



Book of insects' immune system: development and implementation with pbl in increasing students' learning outcome

Dina Maulina^{1*}, Median Agus Priadi¹, Dewi Lengkana¹, Tri Jalmo¹, Ave Suakanila Fauzisar², Mohamad Amin³

¹ Biology Education, Faculty of Teacher Training and Education, Universitas Lampung, Indonesia

² Environment, Fenner School of Environment and Society, Australian National University, Australia

³ Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia

*Corresponding author: dina.maulina@fkip.unila.ac.id

ARTICLE INFO

Article history

Received: 5 March 2020

Revised: 2 May 2020

Accepted: 6 May 2020

Keywords:

Animal physiology

ADDIE

Development book

Insect immune system

Research-based learning



ABSTRACT

The purpose of this research was to develop a research-based reference book and applied it through the problem-based learning (PBL) using reference books in learning activities. The method for the reference book used the ADDIE development models. The reference book's effectiveness test results were conducted using a purposive sampling technique, with a total sample of 55 students and analyzed by t-test. The research results showed that the reference books of the development results were validated by media experts and material experts. The integration of the development of reference books in learning activities has an impact on increasing student understanding as demonstrated through the pre-test and post-test scores that differ significantly with $t\text{-value} > t\text{-table}$ ($4.149 > 2.045$) at $p < 0.05$. Therefore, the development of the insect's immune system book with the PBL model increase the student learning outcomes significantly. Also, this research has been able to improve students' ability and competence in solving problems in insects' immune system subject matter.

© 2020 Universitas Negeri Jakarta. This is an open-access article under the CC-BY license (<https://creativecommons.org/licenses/by/4.0>)

Maulina, D., Priadi, M. A., Lengkana, D., Jalmo, T., Fauzisar, A. S., & Amin, M. (2020). Book of insects' immune system: development and implementation with pbl in increasing students' learning outcome. *Biosfer: Jurnal Pendidikan Biologi*, 13(1), 42-58. <https://doi.org/10.21009/biosferjpb.v13n1.42-58>



INTRODUCTION

Educational problems that are developing nowadays include complex educational issues (Lewis, 2015). The root of the educational issues is also not far from the problem of student awareness in learning, understanding the importance of the concepts being learned, and how educators teach the learning process in the right way (Harlen, 2002; Sudarisman, 2015). The development of various models and methods of learning, learning media, evaluation techniques, and curriculum improvements continue to be made to deal with learning problems (Fajariningtyas, Akbar, & Herowati, 2019; Taufik et al., 2010). This is done to achieve learning outcomes for students following the objectives of education, especially in Indonesia.

Contextual learning could be achieved through a learning process adapted to the demands of the ability to solve problems in the realm of expertise (Park et al., 2012; Rindah, Dwiastuti, & Rinanto, 2019). The problem of education is often encountered in the learning process. In the classroom of science, educators can contextualize learning material into learning content that is easy to understand (Maulina, 2016). Learning science, especially biology, the truth lies in empirical evidence. Therefore, observation becomes one of the alternatives to understand, prove, and uncover biological facts. Learning through observation does not only come from references, but students are trained to observe any changes in their surroundings. The learning process will determine the learning outcomes (Miharja, Hindun, & Fauzi, 2019; Tauhid et al., 2014). One of the factors causing the low learning outcomes and student understanding occurs because it does not develop the appropriate learning characteristics (Ostrow et al., 2017). Science, especially biology as a life-science of learning, is carried out by contextualizing material content (Amin, 2016).

Animal physiology as a branch of biology concerns on the physiology process in organisms gradually and continuously requires a process of contextualization in learning activities (Rubiah, 2016). The insect immune system is part of the topic of study in the Animal Physiology group. Insect immune system learning material is a complex learning material with the scope of the field of study in the area of primary scientific groups in biology learning. Insects have a particular form of self-defense which is different from other animals. The body of an insect has unique and exclusive properties, and its metabolism is different from other types of animals. The body's defense against various threats from pathogens and other foreign bodies has different characteristics and regulations.

The previous observations of the problem were the low student learning outcomes in the Animal Physiology course at the Faculty of Teacher Training and Education, Universitas Lampung, Indonesia. The data showed that in 2015/2016, the even semester showed that the results of studying Animal Physiology. The results showed that only 45% of students understood animal physiology material thoroughly with completeness standard more than 66. It showed that during the learning process in the Animal Physiology course in Biology Education Faculty of Teacher Training and Education, Universitas Lampung, Indonesia was not able to contextualize the material learning with real life. 72% of students have difficulty finding learning resources that have an impact on poor student understanding (Maulina et al., 2016).

The previous results of data through a limited survey showed that 82.7% of the immune system material in insects is the most challenging subject matter to student's understanding (Maulina, 2019). The effort to realize to increase students' understanding of the topic of insect immune system studies in Animal Physiology courses was carried out by conducting research experiments in the laboratory. However, adequate infrastructure and high costs are needed. The problem encountered was the comparison of the number of students and available facilities that were not balanced. Therefore, books become one of the media in learning activities (Johnson et al., 2014).

With the efforts of scientific development and integration in education, the development of research-based reference books needs to be done as a tool to understand contextual

phenomena in learning activities (Barroh et al., 2012; Amin, 2010). Textbooks is as a source of learning for the development of the academic culture of the academic community (Law No. 12 of 2012 Higher Education). The reference book is a book that containing real material presentation about research results that specifically can provide insight, understanding, knowledge for students about the concepts and solutions of various phenomena in the application of life (Muhlisin & Prajoko, 2019). The function and purpose of textbooks other than as a reference by students, as well as evaluation materials, teaching aids in implementing the curriculum, one of the determinants of teaching methods or techniques that educators use (Imran, 2014). One way to contextualize learning requires a thorough understanding so that it takes a form of learning and learning experiences for students in real life.

Books about defense mechanisms in insects currently available are limited to the scope of knowledge without being accompanied by facts and observational evidence. The results of research and data acquisition techniques regarding the immune system in insects need to be used as a basis of reference source of reference. Therefore, the solution to the use of learning media in the form of research-based reference books is essential to building background knowledge. Another fact which is still related to the need for teaching materials in learning activities that 73.73% of respondents stated; teaching materials in the form of reference books are needed to support student learning and understanding. As many as 53.33% of students reveal that the reference books used have not represented the results of the latest research results related to lecture material (Maulina & Amin, 2015). Supporting the results of other studies shows that the implementation of the development of innovative reference books can improve the character and student learning outcomes (Situmorang, 2013). Finally, the need for research-based reference books becomes an essential part in achieving meaningful learning outcomes (Park et al., 2014).

In line with the results of the integration of scientific fields in learning, the Minister of Research and Technology Regulation number 44 of 2015 in article 8 explains that the research results must be referred to in the learning material. Thus, research products provide significant benefits in the educational aspect through teaching materials based on research results. In order to be effective, the development of teaching materials is referenced to the needs of students (Astuti et al., 2016; Ali, & Arif, 2019).

In this case, the course in Animal Physiology with consideration of the facts of teaching material needs that have been revealed previously. The integration of scientific content in learning activities is contained in the subject of the insect immune system.

The integration of learning is carried out with models and learning methods appropriate to the development of the world of education (Kusumatuty et al., 2018). The educational paradigm currently applied is the development of the 21st-century learning era (Major, & Mulvihill, 2018; Kumar & Refaei, 2017). hence, it encourages to be able to think critically in choosing valid and relevant information, and able to innovate creatively, competent to work independently and in groups, be able to solve problems of daily life and have the knowledge base and deep understanding to become lifelong learners (Afandi & Sajidan, 2018). In Indonesia, this formulation is contained in the Law on National Education System No. 20 of 2003 article 3.

The 21st-century educational challenge of the digital 4.0 era explains that the approach to organize learning from various perspectives of science through multidisciplinary science becomes crucial that is needed right now (Hosnan, 2014; Amin, 2017). According to research simulations of real-world events, the application of everyday life problems that are dilemmatic or paradoxical has not been solved. Several examples of material can be easily absorbed by students (Merrit et al., 2017).

The immediate benefits of the multidisciplinary learning model are the acquisition of scientific concepts in daily application and mastery of several alternative solutions to problems

that can be implemented in real life (Afandi & Sajidan, 2018). Thus, this research has an impact on the role of education as a basis for knowledge in multidisciplinary science. It can build knowledge and awareness of students about scientific content and education (Arends, 2008).

Problem-based learning (PBL) is a learning approach that uses real-life problems as a context for students to learn about critical thinking and problem-solving skills and obtain essential knowledge and concepts from the subject matter (Barrett, 2017). Problem-based learning stimulates high-level thinking in problem-oriented situations, including learning how to learn (Astuti, et al., 2019; Chiang & Lee, 2016). Problem-based learning makes students become independent learners, meaning that when they learn, they can choose appropriate learning strategies (Babich, & Stankunas, 2016). Skillfully use these strategies to learn and be able to control their learning processes, and are motivated to complete their learning (Department of National Education, 2003).

The primary purpose of problem-based learning was to explore students' creativity in thinking and motivating students to continue learning (Pratama; 2018; Asyari et al., 2016). Problem-based learning is not designed to help teachers provide as much information as possible to students. However, it is developed to help students expand their thinking, problem-solving, and intellectual skills. Also, learn various adult roles through their involvement in real or simulated experiences and become an independent learner (Cullen & Jackson, 2018; Ibrahim, 2000). Therefore, problem-based learning is focused on student learning development, not to help teachers gather the information that will later be given to students during the learning process (Cindy, 2004; Cindy, 2007).

The integration of the reference books as one of the literacies in learning activities using the PBL model is expected to increase student understanding (Park et al., 2012; Hou, 2014). This study aims to develop research-based reference books on insect immune systems and improve students' learning outcome through PBL.

METHODS

This research consists of two stages of activities, namely the development and experimental research. Development research was conducted to develop a research-based reference book, which was then used as a reference book for learning activities in experimental research. The following was on the staged of the research study (Figure 1).

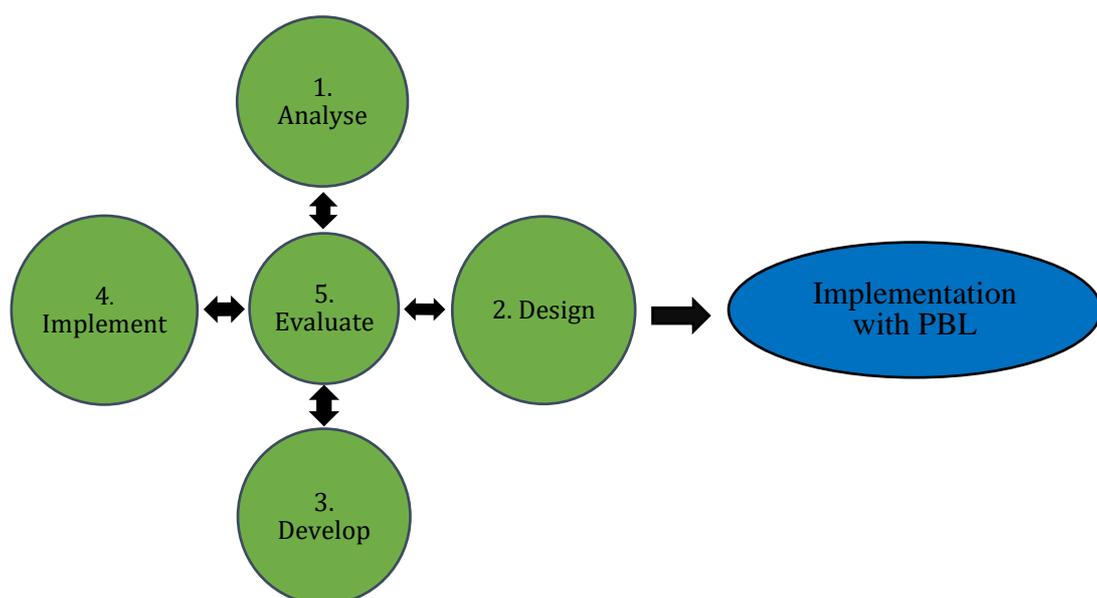


Figure 1. The Stage of Research Study

Development of Research-Based Reference Books

The book development stage uses the ADDIE development model (Branch, 2009). The steps for ADDIE development are carried out in the following stages.

The need analysis (Analysis)

This stage will be carried out an analysis of the needs of Biology Education students at Universitas Lampung. They have taken Animal Physiology courses on the use of reference books in the learning process and the weaknesses or strengths of reference books that have been used so far. By identifying the need for reference books in learning activities through the process of learning analytics, students can be tested to insect immune system material, interview lecturers and students, and provide feedback regarding the use of reference books in lecture activities through questionnaires.

The study was conducted at Universitas Lampung in March 2018, with Biology Education students from the Faculty of Teacher Training and Education, Universitas Lampung, who have taken Animal Physiology courses in the academic year 2016/2017 as a sample in the study. This research is survey research on the analysis of the need for reference books as learning media in Animal Physiology courses. Qualitative data were obtained from a survey of teaching material needs for students through observation during learning with a questionnaire for lecturers and students—the student response data obtained through questionnaires.

The results of the student questionnaire sheet applied with a Likert scale calculation with indicators have been developed regarding the availability of teaching materials in the form of reference books that have been used in learning activities and their needs for students during the learning process. The data obtained were analyzed descriptively as percentages so that the percentage of the class as a whole can be calculated using:

$$\text{Percentage (\%)} = \frac{\text{Total Score Acquired}}{\text{Maximum Score}} \times 100\%$$

The lecturer questionnaire had an open questionnaire that contains the development of learning and reference books during the learning process in Animal Physiology courses.

Book development design based on research findings (Design)

This stage created a draft model of a research-based reference book. From the research results, research materials will be developed into a reference book form. The design of the reference book design refers to the Directorate General of Research and Development Strengthening Ministry of Research, Technology and Higher Education, Indonesia where the reference books must have the following elements: (1) foreword, (2) table of contents, (3) the body divided into chapters (4) bibliography and (5) glossary. The manuscript would be typed using the specific font.

Preparation of research-based reference books (Develop)

The development phase was carried out by undergoing the process of compiling and typing the material and design following the draft. During the development phase of the reference book, a revision is made. Either from the author or the supervisor.

Reference books that have been revised and declared appropriate based on the validation of media experts and material experts. The book evaluation component was carried out using an assessment instrument by the media expert. Specifications for assessment in the form of the book appropriateness in display and legibility were developed from National Education Standards Agency (2014) and modified according to research objectives.

Quantitative data were analyzed in the form of a questionnaire assessment score from the validator. Qualitative data were in the form of responses and suggestions provided by the validator. The compiled book was declared to be suitable for use if the questionnaire scores

were either excellent or very good. The data analysis technique used in analyzing quantitative data in the form of an assessment questionnaire score is to calculate the answer value using the following formula. The assessment score results determine the eligibility criteria of the reference book, which can be reviewed from the assessment in [Table 1](#).

$$\text{Final Score} = \frac{\text{Total Score Acquired}}{\text{Maximum Score}} \times 100$$

Table 1

Criteria of validity data of validator questionnaire assessment

Score	Qualification	Note
80 – 100	Excellent	No need to revise
70 – 79	Good	No need to revise
60-69	Fair	Revision needed
50-59	Deficient	Revision needed
<50	Fail	Revision needed

(source: assessment category aspect from NESAs, 2014)

Implement

This stage tests the effectiveness and practicality of reference book products in a small group of product users. The practicality and feasibility tests for books were obtained through questionnaire sheets. The implementation stage was carried out in the Animal Physiology course at the Universitas Lampung in May 2018 with samples of correspondence of 30 students.

Evaluate product results (Evaluate)

The development of ADDIE at the evaluation stage is cyclic, which means that evaluating can be done at the end of each of the previous stages; thus, evaluating is flexible. Evaluate is in charge of improving and reviewing success at each stage to produce reference book products in this Animal Physiology course.

The evaluation stage has a role in evaluating the reference books that have been developed, the evaluation of reference books includes the feasibility of books based on the evaluation of the validation of reference books by the validator of material experts and media experts. The results of the assessment of reference books by supporting lecturers, the results of questionnaire responses of reference books by students by filling out questionnaire sheets.

Implementation of book-product to the target users with PBL

The reference book's effectiveness test results were analyzed for the cognitive value of pre-test and post-test using paired t-test using SPSS 20.0 statistical test. At this stage, a qualitative calculation was used, which aims to analyze the effect of the use of reference books based on student research through learning Problem-Based Learning by using reference books as literature in learning activities. This research was conducted in October 2018 with four face-to-face lessons. This research was conducted on the subject matter (material topic) of the insect immune system in the invertebrate class.

Implementation of Problem-based Learning in the experimental class was carried out with the stages of learning activities (Barrows, 1986; Barrows 1998; Barret, 2005) through stages: (1) students are oriented towards the problem presentation, (2) students formulate and analyze problems with hypotheses, (3) students conduct a literature study, (4) Organize ideas systematically and analyzed, (5) percentage of analytical results and synthesis of problems, and (6) evaluate the results of the presentation of the problem-solving process and reflection on learning outcomes.

In conventional classes learning activities were carried out through practical learning

activities through the stages of explaining the purpose of learning, a description of the theory, tools, and work materials, work procedures, and the percentage of practical results. In this study, Respondents were biology education students who took the Animal Physiology course in the sixth semester of the academic year 2017/2018 in the Universitas Lampung, Indonesia. The sample consisted of 55 students who were obtained through purposive sampling techniques. The research design used was a pre-experiment, pre-test & post-test design control group (Creswell, 2019) with the scoring technique obtained by measuring the N-Gain value.

The research instrument consisted of 20 items that had been validated by material experts and tested on students who were not research samples. The questions consisted of multiple problem-based choice questions with answer choices consisting of 5 choices (A, B, C, D, and E). Validity and reliability tests were determined based on the results of the trials on 25 biology teacher candidates who were not research samples.

The reliability test results with Crocbachs Alpha showed a result of 0.847. The research data were tested statistically by using ANOVA, which aims to explain the difference between more than two groups of samples with a significance level of 5% ($p < 0.05$) (Mertler, & Reinhart, 2016). The data obtained were first tested on the prerequisite of the analysis, including the Kolmogorov-Smirnov normality test and homogeneity of variance using the Levenes-Test. All data testing was done by using the SPSS program version 22.0 for windows.

RESULTS AND DISCUSSION

The analysis stage was a crucial part of the process of developing reference books. Students need books and subject matter of development as a result of research form the basis of developing books. This stage is obtained from my field observations in the Department of Biology Education, Universitas Lampung in Animal Physiology lectures. The background to the development of books is based on the availability and use of existing learning resources. Besides, the subject matter of Animal Physiology lectures, which are considered confusing, is the primary key in making reference books. Data collection was taken through questionnaire sheets and interviewed with lecturers and students. The following is a representation of the preliminary analysis results presented in Table 2, Table 3, Figures 2, and Figures 3.

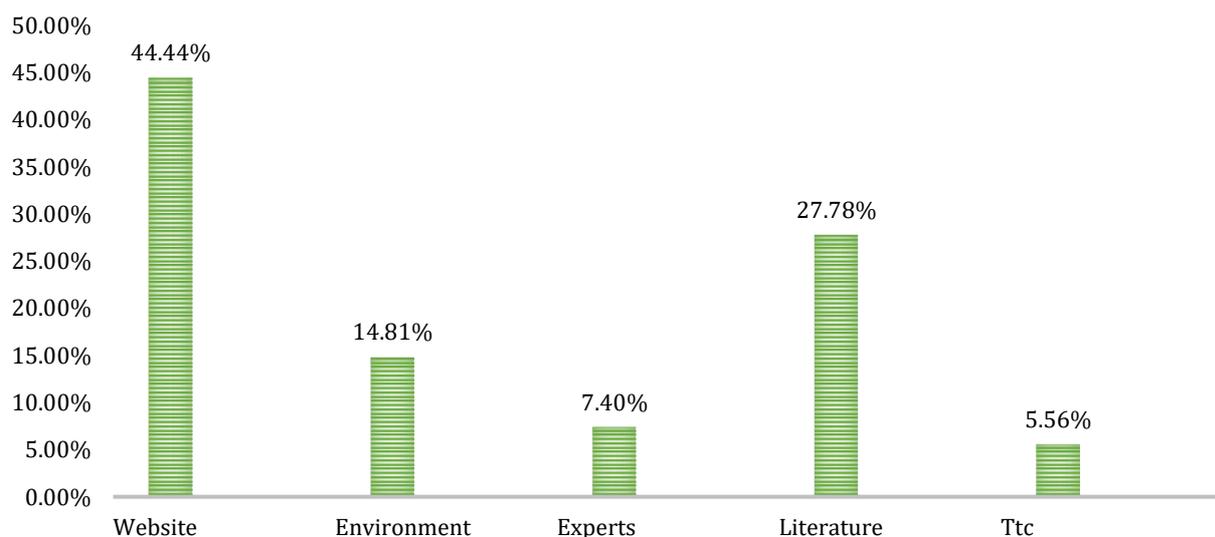


Figure 2. The use of learning resources in lectures

The needs analysis shows that the use of learning resources in lecture activities from 54 student correspondents shows that 44.44% of learning outcomes are taken from the website and 27.78% from various literature books (figure 2). The high use of websites as a learning

reference has both positive and negative impacts. On the positive side, technological advances open up broad insights and make it easier for students to reach an understanding of various learning difficulties. However, in other cases, the use of the website needs attention from the source of truth. Technology makes learning activities easy and facilitated, but the important thing is the accuracy of the source of the website that is being referred to cannot be trusted yet.

The results show that the lecturer gives literature books to students who are the primary reference during animal physiology lectures. As many as 27.78% of students use books as learning resources. Unlike the website, students believe that books have a high degree of authenticity and originality. However, the presentation of reference books that are currently used in the class has not been widely referred to as the latest research on learning material. Therefore, so far, the use of books is not optimal for meeting learning needs.

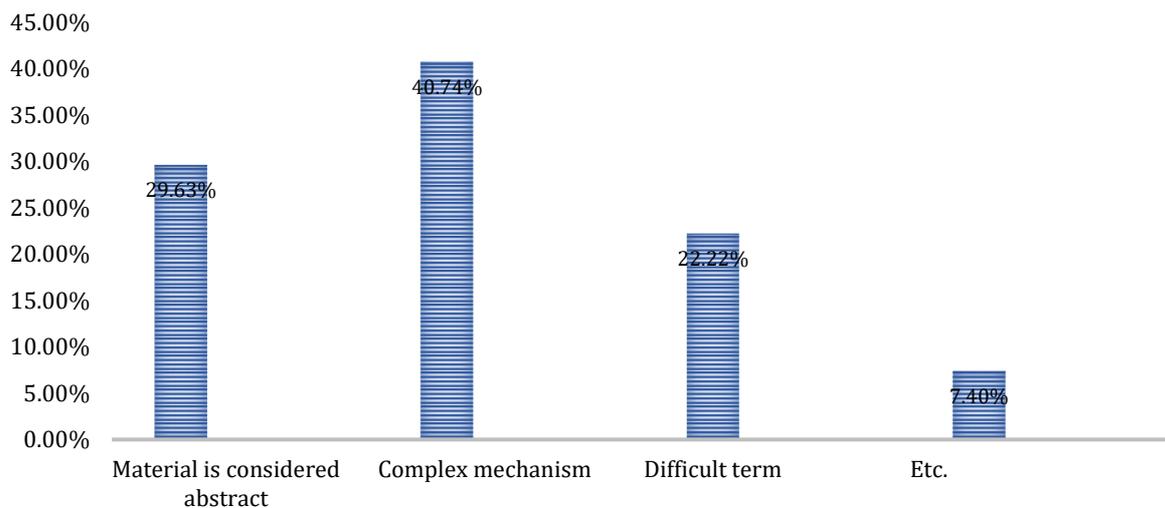


Figure 3. Criteria for the difficulty of the immune system's primary matter in insects

The explanation of reasons students consider immune system material is complicated in [Figure 3](#). This indicator is the criteria in the results of the answers 29.63% of student respondents who consider immunity in insects is considered abstract. Abstract, as explained, is the subject matter that cannot be seen and clearly described. Accordingly, 40.74% of respondents gave the reason that immunity in insects involves various processes of action and reactions from the body's systems so that the process is considered complex and challenging. Another related problem is the use of tricky terms that cause students have difficulty in understanding the contents of the material. As many as 22.22% of student respondents expressed their difficulties in using terms that were not accompanied by image/visualization. Therefore it is necessary to provide a reference book as an ingredient for the enrichment of the immune system in low-level animals in the class of insects in particular.

Table 2.

The need for reference books in lecture activities

No.	Indicator	Percentage
1	The need for reference books in the learning process	73,73%
2	Representation of current research results related to the material	53,33%
3	Reference books become the source of learning in overcoming difficulties in understanding material	30,23%

(source: Assessment Category Aspect from NESAs, 2014)

[Table 2](#) presents the benefits and needs of reference books for students in understanding the material. Animal Physiology Lectures 73.73% of students need a reference book as a

reference and source of the material. The reference book that will be created aims to facilitate students in understanding learning material and can be used to repeat lessons that have been learned or are intended to learn new material (Harlen, 2002).

Reference books are used as a reference for learning resources for students. However, the data shows that 53.33% of the correspondents said the existing reference books did not present various phenomena or research results related to the content of learning material. It indicates that the existing reference books have not linked learning with current issues. Thus, based on the results of the needs analysis above the development of reference books on the subject matter of the insect immune system.

The design of this research-based reference book showed in [Figure 4](#). The details of the book section consisting of the fourth main chapters are as follows: Chapter I describes the insects in general and overall that begins with the morphology of insects and the life cycle that occurs. Insects for most people are known as destructive animals that hurt life. However, in chapter II, it is explained that insects have benefits and roles for the ecosystem and specifically for humans and other organisms on earth. It is explained that evolutionary development states that insects are the oldest group of animals that are still capable and survive. Therefore, insects have high adaptability. Insects are often used as objects in research in terms of regulation and metabolism that occurs in the body which are capable of quickly producing and compounds or substances to maintain itself a bag of foreign substances that are in his body.

Insect defense mechanisms are generally explained at the end of chapter II. The aim is that the reader's understanding could be focused on the immunity reactions that occur in the body of the insect. Therefore, the insect's defense mechanism is explained therein. This section has included color pictures that support the written description to help the reader understand the context of the contents of the description. The end of chapter II explains how the immune system is divided into insects. Therefore in the second chapter, it is explained the mechanism of the immune system humoral directly. The third part of the book is to explain the cellular immune system. The role of cellular response in eliminating various pathogens is significant when entering the body of an insect. The coordination of hemocyte cells is able to do self-defense so that the insect's body can stay alive-explained therein. The fourth chapter of the book explains the humoral immune response mechanism. In particular, insects obtain defenses derived from their parents (innate immunity) humoral and cellular. That is conveyed in the second part of the chapter, and the humoral response is explained and supported by methods and data from the results of laboratory research.

This section also includes illustrations and tables to ease to ease the readers to understand, the image of tools, and an explanation of how to use tools to test humoral defense reactions. The presentation of images from laboratory equipment and the procedures for their use enriches the readers. It presents results from laboratory studies that have been carried out. Therefore, it attracts the readers' curiosity about the book's contents on immune system material that occurs in insects specifically. The results of this research-based book development product are validated against the standard of visual and content feasibility by the validator of media experts and material experts, as stated in [Tables 3](#) and [4](#).

The appraisal of the book's appropriateness subsequently served as material for evaluation and improvement of the book's development. Based on the results of the assessment conducted by the validators, data obtained that the validity of the book visually obtained a feasibility assessment score of 74 out of the 80 maximum scores (92.50%). It means that the results of the development of the book obtained outstanding criteria. The forms of advice from media experts on the design of the contents of the book, which include: writing procedures, letters size, the distance between paragraphs, and writing on the description of the picture. Besides, the results of the content validation gave a score of 47 out of 56 scores for the maximum value of the content assessment (83.92%), which meant obtaining excellent criteria.

Table 3.

The results of the validation of media experts

No.	Assessment of Category Aspects	Score	Category	Test Decision
1.	Book's size component	100,00	Very Valid	No need to revise
2.	Book's cover design component	100,00	Very Valid	No need to revise
3.	Book's content design component	95,54	Very Valid	Revise as necessary

(source: assessment category aspect from NESAs, 2014)

Validation assessment scores from experts are listed in Tables 3 and 4. These results provide recommendations for improving the book, especially on the component presentation of the material's contents. Several parts of the book, specifically the pictures and captions, need to be revised to be understood by the reader. Furthermore, some theoretical study results sourced from books, journal articles, or other scientific research results need to be adjusted and reviewed.

Table 4

Validation result from experts

No.	Assessment of Category Aspects	Score	Category	Test Decision
1.	Appropriateness content component	90,00	Very Valid	Revise as necessary
2.	Presentation component	75,83	Valid	Revise
3.	Language component	100,00	Very Valid	No need to revise

(source: assessment category aspect from NESAs, 2014)

The book evaluation aspect of the user is reviewed in terms of practicality of the book, which includes language, readability, presentation, appearance, and benefits. According to Table 5, all aspects of the assessment of research-based insect immune system reference books are appropriate to use. The following is a representation of the assessment by book users. The book product's linguistic aspect has a score of 91.83, which means the book can be understood and read by the reader.

Table 5.

Evaluation aspect of reference books by users

No.	Assessment of Category Aspects	Score	Test Decision
1.	Language	91,83	Very reliable to use
2.	Readability	87,50	Very reliable to use
3.	Presentation	92,71	Very reliable to use
4.	Layout	87,83	Very reliable to use
5.	Benefits	96,04	Very reliable to use

(source: assessment category aspect from NESAs, 2014)

The results show that this reference book is interesting for students in terms of presentation and appearance. Present pictures and information on the subject matter of the immune system are contained therein. This reference book provides a benefit value of 96.04% of students saying this book provides use value as a source of learning on the subject matter of the insect's immune system.

This reference book was designed per the subject matter of the insect's immune system, which consists of four main sub-chapters; introduction, insect, humoral defense, and cellular defense. The fifth division of this chapter is based on a preliminary analysis of the subject matter of the immune system in insects in animal physiology courses. This reference book is declared worthy of using it by providing information to readers regarding the regulations that occur in insects' bodies to survive and control the application of insect populations in a natural way. Book development with ADDIE models was the best design method (Peterson, 2003). The

development of books that are made referring to the needs analysis of the students would result from an impact on the suitability of achievement targets. This research was to the students' ability to solve problems (Wang & Hsu, 2009; Vaan-Rooij, 2010).

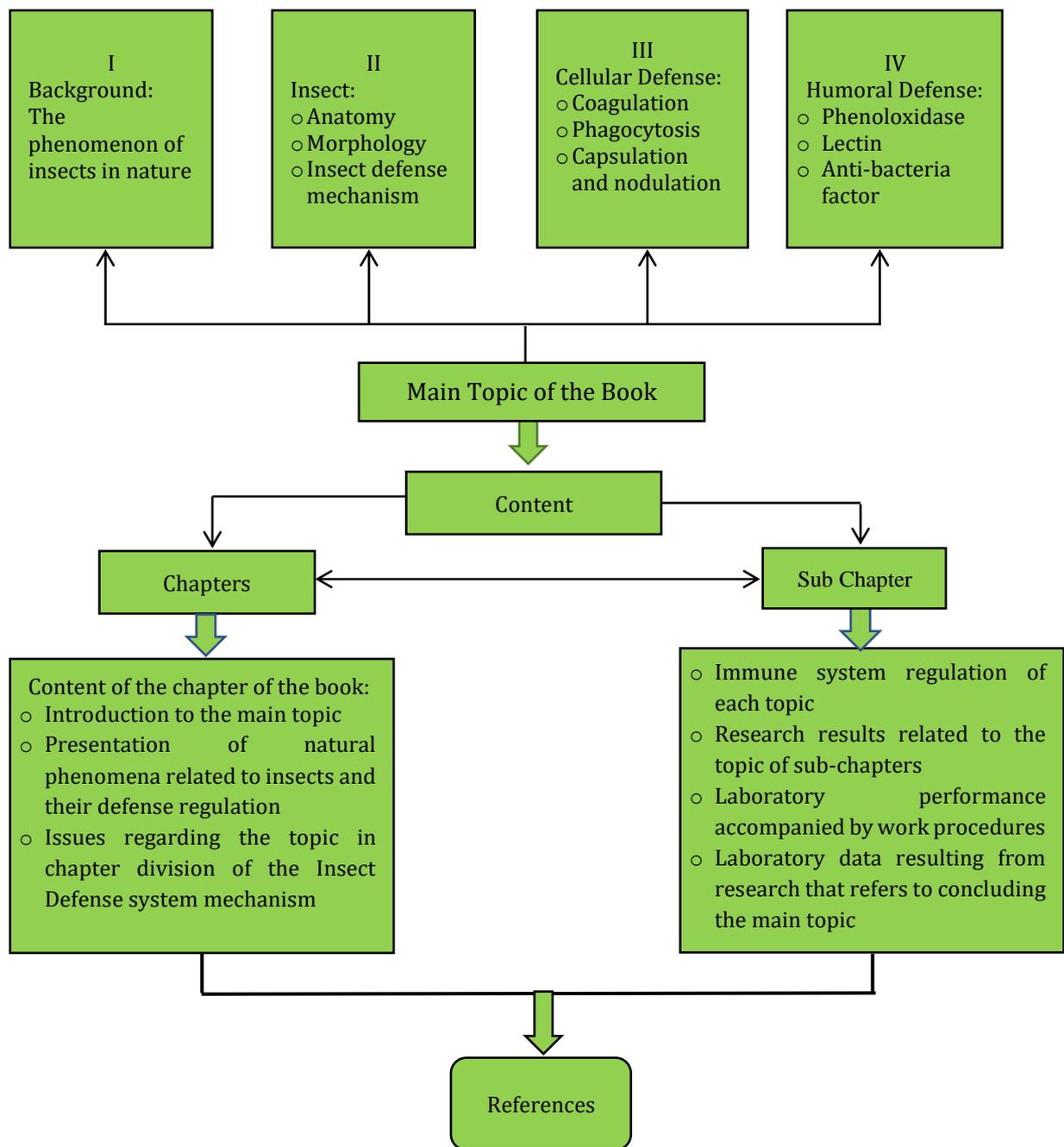


Figure 4. Material Mapping From Reference Books

The book's effectiveness can be seen in the pre-test and post-test results presented in Table 6. The reference book can increase cognitive understanding in students as much as 83.33. The learning process is carried out two times with the subject matter of invertebrate class animal defense systems, insects.

Table 6.

Representation of the significant value of pre-test and post-test in the group design class

Design sample	Paired Differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test - Post-test	16.50000	21.78065	3.97658	24.63303	8.36697	4.149	29	.000

Note: the increase in the value of pre-test and post-test is indicated by the value $t_{val} > t_{table}$ (4,149 > 2,045).

The students' initial understanding is shown by the average results of student pre-test scores of 41.67. The integration of the development of reference books in PBL-based learning activities results in increased student understanding, which is shown through the post-test score of 57.67. Representation of increased pre-test and post-test values can be seen in Figure 4. These results point to a significant difference with the value of $t_{val} > t_{table}$ (4.149 > 2.045) at the level of $p < 0.05$ seen in Table 5. The data shows that PBL has a significant role in student understanding (Minner et al., 2010). Learning holistically by observing and referencing appropriate learning resources helps improve learning outcomes (Timpany, 2009; Güneş & Kırmızı, 2014).

The integration of learning using research-based books and PBL produces a holistic form of learning that can enhance understanding and learning experiences (Usta & Güntepe, 2017; Korthagen, 2013). PBL builds an understanding of concepts, understanding the relationships between material concepts and connecting concepts, procedures, and applications in student-learning (Gijbels et al., 2005). Research-based reference books help students to understand how to develop concepts, connect concepts, and understand the application of immune system material to insects with the environment and real life.

CONCLUSION

Development of the reference books resulting from the development of research results contains scientific concepts about insects, causes of genetic damage, and human efforts to restore the role of the proud as an organism in the ecosystem. Integration of the development of reference books in learning activities using the PBL model has an impact on increasing student understanding as indicated through significantly different pre-test and post-test scores with values of $t_{hit} > t_{table}$ (4.149 > 2.045) at $p < 0.05$. The research-based reference book that has been developed has been adapted to students' needs by referring to learning achievements that contain scientific concepts about insects, causes of genetic damage, and human efforts to restore the role of insects as organisms in the ecosystem. In addition, this research has improved students' ability and competence in solving insect immune system subject matter problems.

ACKNOWLEDGMENT

The authors would like to thank DIPA Grant (No. 3301/UN26.13/PN.01.00.02/2019), Faculty of Teacher Training and Education, the Universitas Lampung, Indonesia which has provided funding for this research.

REFERENCES

- Afandi & Sajidan. (2018). *Stimulation of high order thinking skills concepts and their implementation in 21st-century learning*. Solo: Sebelas Maret University Press.
- Ali, A., & Arif, W. P. (2019). Development of guidance for laboratory practice of islamic science-

- integrated plant anatomy-physiology. *Biosfer: Jurnal Pendidikan Biologi*, 12(1), 70-82. Retrieved from <http://journal.unj.ac.id/unj/index.php/biosfer/article/view/10655>
- Amin, M. (2010) Implementation of research results in biology in learning. S. Widiarti (Eds.). *Proceedings of the national biology seminar* (pp. 12-18). Retrieved from <http://jurnal.fkip.uns.ac.id/index.php/prosbio/article/view/1202>
- Amin, M. (2016). biological development and learning challenges. R. Murtini (Eds.). *Proceedings of the national seminar on biology and science education*. (pp. 8-17) Solo, Indonesia: University of Muhammadiyah Surakarta.
- Amin, M. (2017). Aware of the profession of science teacher, aware of literacy: The challenge of teachers in the 21st century. A. Rahardjanto (Ed.), *Proceedings of the biology, learning, and environment interdisciplinary perspective* (pp. 9–20). Malang, Indonesia: University of Muhammadiyah Malang. Retrieved from <http://research-report.umm.ac.id/index.php/research-report/article/view/967/1337>
- Arends, R. (2008). *Learning to Teach*. Translator: Helly Prajitno & Sri Mulyani. New York: McGraw Hill Company.
- Astuti, T. A., Nurhayati, N., Ristanto, R. H., & Rusdi, R. (2019). Biology problem based learning on cognitive aspects: a meta-analysis. *JPBIO (Jurnal Pendidikan Biologi)*, 4(2), 67-74. <http://doi.org/10.31932/jpbio.v4i2.473>
- Astuti, D.P., Siswandari, & Santoso, D. (2016). E-book for problem based learning to improve learning outcome of the students. *Advances in Social Science, Education and Humanities Research (ASSEHR)*, 158, 220-227. <https://doi.org/10.2991/ictte-17.2017.45>
- Asyari, M., Muhdhar, M. H. I. A., Susilo, H., & Ibrohim. (2016). Improving critical thinking skills through the integration of problem based learning and group investigation. *International Journal for Lesson and Learning Studies*, 5(1), 36-44. <http://doi.org/10.1108/IJLLS-10-2014-0042>
- Babich, S. & Stankunas, M. (2016). The implementation of problem based learning in health service management training programs: Experience from Lithuanian University of health sciences. *Journal of Leadership in Health Services*, 29(4), 390-421. <http://doi.org/10.1108/LHS-04-2015-0010>
- Barrett, T. (2017). *A new model of problem-based learning: inspiring concepts, practice strategies and case studies from higher education*. Maynooth: AISHE. Retrieved from http://www.aishe.org/wp-content/uploads/2017/05/Full-Book-A-New-Model-Of-Problem-Based-Learning-Terry-Barrett_book.pdf.
- Barroh, H., E. Susantini & N. Ducha. (2012). Development of windowed textbooks on human reproductive system materials for RSBI Middle Schools. *Jurnal BioEdu*, 1(2), 1-9. Retrieved from <http://ejournal.unesa.ac.id/index.php/bioedu>.
- Barrows, H. S. (1998). The Essentials of problem-based Learning. *Journal of Dental Education*, 62(9), 630-633. <http://doi.org/10.1111/j.1365-2923.1989.tb01581.x>
- Barrows, H.S. (1986). A taxonomi pf problem-based learning methods. *Medical Education*, 20, 481-486. <http://doi.org/10.1111/j.1365-2923.1986.tb01386.x>
- Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Athena: University of Georgia. [Adobe Digital Editions version]. <https://doi.org/10.1007/978-0-387-09506-6>
- Chiang, C. L., & Lee, H. (2016). The effect of project-based learning on learning motivation and problem-solving ability of vocational high school students. *International Journal of*

Information and Education Technology, 6(9), 709–712. Retrieved from <https://doi.org/10.7763/IJiet.2016.V6.779>

- Cindy E. Hmelo-Silver. (2004). Problem-based learning: What and how do students learn?. *Educational psychology review*, 16(3), 235-266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Cindy, E. Hmelo-Silver, Duncan, R. G. & Chinn, C.A. (2007). Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educational psychologist*, 42(2), 99-107. <https://doi.org/10.1080/00461520701263368>
- Creswell, J. W., & Guetterman, T. C. (2019). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research (6th Ed.)*. New York, US: Pearson. Retrieved from <https://www.pearson.com/us/higher-education/program/Creswell-Educational-Research-Planning-Conducting-and-Evaluating-Quantitative-and-Qualitative-Research-plus-My-Lab-Education-with-Enhanced-Pearson-e-Text-Access-Card-Package-6th-Edition/PGM335066.html>
- Cullen, T., & Jackson, C. (2018). Problem-based learning in the life science classroom, K–12. *Interdisciplinary Journal of Problem-Based Learning*, 12(1), 200-205. Retrieved from <https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1771&context=ijpbl>
- Fajariningtyas, D. A., Akbar, N. A., & Herowati, H. (2019). Developing students' worksheet based on scientific approach in cell as the system of life. *Biosfer: Jurnal Pendidikan Biologi*, 12 (1), 109–121. <https://doi.org/10.21009/biosferjpb.v12n1.109-121>
- Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A Meta-analysis from the angle of assessment. *The Review of Educational Research*, 75(1), 27-61. <https://doi.org/10.3102%2F00346543075001027>
- Güneş, F., & Kirmızı, F. S. (2014). The development of E-book reading attitude scale: the validity and reliability study. *Journal of Faculty of Education*, 3(2), 196-212. <https://doi.org/10.5897/ERR2014.1998>
- Harlen, W. (2002). *The teaching of science: Studies in primary education*. London: David Fulton Publisher.
- Hosnan, M. (2014). *Scientific and contextual approaches in 21st century learning*. Bogor, Indonesia: Ghalia Indonesia.
- Hou, J. (2014). Project and module based teaching and learning. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 8(3), 791-796. <https://doi.org/10.5281/zenodo.1091566>
- Ibrahim, M. (2000). *Cooperative learning*. Surabaya, Indonesia: Surabaya State University
- Johnson, G. Marie., & Buck, G. H. (2014). Electronic books versus paper books: pre-service teacher preference for university study and recreational reading. *International Journal of Humanities Social Sciences and Education*, 1(8), 13-22. Retrieved from <https://www.arcjournals.org/pdfs/ijhsse/v1-i8/3.pdf>
- Korthagen, F.A.J. (2013). Chapter 12 In Search of the Essence of a Good Teacher: Toward a More Holistic Approach in Teacher Education", Craig, C.J., Meijer, P.C. and Broeckmans, J. (Eds.) *From Teacher Thinking to Teachers and Teaching: The Evolution of a Research Community. Advances in Research on Teaching*, 19, 241-273. [http://doi.org/10.1108/S1479-3687\(2013\)0000019015](http://doi.org/10.1108/S1479-3687(2013)0000019015)
- Kumar, R., & Refaei, B. (2017). Problem-based learning pedagogy fosters students' critical

thinking about writing. *Interdisciplinary Journal of Problem-Based Learning*, 11, 2, Art. 1. <http://doi.org/10.7771/1541-5015.1670>

Kusumatuty, A.J., Baedhowi & Murwaningsih, T. (2018). The implementation of problem based learning (Pbl) based e -book to improve the learning outcome of vocational high school (Vhs) students. *International Journal of Educational Research Review*, 3(4), 103-110. Retrieved from <https://jurnal.untidar.ac.id/index.php/ijose/article/view/1285>

Law of the Republic of Indonesia Number 12 of 2012 concerning Higher Education.

Lewis, C. (2015). What is improvement science? Do we need it in education?. *Educational Researcher*, 44 (1), 54-61. <https://doi.org/10.3102/0013189X15570388>

Major, T., & Mulvihill, T. M. (2018). Problem-based learning pedagogies in teacher education: the case of Botswana. *Interdisciplinary Journal of Problem-Based Learning*, 12(1), Article. 1. Retrieved from <https://docs.lib.purdue.edu/ijpbl/vol12/iss1/1/>

Maulina, D & Amin, M. (2015). Analysis of teaching material requirements for animal physiology courses at the University of Lampung. A. Miftahulhuda & S. Budiato (Eds.). *Proceedings on the 2015 National Biology and Biology Education Seminar*. (pp 218-225). Malang: University of Muhammadiyah Malang Press.

Maulina, D & Amin, M. (2016). The analysis of necessity teaching materials on animal physiology learning in Lampung University. *Proceedings of the 2016 National Seminar II, University of Muhammadiyah Malang*. (pp. 113-121). Retrieved from <http://research-report.umm.ac.id/index.php/research-report/article/view/688/897>

Maulina, D. (2019). *Efektivitas biopestisida Mirabilis jalapa dan Bacillus thuringiensis terhadap respon imun humoral Spodoptera litura serta pengembangannya sebagai buku referensi*. (dissertation, Malang, State University of Malang, Indonesia). Retrieved from <http://karya-ilmiah.um.ac.id/index.php/disertasi/article/view/78009>.

Maulina, D., Sumitro, S.B., Amin, M., & Lestari, S. R. (2016). Study of teaching materials for biology cell courses at the Lampung University. R. Murtini (Eds.). *Proceedings of the National Seminar on Biology and Science Education*. (pp. 78-85) Solo, Indonesia: University of Muhammadiyah Surakarta.

Merrit, J., Lee, M., Rillero, P., & Kinach, B. M. (2017). Problem-based learning in K–8 mathematics and science education: A literature review. *Interdisciplinary Journal of Problem-Based Learning*, 11(2), Article 3. <https://doi.org/10.7771/1541-5015.1674>

Mertler, C., & Reinhart, R. V. (2016). *Advanced and multivariate statistical methods: Practical application and interpretation: Sixth edition*. Retrieved from <https://doi.org/10.4324/9781315266978>

Miharja, F. J., Hindun, I., & Fauzi, A. (2019). Critical thinking, metacognitive skills, and cognitive learning outcomes: a correlation study in genetic studies. *Biosfer: Jurnal Pendidikan Biologi*, 12(2), 135-143. <https://doi.org/10.21009/biosferjpb.v12n2.135-143>

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction- what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 47(4), 474-496. <https://doi.org/10.1002/tea.20347>

Muhlisin, A., & Prajoko, S. (2019). Needs analysis of problem-based learning textbook development for environmental courses. *Universitepark Bülten*, 8(2), 134-140. <https://doi.org/10.22521/unibulletin.2019.82.3>

- National Education Standards Agency (NESAs). (2014). *Content Standards*. National Education Standards Agency: Jakarta.
- Ostrow, K.S., Heffernan, N.T., & Williams, J.J. (2017). Tomorrow's EdTech today: Establishing a learning platform as a collaborative research tool for sound science. *Teachers College Record*, 119(3), 45-53. Retrieved from https://cdn.tc-library.org/Rhizr/Files/sHzT6ngX98NEDhAP8/files/38_21779.pdf
- Park, C.S., Kim, M., & Yoo, K. H. (2012). Design and implementation of a problem-based digital textbook. *International Journal of Software Engineering and Its Applications*, 6(4), 213-22. Retrieved from https://www.researchgate.net/publication/290740749_Design_and_implementation_of_a_problem-based_digital_textbook
- Peterson, C. (2003). Bringing ADDIE to life: instructional design at its best. *Journal of Educational Multimedia and Hypermedia*, 12(3), 227-242. Retrieved from <https://www.learntechlib.org/primary/p/2074/>
- Pratama, A. T. (2018). Improving metacognitive skills using problem based learning (pbl) at natural science of primary school in deli serdang, indonesia. *Biosfer: Jurnal Pendidikan Biologi*, 11(2), 101-107. <https://doi.org/10.21009/biosferjpb.v11n2.101-107>
- Regulation of the Minister of Research, Technology and Higher Education of the Republic of Indonesia Number 44 Year 2015. Concerning National Higher Education Standards.
- Rindah, M. A. K., Dwiastuti, S., & Rinanto, Y. (2019). Excretory system learning in senior high school: comparative analysis of students' problem solving skills. *Biosfer: Jurnal Pendidikan Biologi*, 12(2), 249-257. <https://doi.org/10.21009/biosferjpb.v12n2.249-257>
- Rubiah, M. (2016). Implementation of problem based learning model in concept learning mushroom as a result of student learning improvement efforts guidelines for teachers. *Journal of Education and Practice*, 7(22), 26-30. Retrieved from <https://files.eric.ed.gov/fulltext/EJ1112940.pdf>
- Situmorang, M. (2013). Development of high school chemistry textbooks through learning innovation and integration of character education to improve student learning outcomes. R. Agustina (Eds.). *Proceedings of Semirata FMIPA University of Lampung*. (pp. 67-73). Lampung: University of Lampung.
- Sudarisman, S. (2015). Understanding the nature and characteristics of biology learning in answering the challenges of the 21st century and optimizing the implementation of the 2013 curriculum. *Jurnal Florea*, 2(1), 29-35.
- Sudarman. (2007). Problem based learning: a learning model to develop and improve ability to solve problems. *Jurnal Pendidikan Inovatif*, 2(2), 6-12. Retrieved from <http://www.iosrjournals.org/iosr-jrme/papers/Vol-6%20Issue-3/Version-4/I0603045155.pdf>
- Taufik, M., Sukmadinata, M.S. Abdulhak, I & Tumbelaka, B.Y. (2010). Design of learning models to improve the problem solving ability in learning science (physics) of junior high schools in Bandung. *Jurnal Berkala Fisika*, 13(2), 31-44.
- Tauhid, L., Sune, N., & Ntobuo, N.E. (2014). *Description of Activities and student learning outcomes through the PAKEM approach to sound science learning aterials*. Gorontalo: Dinas Pendidikan Kota Gorontalo.
- Timpany, C. (2009). Developing key concepts for the design of hypertext for printed books. *The International Journal of the Book*, 7(1), 81-89. <https://doi.org/10.18848/1447->

9516/CGP/v07i01/36796.

- Usta, N. D. & Güntepe, E. T. (2017). Pre-service teachers' material development process based on the ADDIE model: E-book design. *Journal of Education and Training Studies*, 5(12), 199-210. <https://doi.org/10.11114/jets.v5i12.2820>.
- Van-Rooij, S. W. (2010). Project management in instructional design: ADDIE is not enough. *British Journal of Educational Technology*, 41(5), 852-864. <https://doi.org/10.1111/j.1467-8535.2009.00982.x>.
- Wang, S. K. & Hsu, H. Y. (2009). Using the ADDIE model to design Second Life activities for online learners. *TechTrends*, 53(6), 76-81. <https://doi.org/10.1007/s11528-009-0347-x>