The effectiveness of biology education research textbooks to train students' critical thinking skills

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Article Information	Abstract
	The Biology Education Research (BER) course in the 6th semester of S1 Biology Education FKIP Lambung Mangkurat University, discusses research methodology which includes types of research, methods, variables, theoretical foundations, and hypotheses. However, textbooks that are in accordance with the Semester Learning Plan (LP) and can develop students' critical thinking skills are needed. Based on these problems, the textbook is prepared in accordance with the textbook components in general and develops textbooks based on the State of The Art (SOTA) concept, namely renewal in improving cognitive understanding and obtaining the results of critical thinking by containing exercises in the form of questions based on Bloom's taxonomy ranging from C3-C5. This study aims to produce textbooks on BER that are effective to use and can train students' critical thinking skills. This type of research uses the Education Design Research (EDR) model through the Tessmer Formative Test. Testing the effectiveness of the textbook on BER was carried out to a small group evaluation totaling five students and a field test totaling 25 students. The test uses instruments in the form of working on evaluation questions and college student activity sheets (CSAS). The results of the study based on the expected effectiveness test of the textbook developed with an average value of 69.20 increased to 81.70. While the actual effectiveness tests got an average value of 71.36 increasing to 85.36. Then the average N-gain value is 0.5 which is in the medium category. These results prove that the BER textbook is effective in learning. *Abstrak. Mata kuliah Penelitian Pendidikan Biologi (P2BIO) pada semester 6 S1 Pendidikan Biologi FKIP Universitas Lambung Mangkurat, membahas metodologi penelitian yang meliputi jenis penelitian, metode, variabel, landasan teori, dan hipotesis. Namun, buku ajar yang sesuai dengan Rancangan Pembelajaran Semester (RPS) dan dapat mengembangkan keterampilan berpikir kritis mahasiswa diperlukan. Berdasarkan permasalahan tersebut, buku ajar tersebut disusun sesuai dengan komponen buku ajar pada umumnya dan mengembangkan buku ajar berdasarkan konsep State of The Art (SOTA) yaitu pembaharuan dalam meningkatkan pemahaman kognitif dan memperoleh hasil cara berpikir kritis dengan memuat latihan berupa pertanyaan-pertanyaan berdasarkan taksonomi bloom mulai dari C3–C5. Penelitian ini bertujuan untuk menghasilkan buku ajar tentang P2BIO yang efektif digunakan dan dapat melatihkan keterampilan berpikir kritis mahasiswa. Jenis penelitian ini menggunakan model Education Design Research (EDR) melalui Uji Formatif Tessmer. Pengujian keefektifan buku ajar tentang P2BIO tersebut dilakukan kepada kelompok kecil (small group evaluation) berjumlah lima mahasiswa dan uji lapangan (field test) berjumlah 25 mahasiswa. Pengujian tersebut dengan menggunakan instrumen berupa pengerjaan soal evaluasi dan lembar kegiatan mahasiswa (LKM). Hasil penelitian berdasarkan uji keefektifan harapan terhadap buku ajar yang dikembangkan dengan nilai rata-rata 69,20 meningkat menjadi 81,70. Sedangkan uji keefektifan aktual mendapatkan nilai rata-rata 71,36 meningkat menjadi 85,36. Maka nila rata-rata N-gain sebesar 0,5 yang berada pada kategori sedang. Hasil ini membuktikan buku ajar BER tersebut efektif dilaksanakan dalam pembelajaran.*

A. Introduction

Every university must contain courses on research methodology. Research methods, or scientific methods, are procedures or steps in obtaining scientific knowledge. Students generally do not understand research methodology, so they are less skilled in expressing their ideas in the thesis they are working on. They also have low literacy and experience compiling scientific work (Khoir et al., 2020). This is also similar to the research of Qondias & Winarta (2019), who found that conceptually having courses related to research methodology can benefit students because, later, this knowledge will lead them to become researchers and a basis for completing final assignments. In the BER course, students also received the lowest grade, namely C, because they still had not fully mastered the research methodology.

At the Undergraduate Faculty of Teacher Training and Education, Lambung Mangkurat University (ULM) Banjarmasin, there is a guidebook for writing scientific papers published by FKIP ULM so that it can help the learning process for courses related to research methodology, one of which is the BER course in the Program Biology Education Studies. The BER course is mandatory in semester 4. The material in the BER course is closely related to the discussion of research methodology, which discusses types of research, research methods to be used, research variables, theoretical basis, hypotheses, and so on. The research writing guidebook published by FKIP ULM contains the correct procedures for writing research to make it easier for students to prepare coursework or final assignments in the form of a thesis. However, there are shortcomings in the book, namely that the material presented is not in line with the LP and the demands for learning outcomes in the BER course. This is an obstacle for students studying the material in the BER course, and the book has not triggered critical thinking skills in students. According to Irwandi & Fajeriadi (2019), student learning outcomes are influenced by several factors, including the sources and textbooks used in learning.

Based on the description of this statement, teachers need to develop their textbooks because textbooks developed by others are often unsuitable for students (Piper et al., 2018). Some reasons for textbook incompatibility are material not in line with the curriculum, social, geographical, cultural environment, and so on (Zega & Darmana, 2021). This is why a teacher must develop his textbook according to student characteristics. Textbooks must also contain critical thinking skills that align with the demands of the 21st century. Textbooks that effectively improve students' critical thinking skills are textbooks that can include exercises in the form of questions based on Bloom's taxonomy, starting from C4–C5 (Annisa & Fitria, 2021).

In connection with this problem, the researcher developed a textbook by the LP for the BER course in the Biology Education Study Program, FKIP ULM Banjarmasin, and can improve critical thinking skills. Textbooks are generally prepared according to textbook components and developed based on the SOTA concept, namely innovation in improving cognitive understanding and obtaining critical thinking results (Sari et al., 2020). The textbook being developed is different from the supporting books that have been used in that it contains exercises that are directly related to research methodology. Examples include analyzing journals, identifying journals, providing arguments regarding biological research cases related to research methodology, etc.

Based on the description above, it is necessary to carry out development research to produce effective BER textbooks per the demands of the LP and curriculum. Researchers researched the development of BER textbooks on students' critical thinking skills as a means of learning and how they can be used in the learning process.

B. Material and method

This type of research is development research using the EDR model. In this study, the initial product design was developed through formative evaluation using the Tessmer test. Educational Design Research is a systematic study of designing, developing, and evaluating learning interventions (Plomp, 2013). McKenney & Reeves (2021) also explain that in this system of design, development, and evaluation of learning interventions such as programs, strategies, educational materials, products, and systems, there are solutions to resolve environmental cases in learning practices to advance knowledge about the characteristics of these interventions and the process of designing and developing them.

In the final stages of the Tessmer test, small-group tests and field tests were conducted to obtain data on the expected effectiveness and actual effectiveness. Expected and actual effectiveness data were obtained from the CSAS results and student evaluation questions and then analyzed descriptively based on the N-gain. Students' critical thinking skills were obtained from the results of the CSAS work and evaluation questions, which contained six indicators of critical thinking skills, according to Facione (1990).

Students' critical thinking skills are obtained from formulating questions, identifying assumptions, creating problem solutions, evaluating arguments, and drawing conclusions based on CSAS answer keys and evaluation questions. This assessment uses a rubric with a score of 1–20, which is then calculated and matched with the result criteria, as seen in Table 1. Then, the increase in students' critical thinking skills is a gain calculated using Formula 1 by Hake

(2002), and then categorized following Table 2 by Hake (1999).

Table 1 Critical thinking skill criteria

Score	Criteria
$81 < x \leq 100$	Very effective
$61 < x \leq 80$	Effective
$41 < x \leq 60$	Effective enough
$21 < x \leq 40$	Less effective
$0 < x \leq 20$	Ineffective

(Source: Adaptation from Kunandar, 2015)

$$g = \frac{Sposttest - Spretest}{Smaximum - Spretest} \times 100\% \dots \dots \dots \dots \dots \text{Formula 1}$$

Information:
g = Gain
S = Score

Table 2 Classification N-gain

Nilai g	Category
$g > 0,7$	High
$0,7 > g > 0,3$	Medium
$g < 0,3$	Low

(Source: Hake, 1999)

C. Results and discussion

Figure 1 is the BER textbook cover, and Figures 2 through 5 are the table of contents. In the effectiveness test, expectations were obtained from the results of the students answering the CSAS and evaluation questions. Evaluation questions were given at the first meeting as a pre-test and the fifth or last meeting as a post-test. This test was conducted on a small group of five students taking the BER textbook. The data are presented in Table 3.

Based on the results, the expected effectiveness of the BER textbook developed in the field is by the expectations of the effective category, namely, at the first meeting, 69.20, and continues to increase at the fifth meeting with an average score of 81.70. This shows that the BER textbook, developed to explore students' critical thinking skills, is in the effective category. This is also in line with Dharmono & Riefani (2019), who state that the expected effectiveness of a teaching material can be seen by obtaining an average score above 70.00 so that the teaching material can improve student learning outcomes. Also, research by Nabila et al. (2023) shows the e-book's actual effectiveness N-gain average obtained 5.0 with medium category to train students' critical thinking skills. Besides, Irawan et al. (2023) state the worksheets developed based on critical thinking skills also positively affect student critical thinking.

Table 4 shows the actual effectiveness of the BER textbook developed in the field by the expectations of the effective category, namely, at the first meeting of 71.36, which continued to increase until the fifth meeting obtained an average score of

85.36. This shows that the BER textbook developed to explore students' critical thinking skills is in the effective category.
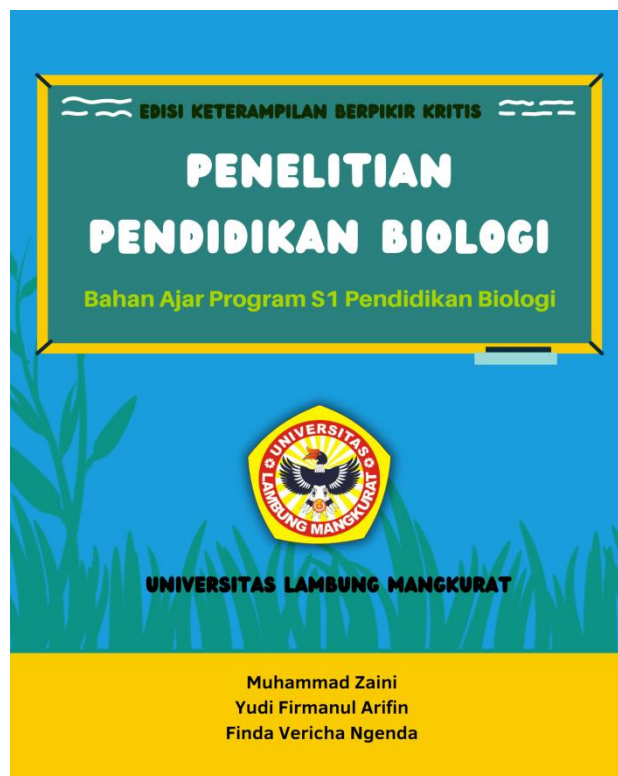

Figure 1 The BER textbooks cover (in Indonesian)

Figure 2 Table of contents page 1 (in Indonesian)

Figure 3 Table of contents page 2 (in Indonesian)

Figure 5 Table of contents page 4 (in Indonesian)

Figure 4 Table of contents page 3 (in Indonesian)

Improving students' critical thinking skills includes several indicators of critical thinking skills in the small-group evaluation and the field test calculated using the formula for the normalized gain value. The results are shown in Table 5. It shows the expected effectiveness is 0.4 and the actual effectiveness is 0.5, which offers an increase in the results of all tests with each category of medium N-gain. N-gain indicates that the developed BER textbook can assist students in practicing critical thinking skills. However, there are still deficiencies in the developed textbooks so that they do not get high N-gain scores, and there needs to be improvements so that the developed textbooks are even better and optimal in improving critical thinking skills. According to Ghufroni et al. (2020); Annisa & Fitria (2021); Taufik et al. (2021), the effectiveness of students' skill achievement can be seen after using teaching materials, one of which is textbooks. It is said to be effective if it positively influences the achievement of learning objectives. The achievement of students' critical thinking abilities in textbooks can be seen through process assessments, observations, and tests. If critical thinking abilities are stated to have increased, then the textbooks are effective.

Students' critical thinking skills were analyzed based on their assessment of filling in the CSAS and answering the evaluation questions. Based on the overall N-gain value, students' critical thinking skills

have a medium N-gain average in terms of expected and actual effectiveness, which means that the BER textbook developed is quite effective in improving students' critical thinking skills in BER learning. According to Rahmawati et al. (2019), the N-gain test, which received the medium category, shows that the product developed is quite effective in improving critical thinking skills because the material is sufficient to trigger these skills and can be used in the learning process.

The CSAS questions used are questions found in the BER textbook. This textbook has the main advantage: it presents a barcode scan containing scientific journals that they can download to stimulate them to enrich their literacy about these scientific journals further and relate them to the discussion material in the BER textbook. In the BER textbook, there is also a self-harnessing section at the end of each book chapter in the form of exercises containing indicators of critical thinking skills that aim to train students' thinking skills.

Textbooks can make it easier for students to study certain subjects. So that students' abilities can increase. Student abilities are not only emphasized in terms of pedagogical abilities. However, it must also be balanced with affective abilities. Apart from that, the effectiveness of students' skill achievement can be seen after using teaching materials, one of which is textbooks. It is said to be effective if it positively influences the achievement of learning objectives. The achievement of students' critical thinking abilities in textbooks can be seen through process assessments, observations, and tests. Critical thinking abilities have increased, so textbooks are effective (Ghufroni et al., 2020; Annisa & Fitria, 2021; Taufik et al., 2021). Based on this description, the following explains indicators of critical thinking skills in learning BER courses and using BER textbooks.

Table 3 Expectation effectiveness result

No	Indicator	Meeting				
		1	2	3	4	5
1	Interpretation	79,50	76,00	78,50	76,50	86,50
2	Analysis	63,50	69,50	74,50	76,00	75,00
3	Evaluation	68,50	68,00	75,50	80,50	79,50
4	Inference	69,00	66,00	65,50	80,00	80,50
5	Explanation	65,50	76,00	65,50	76,50	87,00
Amount		346,00	355,50	359,50	389,50	408,50
Mean		**69,20**	**71,10**	**71,90**	**77,90**	**81,70**

Table 4 Actual effectiveness result

No	Indicator	Meeting				
		1	2	3	4	5
1	Interpretation	69,50	72,00	72,00	85,80	84,00
2	Analysis	74,50	68,25	70,50	80,80	84,30
3	Evaluation	79,50	75,80	73,50	80,50	87,00
4	Inference	74,80	79,50	74,00	80,50	87,00
5	Explanation	58,50	68,50	74,25	76,50	84,50
Amount		356,80	364,05	364,25	404,10	426,80
Mean		**71,36**	**72,81**	**72,85**	**80,82**	**85,36**

Table 5 Students' critical thinking skills N-gain test results

No	Critical Thinking Skills Indicator	N-gain	
		Small test	Field test
1	Interpretation	0,3	0,5
2	Analysis	0,3	0,4
3	Evaluation	0,3	0,4
4	Inference	0,4	0,5
5	Explanation	0,6	0,6
Mean		**0,4**	**0,5**
Category		**Medium**	**Medium**

1. Expectation Effectiveness

Based on the results of the expected effectiveness test of the BER textbook developed in the field, it aligned with expectations for the effective category, namely at the first meeting of 69.20, and continued to increase at the fifth meeting by obtaining an average score of 83.08. This shows that the BER textbook was developed with the hope of being able to explore students' critical thinking skills in the effective category.

The N-gain data in the small group evaluation was 0.3. This states that the skills in the interpretation section are included in the medium category. Interpretation skills require students to have skills in categorizing, understanding significance coding, and classifying meaning. That interpretation skill will make it easier to determine problems related to the learning material being taught. If they can find the problem correctly, it will be easy to make a correct hypothesis (Nuraida, 2019; Hunaepi et al., 2020).

The N-gain data obtained in the small group evaluation was 0.3. This states that the skills in the analysis section are included in the medium category. Students' analytical skills can be seen when they formulate solutions to the problems they find in the discourse provided. Students carry out problem-solving analyses of the data they get from the results of working on the CSAS and evaluation questions related to the BER textbook being developed. This analysis skill requires students to have skills in reviewing ideas (arguments, terms, ideas, concepts, statements, and problems), identifying arguments, and analyzing arguments. Analyzing skills is essential to know the truth of the data obtained based on the theory they have accepted previously (Munawwarah et al., 2020; Wahyudi et al., 2020).

The N-gain data obtained in the small group evaluation was 0.3. This states that the skills in the evaluation section are included in the medium category. This shows that these evaluation skills require students to have skills in evaluating claims and evaluating arguments. This skill can be seen from working on CSAS and evaluation questions when they assess statements or opinions received from themselves or others. Evaluation skills get a medium score because, in the learning process, students evaluate opinions or statements regarding problem-solving. Students who can carry out evaluations know the level of understanding and mastery of a topic easily and can develop their critical thinking skills (Seibert, 2021).

The N-gain data obtained in the small group evaluation was 0.4. This states that the skills in the inference section are included in the medium category. Based on this, it shows that inference skills require students to have skills in questioning evidence, guessing alternatives, and drawing conclusions. This is in line with Syugiyanto (2021), who says that inference skills can be seen when students can correctly conclude the solutions they find. Samitra & Kristiawan (2021) explain that inference skills are medium, meaning students can easily make conclusions.

The N-gain data obtained in the small group evaluation was 0.6. This states that the skills in the explanation section are included in the medium category. This explanation skill requires students to have skills in communicating results, justifying procedures, and presenting arguments. Rahayu &

Alyani (2020) explain that explanation skills are the skill of stating and justifying reasons based on reality, conceptual, methodology, logical criteria, and contextual considerations, as well as presenting one's reasoning in the form of convincing arguments. This skill requires explaining statements or opinions that have been expressed to become a strong opinion (Munawwarah et al., 2020).

2. Actual Effectiveness

Based on the results of the actual effectiveness of the BER textbook that was developed in the field, it was in line with expectations for the effective category. Namely, at the first meeting, it was 71.36 and continued to increase until the fifth meeting, when it obtained an average score of 86.80. This shows that the BER textbook was developed with the hope of being able to explore students' critical thinking skills in the effective category.

The N-gain data obtained in the field test was 0.5. This states that students' interpretation skills are included in the medium category. The increase in N-gain from the small group evaluation data results explains that the CSAS and evaluation questions related to the BER textbook that were developed have advantages, including having complex material that makes it easier for students to learn. The interpretation skills carried out by students can be seen when they work on CSAS and evaluation questions. When students read the discourse on the CSAS and the evaluation questions, they can examine a problem from the discourse so that they gain the ability to interpret appropriately and correctly. This is because CSAS and evaluation questions related to BER textbooks have several advantages, such as allowing students to download valid scientific journals and indirectly triggering curiosity regarding these scientific journals. Apart from that, the material is systematic and uses language that is easy for students to understand.

According to Hunaepi et al. (2020), critical thinking skills can emerge by using basic thinking to come up with each basic interpretation. This is also in line with Agnafia (2019), namely that interpretation skills are used in formulating categories or differences to determine characteristics, interpret information, and understand the meaning of a problem.

The N-gain data obtained in the field test was 0.4. This states that students' analytical skills are included in the medium category. This shows that the analytical skills possessed by students are the ability of students who are skilled in choosing strategies and solution procedures to guess the best answer based on the selected solution procedure. The activities involved in critical thinking skills, such as analyzing, are essential for dealing with real-world situations because these skills allow them to learn through discovery. This analysis was carried out to prove the truth of their hypothesis regarding problems in the

interpretation process. If the data collection procedures are correct, the data collected is by the process demands, and the analysis is accurate, correct information will be obtained (Wahyuni et al., 2019; Purwanti et al., 2022).

The N-gain data obtained in the field test was 0.4. This states that students' evaluation skills are included in the medium category. In this case, it says that critical thinking skills in the form of evaluation mean assessing the credibility of a statement or other representation regarding perceptions, experiences, situations, judgments, beliefs, or opinions; assessing the actuality and logicality of an opinion, description, question, or other form of representation, so that this skill makes students directly involved in the process of preparing work procedures to collect field data, which is then used to carry out data analysis. Textbooks developed with critical thinking aspects of evaluation encourage students to play a role in assessing the credibility of statements from other people, assessing the logical strength of statements, descriptions, or questions, and assessing the strengths and weaknesses of arguments. In addition, this skill can access statements, data, facts, concepts, or other forms of relationships. With this evaluation aspect, it is hoped that students will be able to assess the statements received credibly according to the data obtained (Lufthansa et al., 2020; Vaan Laar et al., 2020; Rahayu & Alyani, 2020; Seibert, 2021).

The N-gain data obtained in the field test was 0.5. This states that students' inference skills are included in the medium category. Improving inference skills received a medium score because students used the BER textbook, which has advantages; one is that the materials in each chapter contain discourse or problems related to research methodology, making it easier for students to draw conclusions based on the issues they face. According to Wale & Bishaw (2020), the conclusions drawn should be the key or answer to the problem being created so that they can prove the truth of the opinion put forward in the assumptions. Students who can carry out inference skills show that they can carry out analysis correctly because they must carry out data analysis with the correct process for a problem so that the conclusions obtained are valid (Din, 2020).

Inference skills are needed to identify each argument needed to draw reasonable conclusions, form conjectures and hypotheses, and consider relevant information (Amaliah et al., 2020). For example, indicators of inference skills can be interpreted as concluding from given data or premises. Inference skills in research using indicators such as making explanations or arguments based on references, drawing conclusions based on references, and solving problems based on references (Syugiyanto, 2021; Listiara et al., 2022).

The interpretation indicator for the N-gain value obtained in the small-group evaluation was 0.3, and the field test was 0.5. The increase in N-Gain explained that the developed CSAS and evaluation questions had advantages; the N-gain data obtained in the field test was 0.6. This states that students' explanation skills are included in the medium category. In the explanation aspect, students explain the statements or opinions expressed to form a strong opinion. This is in line with the opinion of Salim & Saputra (2019) that textbooks developed with aspects of critical thinking skills in the form of explanation skills aim to encourage students to play a role in describing phenomena, causal relationships, or processes and strengthening arguments using empirical data as a basis for explanation. According to Supena et al. (2021); Agnafia (2019), explanation is the ability to provide arguments and establish them logically based on the data or facts obtained.

3. Critical Thinking Skills

Improving students' critical thinking skills includes several indicators of critical thinking skills in small group evaluations and field tests calculated using the normalized gain value formula. The results obtained from the expected effectiveness of 0.4 and the actual effectiveness of 0.5 shows an increase in all tests' results, each in the medium N-gain category. Medium N-gain means that the BER textbook being developed can help students practice critical thinking skills. The N-gain calculation only uses the CSAS assessment and evaluation questions, which contain five indicators of critical thinking (interpretation, analysis, evaluation, inference, and explanation). For self-regulation skills, the way to obtain data results is different from other tests. This data was obtained from the assessment of the metacognition skills sheet, which was filled out by the students themselves, to determine the extent to which students assessed their abilities after working on the CSAS and evaluation questions related to the material in the BER textbook.

D. Conclusion

The research findings showed that the BER textbook improved students' critical thinking skills, as evidenced by the significant increase in evaluation scores from the expectation and actual effectiveness tests. However, the N-gain cut-off, which is in the medium category, indicates room for further improvement. The next iteration of the textbook is recommended to include elements of creative thinking skills by the course requirement for students to produce scientific research work. In addition, enhancing the textbook with issues related to biology education research and supplementing it with more visual aids could improve its comprehensiveness. In addition, future research may benefit from increasing the number of meetings for the effectiveness test to generate richer data for comparison and analysis, potentially resulting in more robust findings.

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