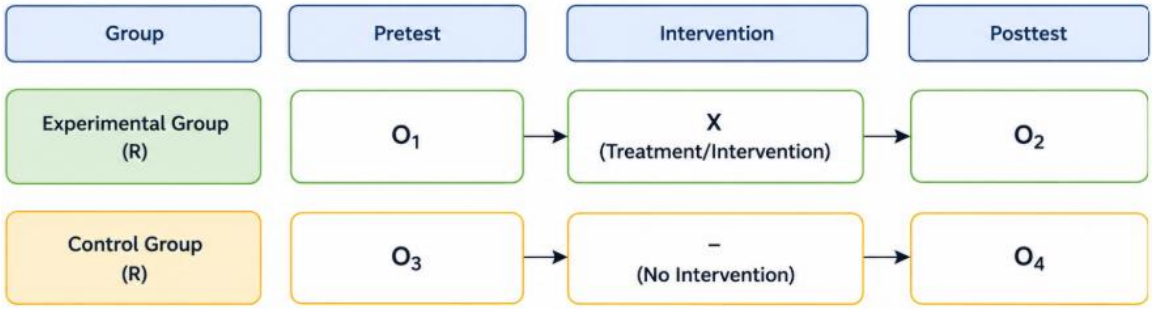


Figure 2. A quasi-experimental using a pretest–posttest control group design.

Description:
O1 = pretest in the experimental group
O2 = posttest in the experimental group
O3 = pretest in the control group
O4 = posttest in the control group

In this study, the Problem-Based Learning (PBL) model was implemented in both the experimental and control classes to ensure that the learning model remained constant across groups. Therefore, the independent variable examined was the type of teaching material used during instruction. The experimental class used research-based supplementary teaching materials integrating scientific research findings, obesity-related issues, BMI calculation activities, and health-caring action plans. In contrast, the control class used the standard biology textbook commonly employed in classroom instruction. By controlling the learning model and teacher, any differences in students' scientific literacy and health-caring attitudes could be attributed primarily to the differences in teaching materials.

The data analysis technique for validity was conducted by material experts, media experts, and readability testing using a Likert scale for the assessment options. The

questionnaire results were analyzed quantitatively using a formula according to Sudijono (2006) as follows:

$P = \frac{f}{N} \times 100\%$

Description:
P= percentage score
f = obtained score
N= maximum score

Based on the above calculation, the percentage obtained from the data on potentials and problems is presented in Table 2 below.

Table 2. Percentage range categories of potential and problem data results

Percentage Range (%)	Criteria
83-100	Very Good
65-82	Good
47-64	Fairly Good
29-46	Poor
10-28	Very Poor

The data on potentials and problems are considered good if the percentage results from respondents are ≥ 75%, falling within the good to very good categories.

Data were collected using a scientific literacy test and a health-caring attitude questionnaire, both validated by subject-matter and evaluation experts. Reliability was tested using Cronbach's Alpha to ensure internal consistency. The scientific literacy test was developed based on three scientific literacy competencies adapted from the PISA framework: (1) identifying scientific questions or issues, (2) explaining phenomena scientifically, and (3) using scientific evidence. These competencies were operationalized into 25 multiple-choice items covering digestive system concepts, digestive disorders, nutrients, digestive enzymes, and obesity-related health contexts. The distribution of the items across the scientific literacy competencies is presented in Table 3.

Table 3. Blueprint of the scientific literacy test

Scientific Literacy Competency	**Indicator**	**Cognitive Level**	**Item Numbers**	**Number of Items**
Identifying Scientific	Identifying scientific issues related to nutrients and digestive disorders	C1–C2	1, 3, 5, 17, 18, 19	6

Scientific Literacy Competency	**Indicator**	**Cognitive Level**	**Item Numbers**	**Number of Items**
Questions or Issues				
Explaining Phenomena Scientifically	Explaining digestive processes, enzyme functions, and organ functions using scientific concepts	C1–C3	4, 8, 9, 10, 11, 12, 13, 14, 15, 22, 24	11
Using Scientific Evidence	Analyzing symptoms, interpreting data, evaluating evidence, and drawing conclusions	C2–C4	6, 7, 16, 20, 21, 23, 25	8
Total				**25**

Prior to hypothesis testing, the data were subjected to normality and homogeneity tests to ensure that the assumptions for parametric analysis were met. To determine the improvement within each group, a paired sample t-test was conducted by comparing pretest and posttest scores. To compare the effectiveness of the treatment between the experimental and control groups, an independent sample t-test was performed on the N-gain scores.

The hypotheses for the independent sample t-test were formulated as follows:

H_0: There is no significant difference in the improvement of scientific literacy and health-caring attitudes between students who learned using research-based supplementary teaching materials and those who learned using conventional teaching materials.

H_1: There is a significant difference in the improvement of scientific literacy and health-caring attitudes between students who learned using research-based supplementary teaching materials and those who learned using conventional teaching materials.

The significance level used in this study was $\alpha = 0.05$. Statistical analyses were conducted using SPSS 18.0 for Windows. If the significance value (p) was less than 0.05, H_0 was rejected, indicating a significant difference between groups. Conversely, if the significance value (p) was greater than 0.05, H_0 was accepted. The improvement in students' learning outcomes was analyzed using the normalized gain (N-gain) formula proposed by Richard Hake (1999), as follows:

$$g = \frac{posttest - pretest}{100 - pretest}$$

Table 4. Categories of N-gain percentage range

Range	Qualitative Criteria
$0.7 \leq g \leq 1.0$	High
$0.3 \leq g \leq 0.7$	Medium
$0.02 \leq g \leq 0.3$	Low

Students' scientific literacy is considered effective if at least 75% of students achieve N-gain scores in the medium to high categories. Data analysis included tests of normality and homogeneity, followed by an independent samples t-test to determine differences between groups. Furthermore, N-gain analysis was used to measure the improvement in students' scientific literacy and health-caring attitudes after the implementation of the supplementary teaching materials (Richard Hake, 1999; Sugiyono, 2016).

RESULT AND DISCUSSION

The results of Research and Development (R&D) using the model proposed by Borg and Gall need to go through several stages, including:

Potential and Problems

The problems identified in senior high schools and Madrasah Aliyah indicate that teaching materials on the digestive system are still incomplete. Based on questionnaire results, many students show interest in the digestive system topic and are attracted to materials that present real-life facts. However, this high level of interest is not matched by the quality of materials in meeting students' learning needs. In the digestive system topic, the information is generally presented only as a list with brief descriptions, without detailed explanations of the causal relationships behind the disorders. This condition highlights the need to develop research-based supplementary teaching materials that examine the impact of obesity on digestive system disorders.

Data Collection

This stage aimed to gather data that could be utilized to support the development of teaching materials on the digestive system. The study employed a quasi-experimental method using a Pretest–Posttest Control Group Design.

In this study, two classes were involved, both taught by the researcher. Class C was given treatment (X_1), while Class E received treatment (X_2). Class C was taught using a supplementary teaching material approach, whereas Class E was taught using a textbook-based approach. Class C, which received the supplementary material treatment, was designated as the experimental group, while Class E served as the control group.

Product Design

The design stage consists of several steps, including:

Media Selection: Determining the type of media based on teachers' and students' needs, namely supplementary teaching materials to enhance learning on obesity..

Format Selection: Analyzing the appropriate format and design of the materials, aligned with the Problem-Based Learning (PBL) approach.

Initial Design: This stage involves the preliminary design, focusing on analyzing the components of the developed supplementary teaching materials. The following is an explanation of each component of the supplementary materials.

Table 5. Components of the supplementary teaching material

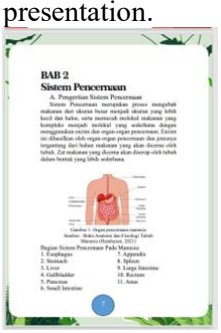
Image	Description	Image	Description
Front cover of the book. 	1. The cover of the supplementary teaching material is designed in color, with a clear title and illustrations representing the digestive system and health issues to attract students' interest in reading.	Introduction section 	2. The introduction provides a contextual overview that links the digestive system material to real-life health problems as an initial learning apperception.
Beginning of digestive system material presentation. 	3. The digestive system material is presented systematically, supported by colored illustrations and a balanced text–image layout to aid conceptual visualization.	Research-based information. 	4. Research-based information is presented as content reinforcement to enhance students' scientific literacy.
Summary of the material.	5. The material summary is organized systematically to help students consolidate scientific literacy and health-caring attitudes.	Concept reinforcement.	6. Concept reinforcement and health messages are presented using communicative language to foster students' health-caring attitudes.

Image	Description	Image	Description
			

Design Validation

In this study, the credibility of the supplementary teaching materials was evaluated through a validation process conducted by subject-matter experts and media experts. The material expert assessment covered several components, including content, presentation, and language. Meanwhile, media expert validation included aspects such as book design, cover design, and content layout. The evaluation instrument employed a feasibility formula to determine the quality category of the supplementary teaching materials. The results of the material expert assessment are presented in Table 6, while the results of the media expert validation are shown in Table 7.

Table 6. Material Expert Validation

Aspect	Average	Category
Content	95.7%	Very Feasible
Presentation	97%	Very Feasible
Language	87.3%	Feasible
Overall	**93.4%**	**Very Feasible**

Table 7. Media Expert Validation

Aspect	Average	Category
Book Design	100%	Very Feasible
Cover Design	81.4%	Feasible
Content Design	87.1%	Feasible
Overall	**86.5%**	**Feasible**

Design Revision

The product design revision was carried out based on suggestions and feedback from both media experts and subject-matter experts in their respective fields. The improvement of the supplementary teaching material design aimed to address deficiencies in the teaching materials. Media design revisions were conducted twice using different media validators, as several aspects of the book design did not comply with established standards for textbook development. Meanwhile, material revisions were carried out only once because the

improvements required only minor adjustments. The revisions provided by the validators improved the design, making it better and more valid than before, so that it can be used in the learning process, as shown in Table 8.

Table 8. Supplementary teaching material revisions

Suggested Improvement		**Follow-up Action**	
Change the color and capitalize the initial letters		The color has been changed and the initial letters have been capitalized	
Add information related to obesity and existing research findings		Information on obesity and existing research findings has been added	
Add images to the digestive mechanism section.		Images have been added to the digestive mechanism section	

Small-Scale Trial

The small-scale trial in this study aimed to determine whether the teaching material on the digestive system was feasible for use. This trial was also used to improve the learning materials. In this study, the small-scale trial involved 24 students and a biology teacher who completed a questionnaire regarding their responses to the teaching material. The development of the test was guided by 10 scientific literacy indicators.

The readability data of the supplementary teaching material were obtained through assessments by both the teacher and students in the small-group trial, covering several aspects such as content, presentation, and level of difficulty. The results of the readability test of the supplementary teaching material are presented in Tables 9 and 10 in full.

Table 9. Teacher readability test

Aspect	**Average%**	**Description**
Material	100%	Very Feasible
Display	86.7%	Feasible
Ease Of Use	93.3%	Very Feasible
Overall	**93.3%**	**Very Feasible**

The results of the readability test of the supplementary teaching material conducted by the teacher show that, overall, the teaching material has a high level of readability. The teacher's average assessment across the aspects of content, presentation, and ease of use ranged from 86.7% to 100%. This indicates that the developed supplementary teaching material has met good standards and is easy to understand for users.

Tabel 10. Student readability test

Aspect	Average%	Description
Material	93%	Very Feasible
Display	87.8%	Very Feasible
Ease of Use	93.3%	Very Feasible
Overall	**91.4%**	**Very Feasible**

Meanwhile, the results of the readability test of the supplementary teaching material conducted by students show that, overall, the material has a very high level of readability, with average scores ranging from 86% to 98%. The supplementary teaching material is considered suitable for implementation in terms of content, presentation, and ease of use. The detailed readability scores from the students are presented below.

Product Revision

The small-scale trial results showed positive responses from both students and teachers toward the research-based supplementary teaching material on the digestive system. Questionnaire findings indicated agreement on its content, presentation, and usefulness, so no revisions were needed and the material was deemed suitable for use in learning.

Large-Scale Trial

The large-scale trial in this study resulted in a product that had undergone revision based on feedback from field testing. At this stage, the learning media had been validated, tested, and considered feasible for use as an instructional medium. The final product was refined after the completion of the field trial.

The effectiveness of the supplementary teaching material was analyzed to determine the extent to which its implementation produced better outcomes in the experimental class compared to the control class, which only used textbooks. The measurement of effectiveness was conducted through N-gain calculation, analysis of learning mastery (KKTP), and statistical testing using the t-test to examine the significance of differences. These results are necessary to identify the role of PBL-based supplementary teaching materials in improving students' scientific literacy and health-caring attitudes (Sadler, T. D., & Dennis L. Zeidler, 2005).

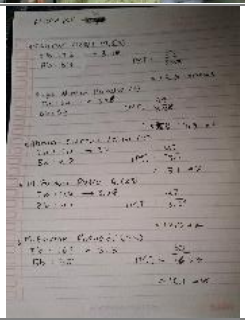
The implementation of the supplementary teaching material in the experimental class was carried out using the Problem-Based Learning (PBL) model as a guide for the learning process (Dochy et al., 2003; Aydin & Aytekin, 2018). The PBL model used in this study has

been shown to increase student engagement in learning. However, its effectiveness is highly influenced by the quality of the problems presented and students' initial readiness in understanding basic concepts (Savery, 2006; Loyens et al., 2015).

The supplementary teaching material was implemented over five meetings, where each meeting could include one or more stages of the PBL syntax according to the learning needs. Each stage in the PBL syntax has specific outcomes that are carried out systematically and are mutually supportive. A more detailed explanation of the results of the implementation of the supplementary teaching material through PBL is presented in Table 11.

Table 11. Description of the implementation activities of the supplementary teaching material

Meeting	PBL Stage	Activity Description	Output Form
Meeting 1	Problem Identification	Students were presented with an ill-structured problem related to obesity and digestive health through guiding questions and contextual case scenarios. For example, students analyzed a case describing an adolescent with obesity who experienced digestive disorders and were asked to identify possible causes, consequences, and preventive measures based on scientific evidence. Through group discussions, students identified the main problem, formulated research questions, and determined the focus of their investigation. This activity encouraged students to connect digestive system concepts with real-world health issues and develop evidence-based reasoning skills.	
Meeting 2	Information Gathering	Students read materials on digestive organs, digestive mechanisms, and causes of obesity presented in the supplementary teaching material. They explore the causes and effects of the phenomenon.	

Meeting	PBL Stage	Activity Description	Output Form
Meeting 3	Analysis and Solution Development	Students analyze data from the Research Results section—cholesterol tables, triglycerides, visceral fat weight graphs—to connect biological concepts with health conditions.	 BAB 4 Hasil Riset A. Langkah-Langkah Penelitian Riset terkait analisis profil lipid pada model tikus obesitas dengan induksi ekstrak kulit rambutan dilaksanakan di Laboratorium Biologi Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Negeri Semarang (FMIPA UNNES) dan Laboratorium Kesehatan Provinsi Jawa Tengah dengan menggunakan sampel sebanyak 25 ekor tikus putih jantan galur wistar (Rattus norvegicus) yang berumur 2-3 bulan dengan berat badan 150-200 gram. Tikus yang digunakan dalam kondisi sehat, normal dan tidak memiliki kelainan. Tikus dibagi menjadi 5 kelompok, masing-masing kelompok terdiri dari 5 ekor. Kelompok percobaan tersebut meliputi kelompok kontrol normal, kelompok kontrol obesitas, dan 3 kelompok perlakuan dengan perbedaan dosis pemberian ekstrak kulit rambutan (15 mg/KgBB, 30mg/KgBB, dan 60mg/KgBB). Variabel yang diamati yaitu kadar trigliserida dan kolesterol total sebagai variabel utama serta bobot lemak visceral tikus sebagai variabel pendukung. Dalam percobaan ini digunakan alat dan bahan antara lain serangkat kandang tikus lengkap dengan tempat minumnya, oven, food processor, neraca analitik, saringan, gelas ukur, gelas beaker, rotary evaporator/oven, batang pengaduk spatula, sarung tangan, sonde tikus, seperangkat alat bedah hematokrit, microtube 5cc, sentrifuge merk seiliger, mikropipet dan tip. 46
Meeting 4	Group Discussion / Solution Evaluation	Students conduct group discussions to compare analysis results and proposed solutions between groups, and relate them to book content (research and theory).	
Meeting 5	Reflection & Action	Students calculate BMI using the format in the book (hal. 58–59), reflect on their lifestyle, and develop a personal health-caring action plan.	

In the control class, learning was conducted using textbooks with a Problem-Based Learning model supported by discussion worksheets. At the end of the lesson, students were divided into several groups to discuss simple examples of digestive health actions and the application of healthy lifestyle practices in daily life (Sadler & Zeidler, 2005). This discussion guided them to formulate practical steps that could be taken, such as adopting nutritious eating habits and monitoring body weight.

However, because the textbook did not provide in-depth discussion on obesity, activities in the control class tended to be limited without the support of specialized materials such as those available in the supplementary teaching material. An example of student implementation can be seen in Figure 3.

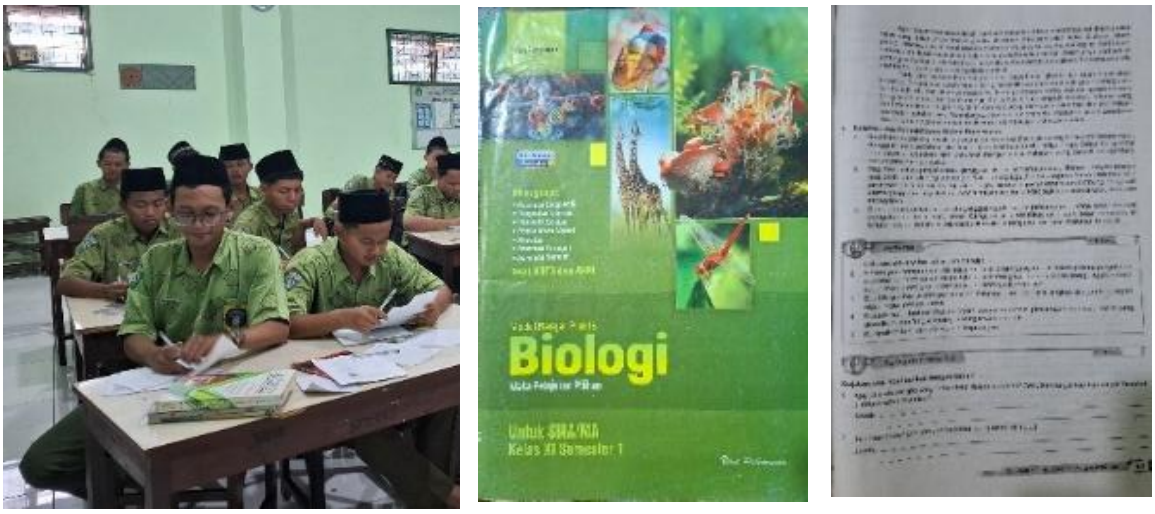


Figure 3. Student activities in the control class

The improvement in scientific literacy in both the experimental and control classes is evident from the analysis results after the implementation of the supplementary teaching materials. Students who completed the initial questionnaire showed differences in scores compared to the final questionnaire after participating in learning in the experimental and control classes, as presented in Table 13.

Product Revision

Based on the results of the large-scale product trial, if both teachers and students respond that the product is engaging, it can be concluded that the development process has been completed, resulting in the final product.

Final Product

This study developed research-based supplementary teaching materials on the human digestive system for Grade XI Madrasah Aliyah. The materials integrate scientific research and obesity-related health issues, making them contextual and relevant to students' daily lives (Sugiyono, 2015).

The developed supplementary teaching material consists of an introduction, core content, colored illustrations, summaries, and research-based conceptual reinforcement. The visual presentation and the use of simple and easily understandable language are intended to facilitate students' understanding of digestive system concepts in an engaging way. The inclusion of illustrations and health-related contexts is expected to increase student engagement in the learning process, as contextual teaching materials play an important role in fostering scientific literacy (Yuliati, 2017; Cimer, 2012).

The feasibility of the supplementary teaching material was determined through validation by subject-matter experts and media experts. The validation results indicated that the material was categorized as suitable for use after several revisions were made based on

the validators' suggestions. These revisions mainly focused on improving language clarity and layout design to ensure that the material is more communicative and easier for students to understand (Sugiyono, 2016).

These findings show that the supplementary teaching material meets high-quality criteria, including curriculum alignment, clear presentation, and effective visual design, in line with studies highlighting the role of expert validation in ensuring educational quality.

Table 12. T-test results of scientific literacy

		Independent Sampel Test				
		F	**Sig.**	**t**	**df**	**Sig.(-tailed)**
Scientific Literacy	Equal Variances assumed	0.757	0.387	4.151	65	0.000
	Equal variances not assumed			4.136	60.603	0.000

Based on the above test results, a significant value (Sig. 2-tailed) of 0.000 was obtained with a degree of freedom (df) of 65. This significance value is below 0.05, indicating that there is a statistically significant difference between the two groups. In other words, the use of supplementary teaching materials has a significant effect on improving students' scientific literacy compared to the learning method used in the control group.

This is also supported by the results of the t-test analysis of students' health-caring attitudes in Table 13, which shows the results of the t-test on health-caring attitudes between the control group and the experimental group that received learning using supplementary teaching materials on the digestive system topic.

Table 13. T-test results of health awarness

		Independent Sampel Test				
		F	**Sig.**	**t**	**df**	**Sig.(-tailed)**
Health-Caring Attitudes	Equal Variances assumed	0.017	0.896	5.010	65	0.000
	Equal variances not assumed			5.015	64.962	0.000

Based on these test results, a significance value (Sig. 2-tailed) of 0.000 was obtained with a degree of freedom (df) of 65. This significance value is lower than 0.05, indicating that there is a statistically significant difference between the two groups. In other words, the use of supplementary teaching materials has a significant effect on improving students' health-caring attitudes compared to the learning method used in the control group.

The effectiveness of the supplementary teaching material was further tested through a field study using a pretest–posttest control group design. The results of the analysis showed

an improvement in students' scientific literacy and health-caring attitudes in the experimental group that used the research-based supplementary teaching materials compared to the control group, as presented in Table 14.

Table 14. Comparison of the improvement in scientific literacy and health-caring attitudes

Variable	Group	Pretest	Posttest	N-Gain
Scientific literacy	Experimental	62	83	0,5
	Control	59	64	0.1
Health-caring attitude	Experimental	79	89	0.3
	Control	67	74	0.1

Students' learning improvement was analyzed using N-gain analysis. The results showed that the experimental group achieved a medium to high level of improvement, while the control group showed a low to medium level of improvement. These findings indicate that research-based supplementary teaching materials are effective in improving the quality of Biology learning (Richard Hake, 1999).

The findings of this study indicate that the use of research-based supplementary teaching materials significantly improves students' scientific literacy and health-caring attitudes compared to conventional learning materials. The experimental group achieved a moderate increase in scientific literacy (N-gain = 0.5), while the control group only reached a low level of improvement (N-gain = 0.1). An N-gain value of 0.5 in the medium category suggests that the research-based supplementary material is quite effective in improving scientific literacy. However, to achieve a high category, more intensive and continuous learning involving repeated scientific inquiry activities is required (Richard Hake, 1999; Cindy E. Hmelo-Silver, 2004).

Similarly, students' health-caring attitudes increased more substantially in the experimental group (N-gain = 0.3) than in the control group (N-gain = 0.1). The improvement in health-caring attitudes, which falls within the low to medium category, indicates that attitude change is not only influenced by classroom learning but also by external factors such as family environment, lifestyle habits, and social influences (Nutbeam, 2008; Dudley et al., 2015).

Nevertheless, the interpretation of the improvement in health-caring attitudes should be approached with caution. The pretest results revealed a notable difference between the experimental group (79) and the control group (67) prior to the intervention. This finding indicates that the two groups were not fully equivalent in terms of their initial health-caring attitudes. Therefore, the higher posttest score and N-gain achieved by the experimental group may have been influenced not only by the implementation of the research-based supplementary teaching materials but also by the students' pre-existing attitudes. In other words, the initial difference may have acted as a confounding variable that affected the post-

intervention outcomes. Consequently, the positive effect of the developed materials on health-caring attitudes should be interpreted carefully. Future studies are recommended to use groups with more comparable baseline characteristics or to apply statistical controls, such as ANCOVA, to minimize the influence of initial differences between groups.

These results show that integrating scientific research and contextual health issues, such as obesity, helps students understand biological concepts while promoting healthy lifestyle awareness (Manganello, 2008). The findings align with studies highlighting that contextual and inquiry-based materials improve scientific literacy by enabling students to identify issues, explain phenomena, and use evidence (Yuliati, 2017; Gormally et al., 2012).

Likewise, Holbrook and Rannikmäe (2009) and McBride et al. (2013) emphasize that real-world relevance in science learning enhances students' ability to apply scientific knowledge in everyday life. In addition, the improvement in students' health-caring attitudes found in this study is in line with research highlighting the role of health-related contexts in Biology learning. According to Nutbeam (2008), integrating health education into science learning can increase students' awareness of healthy behaviors and strengthen their ability to make appropriate health decisions. Contextual health issues such as obesity provide meaningful learning experiences because students can directly connect biological concepts with their personal lives.

Compared with previous studies that mainly focused on improving cognitive learning outcomes or conceptual understanding, this research contributes by simultaneously examining scientific literacy and health-caring attitudes as integrated learning outcomes. This approach is highly relevant in Biology education, where understanding scientific concepts should also promote responsible health behaviors. By integrating research findings and current health issues into supplementary teaching materials, the developed product supports a more holistic learning process that combines knowledge, scientific reasoning, and health awareness (Gormally et al., 2012; Cimer, 2012).

The findings indicate that the research-based supplementary teaching materials contributed not only to students' conceptual understanding but also to the development of scientific literacy and health-caring attitudes. The improvement in scientific literacy can be attributed to the integration of research findings, obesity-related case studies, and data interpretation activities that required students to identify scientific issues, explain phenomena scientifically, and use scientific evidence in decision-making. These activities provided opportunities for students to apply biological concepts to authentic health contexts rather than merely memorizing factual information. Furthermore, the inclusion of BMI calculation activities, obesity prevention strategies, and personal health action plans encouraged students to reflect on their own health behaviors, thereby supporting the development of health-caring attitudes. The contextual nature of the teaching materials helped students connect digestive system concepts with everyday health issues, making learning more meaningful and relevant.

Therefore, the developed supplementary teaching materials can be considered feasible and effective in promoting both scientific literacy and health-caring attitudes among students.

This study shows that research-based supplementary teaching materials not only enhance conceptual understanding but also foster scientific literacy and health-caring attitudes. Integrating research findings and health issues helps students connect digestive system concepts with real-life contexts, supporting both understanding and awareness of personal and public health (Yuliati, 2017; Fives et al., 2014). Overall, the developed supplementary teaching materials were found to be feasible and effective in improving students' scientific literacy. The materials also showed positive potential in enhancing students' health-caring attitudes. These findings are consistent with Sugiyono's (2015) view that educational products should be valid, practical, and effective.

CONCLUSION

This study developed research-based supplementary teaching materials on the human digestive system designed to support Biology learning for Grade XI Madrasah Aliyah students. Expert validation results indicated that the developed materials were feasible for use after minor revisions. Furthermore, field testing showed that the supplementary teaching materials were effective in improving students' scientific literacy compared to conventional instructional materials, as indicated by higher N-gain scores in the experimental group. The integration of scientific research findings and contextual health issues, particularly obesity, enabled students to better connect biological concepts with real-life situations.

The developed materials also demonstrated positive potential in enhancing students' health-caring attitudes. However, the interpretation of this improvement should be made with caution because the experimental and control groups exhibited different baseline scores prior to the intervention. Therefore, the observed differences in health-caring attitudes cannot be attributed solely to the implementation of the developed supplementary teaching materials. Future studies are recommended to involve groups with more comparable initial conditions or apply statistical controls to further examine the effectiveness of the materials in improving students' health-caring attitudes. Overall, the developed supplementary teaching materials can serve as an effective supporting resource for Biology learning to enhance scientific literacy and promote students' awareness of healthy lifestyles.

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