

Developing STEM Based Student's Book for Grade XII Biotechnology Topics

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ABSTRACT

The study aims to develop a valid, practical and effective Biology student's book based on Science Technology Engineering and Mathematics (STEM) on the topic of biotechnology for Grade XII. The method applied for the study was research and development with the 4-D model. The subjects were 58 Grade XII students of SMAN 1 Muncar, Banyuwangi-Indonesia. The results showed that the average of validation result of STEM-based student's book was 86.4% which fell under a strong valid category. The average percentage of legibility test and practicality were in very good category of 87.18% and 96.53%, respectively. Meanwhile, the average of effectiveness test was 0.77 of normalized gain categorized in high criteria. In conclusion, it could be determined that STEM-based student's book of biotechnology is valid, practical, and effectively used in learning process.

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1. INTRODUCTION

The new curriculum 2013, the National Curriculum, was introduced in July 2013 as a way to improve the quality of education in Indonesia. Curriculum 2013 aimed to encourage students to be better at observing, inquiring, reasoning, and communicating what they have learnt or what they know after the learning process. One of the supporting factors for the success of a curriculum is the learning materials [1, 2]. Learning materials are all kinds of materials such as a set of systematically arranged-teaching-material to assist teachers in implementing learning activities and allowing students to study [3]. Textbooks are the main learning material for achieving basic competencies and core competencies [4]. Therefore, innovation in learning materials is necessary in order to produce good learning materials, one of which was by developing student's book based on Science Technology Engineering and Mathematics (STEM) approach in Senior High School. Developing learning materials based on STEM approach is useful to facilitate the students to be in touch with the world through activities such as identifying problems, gathering data to solve problems, thinking of solutions, and considering the result multidisciplinary. This learning material is an innovative source of learning in accordance with the demands of curriculum and learning characteristics of 21st century students [5, 6].

Biotechnology is an important topic in Biology subject for Grade XII which is very complex, multidimensional, highly scientific, technological, sociological and applicative [5]. Based on the need assessment results of eighty students and three biology teachers in SMAN 1 Muncar, almost 90% students faced problems in understanding and applying the biotechnology concepts in their daily life. The main reasons were that there was no laboratory or practicum activities and no suitable learning materials. Developing science learning materials based on STEM approach may cater the needs of Grade XII students

of this particular topic, because students are given the opportunities to construct its existing knowledge to learn new knowledge. Learning from the real thing may be easier and be considered beneficial. Aspects of experience can be drawn from the integration of science, technology, engineering and mathematics in solving the everyday problems [7, 8].

The purpose of this study was to determine the process, validity and effectivity of learning material development based on STEM approach on the subject of biotechnology of Grade XII.

2. RESEARCH METHOD

This study adopted research and development method. Learning materials were developed in the form of student's book. Development model of learning materials used in this study was a 4D Model [9], which consists of define, design, develop, and disseminate phase [10]. The draft of learning materials further tested on nine Grade XII students, during which process the researchers acted as a teacher. Then, students were asked to complete a questionnaire measuring the legibility and level of difficulty as well as students' response. Data of legibility test and difficulty test were analyzed descriptively by examining the results of student assessment given to the student book. Student questionnaire responses were used to determine students' opinion of the developed student's book. Analysis of data obtained from the validators was descriptive in the form of suggestions and comments. The data obtained was analyzed using percentage techniques. Below is the formula for the overall data processing:

$$P = \frac{\sum_{i=1}^n x_i}{\sum_{i=1}^n y_i} \times 100 \quad (1)$$

x_i = number of answers to the assessment of the validator for the aspect -i

y_i = maximum value for the aspect -i

P = percentage of overall assessment

n = aspects were assessed

i = 1,2,3 n

The students' cognitive results from the pre-test and post-test can be analyzed using the gain index formula [11]:

$$N(\text{gain}) = \frac{\langle \text{post-test score} \rangle - \langle \text{pre-test score} \rangle}{\text{maximum score} - \langle \text{pre-test score} \rangle} \quad (2)$$

3. RESULTS AND ANALYSIS

3.1. Developing Process of Student's Book Based on STEM Approach

Define Phase

In the 'define' stage, there were basic problems in biotechnological topic, such as lack of concepts application in daily life, lack of students' knowledge about the application of biotechnology with STEM in various science subject areas, thus they were lack of the understanding of the benefits of studying biotechnology topic. The problems typically encountered in learning related to students were students' initial knowledge and students' character.

Its fit with statement "Period III starting from 12 to 18 years is a stage of self discovery and sensitivity of social taste as well as the period of developing thinking power under high school education" [12]. The study was conducted on students of Grade XII who were 17-18 years of age in average. Based on the results of the questionnaires, it was found that students were not accustomed to learning critical thinking in solving problems around. It was used as a consideration in the preparation of developing students' book based on STEM approach. STEM approach can help students to be familiar to learning with critical thinking, to thinking better and to be accustomed to developing curiosity to the problems around them.

Design Phase

The student's book was developed by using a multiple choice test of 20 questions with five possible answers and descriptions about the problem as much as 5. The student's book was designed based on Science Technology Engineering and Mathematics (STEM) approach. STEM approach encouraged students to develop critical thinking processes such as solving problems, designing experiments, conducting experiments, and reporting. The integration of the STEM approach in teaching and learning may be run at all levels of education, from elementary schools to universities. This may be possible because aspects of STEM implementation such as intelligence, creativity, and design skills are age independent. In addition to improve

students' interest, the idea of integrating STEM is also the genesis of the view that science, technology, engineering, and mathematics are inseparable in their application in the 21st century education [13].

The students' book based on STEM approach was developed in biotechnology topic and intended for Grade XII. The student's book composed of preface, table of contents, core competencies and base competencies, the advantages of book, the character of the STEM approach, book manual, concept maps, summaries, glossary and index. In addition to the designs described above, the cover of the student's book developed was dominated by the color of green is shown in Figure 1. However, not all pages were dominated by green. The selection of green color is meant for the student's book to have a bright appearance. The effect of color on the learning process can bring more impact related to psychological effect. Broadly, the effect of color provides a positive stimulus. Some interrelated influences are attraction, attention, distinction, and warning [14].

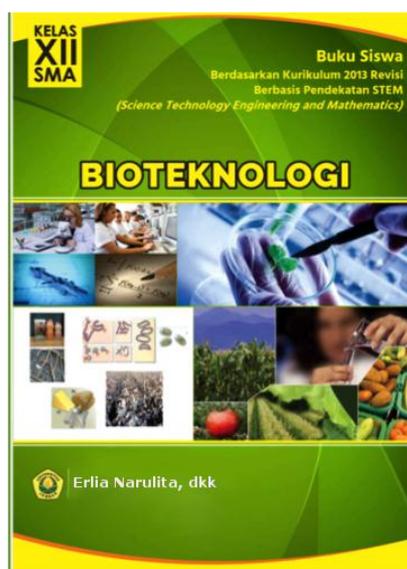


Figure 1. The Cover of the Students' Book Developed Based on STEM Approach

The characters of the STEM approach were shown in the developed-student book through several activities as follows in Figure 2:

- Requiring the students to identify social problem or issues in community from any sources (online media/news/newspaper). The developed students' book facilitates this first character through an activity entitled "Ilustrasi Permasalahan (Problem Illustration)" shown in Figure 2A. It presents the agricultural problems and students were required to identify problems and provide an alternative solution.
- Involving students to find problems around them related to biotechnology and to provide solutions to be applied in daily life. This character is part of "STEM Creativity" shown in Figure 2D.
- Involving students to seek scientific information as reference to provide solutions of problems related to biotechnology. This character is visualized in the form of "Proyek (Project)" shown in Figure 2C. The "Proyek" activity provides illustrations of problems, then students search for literature or references in accordance with the illustrations provided and practice in groups beyond the class.
- Using science and technology problems to learn the topic. The developed students' book presents knowledge related to the invention of biotechnology, which can be a new insight for students. It is available in term of "STEM Info" and "Rumah Ilmu (Science Info)" shown in Figure 2E & 2B.
- Increasing awareness of impact of science and technology development. Activities that directly nurture students' awareness are located before summary entitled "Seberapa Peka (How Sensitive)" shown in Figure 2F. Students may assess their self-awareness in analyzing the impact of biotechnology upon receiving the material. In addition, the developed students' book also encourage fun learning for students through humor described as "Yuk Berimajinasi (Lets imagine)" shown in Figure 2G.

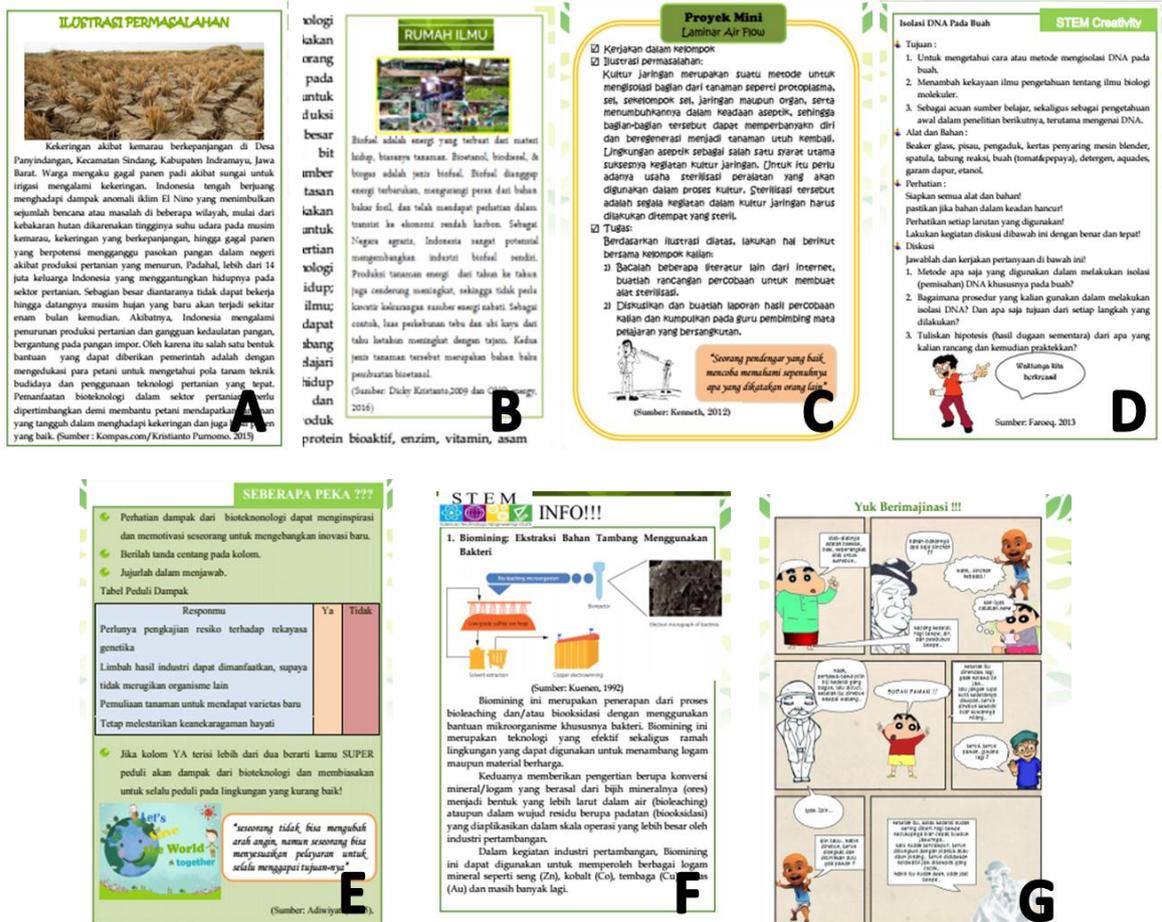


Figure 2. Integration of STEM Characteristic in the Developed Student's Book: A. Problem Illustration, B. Science Info, C. Project, D. STEM Creativity, E. How Sensitive, F. STEM Info, G. Lets Imagine

Development Phase

The development phase aims to produce a revised learning material based on validators input and data obtained from the development test. Activities at the development phase were experts' validation and development test or limited product trial. Experts' validation and users' validation serve to validate and provide suggestions and comments on learning materials that have been developed from content, media, and development process. The average percentage value of validators was 86.4%, which means that the developed student's book meets the strong valid criteria and can be used for the learning process directly shown in Table 1. However, in order to attain perfection of students' book, we conducted a minor revision based on validators advices.

Table 1. Validation Average of Draft of Students' Book

No.	Name	Value (%)
1.	Expert for development	80
2.	Expert for media	89,6
3.	Expert for content	81
4.	User 1	85
5.	User 2	92
6.	User 3	91
Average 86,4		
Criteria: strong valid		
Description: the product can be used for learning process		

Test of legibility and the difficulty level were administered after the draft of student's book was validated and revised into second draft, and then continued by limited trial in a class of Grade XII. The results obtained on the legibility and the difficulty of students' book was good or positive. This was indicated by an average of 87.18% of the overall aspects shown in Table 2. Students responded positively if value of percentage of agreement $\geq 50\%$ [10]. The result meant that the students easily understood the student books and also shown that the developed book covered comprehensible contents and simple language. Legibility level of the text were represented by the sentence structure, the density of words in sentences and difficult words contained in the discourse [12]. It should match the reading ability of the reader [15].

Table 2. Result of Test of Legibility and Difficulty Level

No	Statement Description	Easy		Difficult	
		P	%	P	%
1	Legibility of students' books:	9	100	-	-
	1. The presented material				
	2. The language used	9	100	-	-
	3. The presented table/graphic	9	100	-	-
	4. The presented image	9	100	-	-
	5. Completeness of presentation	5	55	4	44
Average		91.2		8.8	
2	Components of activities that include:				
	1. The lab/practicum activities	9	100	-	-
	2. The inquiry presented	5	55	4	44
	3. The presented material	9	100	-	-
	4. Completeness of presentation	6	66	3	33
Average					
3	Evaluation questions	5	55	4	44
		55			
	The overall average	87,18	12,13	44	
	P=number of students				

3.2 Practicalities and Effectiveness of Student's Book Based on STEM Approach

The students responded positively to the developed students' book related to presentation materials, presentation of student activities, the use of language, image selection, presentation layout, and choice of STEM approach in accordance with the material. It was proven by the agreement of the 96.53% of 58 students as average percentage of students' response to the developed book. The student response shown in Table 3.

Table 3. Student Response

No	Statements	Average (%)
1.	Interest	99
2.	Material	93
3.	Language	97,6
	Overall average	96,53
	Criteria: Strongly Agree	

Teaching and learning activities were conducted to examine the effectiveness of the developed student's book. Before the lesson began, students answered the pre-test questions to see their initial knowledge. At the end of the lesson, students were given post-test questions to determine the level of objectives that can be achieved as well as see the effectiveness of the developed student's book. The results of the pre-test and post-test were analyzed by Normalized Gain and reached of 0.77 which indicated a high level shown in Table 4; [9]). About 91% of the students passed the minimum criteria of mastery (KKM) of 75 and 9% took a remedial lesson. This showed that the students' book based on the STEM approach on biotechnology topic can be used as learning material effectively. The results of this study were similar to the results of the study [15] that the synthesis results from eight research articles indicated that STEM integrated learning had a positive effect on the learning outcomes of learners. Through STEM learning, students have the scientific and technological literacy that emerge from reading, writing, observing, and doing science so that it can be used to live in society and solve problems they may encounter in their daily life related to the field of STEM [7].

Integrated STEM, where the emphasis is E for Engineering, encouraged the students not only to work cooperatively to develop problem solving and decision making skills but also to think critically and creatively to demonstrate an actual understanding of concepts during science lessons. Engineering design on STEM also promotes critical intelligence and intellectual traits, which are important components for stimulating science especially in the purpose of fostering higher order thinking skills [17,18].

Table 4. Pretest-Posttest Result

Subject	Pre-Test average	Post-Test average	Normalized Gain average	Criteria
58 Students	45	87.5	0,77	High

4. CONCLUSION

In summarize, the developed-student's book based on STEM approach was significantly valid, practical and effective as learning material. The integrated STEM approach in student's book enhanced students' learning experiences and encouraged them to become problem solvers, inventor, independent, logical, and technology literate.

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