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Research Article

The validity and effectivity of learning using STEAM module with biotechnology game

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ABSTRACT

Provision of teaching materials in term of module can be an alternative to meet the learning needs of science. The study aimed at describing science module constructed based on Science, Technology, Engineering, Art and Mathematics (STEAM) equipped with valid and effective biotechnology games for learning science in junior high school. This Research and Development (R&D) was developed using the 4D model (Thiagarajan). This research was conducted at MTsN (State of Islamic Secondary School) 2 Jember, involved 30 IX graders. The design used was one group pretest-posttest design as the test of effectiveness. This study used STEAM-based science module equipped with biotechnology games, test, and validation sheets as research instruments. The validation results by experts were converted into categories. The effectivity test data was analyzed using N-gain and paired samples t-test. The average of validation results of material, media, and users was 87.17 (very valid). The effectivity test results showed the increase of students' cognitive learning outcome [N-gain value = 0.72 (high category), $t(29) = 9.030$, $p < 0.05$]. Therefore, the module developed is valid and effective in improving the learning of biotechnology science which means that the use of this module is recommended to be implemented in biotechnology learning process.

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INTRODUCTION

Learning in the 21st-century requires teachers and students to be more competitive to be able to compete with the global society. Skills such as the ability to communicate, think creatively, collaborate, think critically, solve problems supported by the mastery of technology are competencies that must be mastered (Barko & Sadler, 2013; Sunwook et al., 2017). Responding to these demands, the government sparked the 2013-Curriculum to prepare Indonesian students to have the ability to live as individuals and citizens who are faithful, productive, creative, innovative, and practical and able to contribute to the life of society, nation, state and world civilization. One of the contents of the 2013-Curriculum that is taught in secondary schools is science.

The quality of education is associated with the progress of a nation. Science is a scientific family that can be used to measure the progress of education. Indonesian students' scientific understanding is routinely assessed through TIMSS and PISA. The results of a study by the Trends in Mathematics and Science Study (TIMMS) in the realm of science in 2011 found that Indonesia's score ranked 40th out of 42 countries (Kim, Gerber, & Kruse, 2016). These results provide evidence that students in Indonesia have difficulty in solving problems related to science. These difficulties include when dealing with problems with indicators analyzing, evaluating, and creating, as well as HOTS aspects that are included in the TIMSS reasoning items (Utomo, Narulita, & Shimizu, 2018). Whereas the results of the PISA survey in 2015 stated that the Indonesian scientific literacy score was 403, with this score, Indonesia occupies 62 positions out of 70 other participants (Weisberg, 2015). This shows that Indonesia is still lagging behind other countries in the field of science or science. Assessments like these play an essential role in improving the education system, curriculum, quality of teaching, and student learning (Wahono & Chang, 2019). Thus, there needs to be a change in strategy to catch up with other countries. The strategy can be in the form of a learning approach that can hone critical thinking skills, be creative, and master scientific concepts and technological literacy.

An approach that can help students to be able to compete in the 21st-century by instilling scientific ability in students, namely the Science, Technology, Engineering, Art, and Mathematics (STEAM) approach. STEAM provides learning experiences for students to think logically, mathematically, experimentally, and scientifically (Eastwood & Sadler, 2013). Countries with advanced education, such as Finland, America, Australia, Vietnam, China, Malaysia, the Philippines, have first implemented this approach ten years ago (Pal, Kiran, Rao, & Manimaran, 2016). However, in Indonesia, this approach is not yet well known. Based on the results of the distribution of questionnaires to 90 Teachers of Natural Sciences in Jember region showed that 72% of teachers were not familiar with STEAM-based learning. As many as 69% of teachers expressed the need for the application of the STEAM approach in learning science.

STEAM's approach is the integration of science with technology in a thoughtful way to techniques and arts, in which all of these disciplines contain elements of mathematics as the parent of science (Ni, Qi, & Mu, 2018). STEAM is formed based on a combination of several scientific disciplines, namely science, technology, engineering, arts, and mathematics. According to (Khazaei et al., 2017), STEAM refers to three components: (a) creative design, (b) emotional touch, and (c) content convergence and integration. According to Yakman and Lee (2012) define the elements of art in STEAM in the form of aesthetic values, ergonomics, sociology, psychology, philosophy, and education or, more specifically, can be in the form of language arts, physical/physical arts, social arts, and fine arts. The excess of the element of art in STEAM, according to Sochacka, Guyotte, and Walther (2016), can enrich creative ideas and can better prepare students to overcome the complex socio-technical challenges of the 21st-century. Based on the explanation of STEAM it can be said that STEAM is an approach which combines several disciplines in the form of science, technology, engineering, art and mathematics and trains creativity and sensitivity to the surroundings.

The STEAM approach can be applied in learning in various ways, one of which is used as an approach in developing teaching material. Following Government Regulation No.32 of 2013 Article 43 on National Education Standards states that each education unit has the right to develop learning resources other than textbooks according to the characteristics of the material, students, and education units. The need for the teacher's role in helping students in building their knowledge is manifested in ineffective teaching materials (Ningsih, Suratno, & Narulita, 2018). Based on the questionnaire for the preliminary study, 64% of the teachers obtained the teaching materials used were not self-made. Most schools use textbooks (45%) and student worksheet (30%) published by government and local publishers. Some teachers said that they had developed instructional materials, which on average, were student worksheet, but only 11% had developed modules. These results indicate that module teaching materials have not been widely used and produced.

The era of 21st-century learning is the millennial century when the learning process is more effective, efficient, interactive, broad, and not patterned only in the classroom (Hiepe, Ros, Reichenbach, & Herrmann, 2009; Moran et al., 2020). Teaching materials that are considered capable of helping students and teachers in the learning process are modules. Among the advantages of the module, namely, the module has an independent command that allows students to learn on their own with the module, and the teacher is no longer the only source of learning for students. Also, modules are arranged systematically and attractively, covering the content of the material, methods, and evaluations developed (Bequette & Bequette, 2012; Goh & Sze, 2019; Wahono & Chang, 2019; Watson, Pelkey, Noyes, & Rodgers, 2016). According to Connor, Karmokar, and Whittington (2015) added the learning system with modules will make learning more efficient, effective, and relevant compared to conventional learning, which tends to be classical and carried out face-to-face.

In the digital era, like nowadays, teaching materials such as modules can have a more significant effect on students if accompanied by things that interest students. Middle school students ranging in age from 12-15 years are a transition from children to adolescents. Students still like playing activities; one of them is playing games. In this digital era, teachers can use it to support learning to make it more interesting, fun, and not boring for students. Combining learning with mobile game media is an appropriate breakthrough by assessing the characteristics and developments of the digital age (Conradty & Bogner, 2019; Elder, Franco, Gulley, Hughes, & Infanti, 2019). Based on the needs analysis questionnaire distributed by researchers, students' responses to the use of games in learning 84% of students were very enthusiastic in following it, and 57% agreed with the use of biotechnology games in learning. Research Huizenga, Admiraal, Akkerman, and Dam (2009) mentioned that the game or mobile-based game combined with education needs further research to find out whether mobile games are an excellent, active and can create constructive learning fun. According to Putra and Iqbal (2016) the use of games in previous research can increase student motivation in learning material.

Implementation of game use in biotechnology materials has been implemented in Florida (Barko & Sadler, 2013), and in the United States (Eastwood & Sadler, 2013; Kim et al., 2016). Implementation of the use of STEM has often been used by combining STEM with PBL in Taiwan (Kuo, Tseng, & Yang, 2019), STEM with LBL on biotechnology materials in Jember (Ningsih et al., 2018), STEAM hands-on inquiry-based math module in Finland (Thuneberg, Salmi, & Bogner, 2018), STEAM-LW on biotechnology materials in Jember (Utomo, Novenda, Budiarso, & Narulita, 2017).

Based on this, it can be seen that research learning using a STEAM module with biotechnology games has never been done. This research will be renewed because the combination of the STEAM module with the biotechnology game will make it easier for students to learn biotechnology materials. Biotechnology material is material that requires an in-depth understanding, so it is necessary to modify the way it is delivered to students. Some of these studies show that the use of games is very effective in learning biotechnology materials. Some of these studies also show that the combination of STEAM with other methods makes learning effective. Some of these studies also show that STEAM plays a role in learning biotechnology materials. Based on this, this research is a combination of STEAM-based modules and games that will make learning biotechnology materials more interesting and effective in learning activities so that educators in Indonesia can print generations of human resources experts in the field of biotechnology.

The study aimed at describing science module constructed based on STEAM equipped with valid and effective biotechnology games for learning science in junior high school. It is hoped that this research can later become a reference for educators in learning biotechnology materials by attracting and easily being understood by students.

METHOD

This type of research is included in the research and development (R&D) research. The product developed is a STEAM-based science module equipped with biotechnology games for valid, practical, and effective junior high school students. The development model used is 4D (Thiagarajan) with stages including (1) defining, (2) planning, (3) development, and (4) dissemination.

The definition stage is carried out by formulating the problems obtained in the field. Then proceed with the planning stage in the form of design and preparation of products developed, namely the biotechnology science module based on the STEAM approach. Product trials are carried out at the development stage to find out whether the product being developed is suitable for use. At this stage of development, the validity and effectiveness of the biotechnology science modules based on the STEAM approach.

The research subjects used in this study were junior high school students in class IX. The trial product development research was conducted at MTsN 2 Jember, involving the partitioning of 30 IXF grade students. The research instrument in this study consisted of validation sheets, and test questions to find out the effectiveness of N-gain pre-test and post-test student learning. Before testing, the product is first validated to measure product viability. Product validation in this study is based on logical and empirical validation.

The validation results of STEAM-based Science Module with biotechnology games were analyzed by calculations Formula 1 (xi is number of answers from the validator for the i-th aspect of, yi is maximum number of values for aspect i, P is percentage of overall assessment, n is many aspects assessed, and i is 1,2,3, ... n).

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

Data validation results were analyzed using percentage techniques (Utomo et al., 2017), then converted to quantitative data according to the criteria of Table 1. If the validation results reach 59.26, then the STEAM-based science module equipped with biotechnology games is declared valid and can be continued for effectiveness testing.

Table 1. Validity criteria

No.	Value	Category	Conclusions
1	79.26 to 100	Very Valid	Can be used without repair
2	from 59.26 to 79.25	Invalid	Can be used with little improvement
3	39.26 to 59.25	Invalid Less	to be used with slight improvement
4	19 to 39.25	Invalid	Not applicable

Validity of the STEAM-based IPA module equipped with biotechnology games is accepted if the average score obtained is> 62.51 or in good criteria. The effectiveness of STEAM-based science modules with biotechnology games was analyzed quantitatively based on the data from the pre-test and post-test results at the field test stage. To determine the effectiveness of student learning outcomes, carried out using the Normalized gain (N-gain) formula. Data obtained by analyzing the pre-test and student test posts. The N gain index is calculated using the N gain index Formula 2 and Table 2.

$$N\ (gain) = \frac{\langle posttes\ score\rangle - \langle pre-tes\ score\rangle \quad \langle posttes\ score\rangle - \langle pre-tes\ score\rangle}{Maximum\ Score - \langle pre-test\ scrore\rangle Maximum\ Score - \langle pre-test\ scrore\rangle} \qquad (2)$$

Table 2. n criteria (gain)

Gain score	Criteria
G <0.3	Low
0.3 0.3 ≤ g <0.7	Medium
G ≥ 0.7	High

To determine the effect of modules on improving student learning outcomes, pre-test and post-test data were analyzed with the help of SPSS 25. The t-test technique used was a paired sample t-test with α = 0.05. Guidelines for decision making in paired sample t-test based on the significance value (Sig.) of the SPSS output are as follows: 1) If the value of sig. (2-tailed) <0.05, then H0 is rejected, and Ha accepted, and 2) If sig. (2-tailed)> 0.05, then Ha rejected, and Ha received.

RESULTS AND DISCUSSION

Developed modules associated with 2013-Curriculum revision edition and appropriate with the teacher and student need. Module content was biotechnology in accordance with Core competency (or *Kompetensi Inti*/KI) and Basic competency (or *Kompetensi Dasar*/KD). KI include cognitive mastery of students in KI-3 and mastery of skills in KI-4. KD in the form of competencies that must be mastered by students related to the material. In this research, biotechnology material is in KD-3.7 and KD-4.7. In biotechnology material, students are expected to be at least able to master in the realm of understanding (C.2), so students can explain about biotechnology material and its application while the learning objectives in this study are arranged up to the field of creating (C.6).

Module preparation was done by (1) compiling the module framework with the title "STEAM-based Science Module equipped with biotechnology games," (2) the next step is determining the format and design of the module with the module cover design using adobe illustrator*,* A4 module size (8.27 'x 11.69 '), orange color domination of font type Book Antiqua*,* font size 12, 1.5 spaces, equipped with games biotechnology on conventional biotechnology sub material created with Android Studio*.* After determining the format of the module, the next step is to make an outline of the module i.e. the initial part includes: cover, cover page, preface, table of contents, introduction; Core sections include: BC, learning objectives, material description, STEAM activities, understanding tests; the final section includes: competency test, summary, glossary, bibliography, answer key, author profile. The IPA module section, based on the STEAM approach with biotechnology games, can be seen in Figure 1.

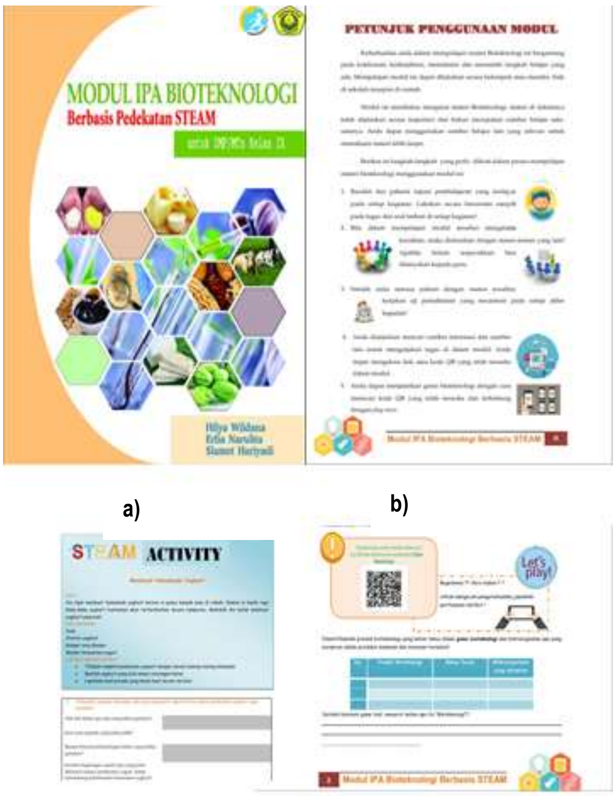
The preparation of biotechnology games is adjusted to the applicable KI and KD. The type of game developed is a mobile game. Mobile games are similar to video games but are played on mobile devices (Choi & Morawitz, 2017; Enke, Kraft, & Metternich, 2015). Game Simple biotechnology here discusses fermentation materials or conventional biotechnology. The use of games in the module is done at the beginning of learning to attract students' interest and instill the assumption that games can be linked to lessons. Students can more easily access this game even though outside the classroom or learning. This video game will provide an interesting social experience, cognitive and emotional. An outline of the appearance of biotechnology games can be seen in Figure 2.

Whether or not a module to be used is obtained from expert validation results before being tested on a small scale. Validation here consists of two validations, namely instrument validation, and product validation, in the form of a STEAM-based biotechnology module equipped with *games* biotechnology. The results of the assessment by the three validators can be seen in Table 3.

Expert validation was done to find out weaknesses, eligibility, and what improvements needed in product development. A validator is a person who is an expert in a field/science to be able to provide an assessment (Biagioli, Kenney, Martin, & Walsh, 2019; Choi & Morawitz, 2017; Feng, Liu, Huang, Qiang, & Chang, 2019). Validation from a material expert in the form of assessments and suggestions for improvements needed so that the material aspects of the product being developed are feasible, both in the material recognition, presentation, and use of language. The validation of media experts and developers was made one, a validator of a Biology Education Lecturer at the Faculty of Mathematics and Natural Sciences, the University of Jember, who was in charge of a development course and learning media that understood the development and manufacture of instructional media including learning games. Aspects assessed in the form of the appropriateness of module graphics and games as well as the suitability of development. The user validators in this study were three science teachers in class IX as a place for large group research. Based on Table 3, it is known that the STEAM-based biotechnology module equipped with biotechnology games is suitable for use in learning activities. They are considered feasible because it fits the validation criteria. Valid products can then be used in development tests (Dhaliwal, Simpson, & Sing, 2018; Haddad & Sepehrnoori, 2017).

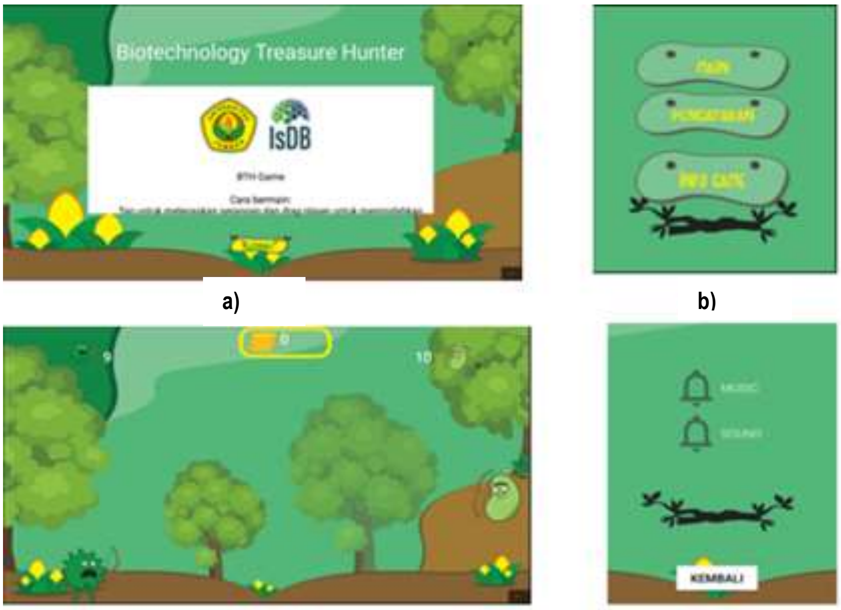
Table 3. The results of the validation of biotechnology science modules are equipped with the game

No	Validator expert	Average score of	Category
1.	Material	92.95	Very valid
2.	Media and Development	83.18	Very valid
3.	User	85.38	Very valid
Average validation results		87.17	Very valid



a) b) c) d)

Figure 1. a) Module cover, b) module usage instructions, c) STEAM activities, d) pages game biotechnology with barcodes



a) b) c) d)

Figure 2. a) Display of info game, b) main menu game, c) display game play, d) settings game

The module effectiveness test is obtained from the pre-test and post-test data. Complete data for student learning outcomes can be seen in Table 4. The effectiveness of modules can be reviewed based on student's N-Gain scores. The results of the effectiveness test showed that student learning outcomes increased with high categories. Before conducting the t-test, the pre-data Test and posttest students must meet the requirements that the data are normally distributed, as in Table 5. The results of the normality of pre-test and post-test data indicate a sig value> 0.05, which means that the data is normally distributed. Furthermore, it can be done paired sample t-test with the help of SPSS, as shown in Table 6.

Table 4. Recapitulation of the results of the small-scale pre-test and post-test gain values

The aspect of	Average the value of the		N-gain	category
	pre-test	**post-test**		
Cognitive	28.0	80.13	0.72	High

Table 5. Normality test

	Kolmogorov-Smirnov[a]		
	Statistic	**df**	**Sig.**
pretest	.125	30	.200*
posttest	.154	30	.066

*. This is a lower bound of true significance.
a. Lilliefors Significance Correction

Table 6. Paired samples test results test

	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	-29.667	17.995	3.285	-36.386	-22.947	-9.030	29	.000

The results of module effectiveness are seen from the differences in pre-test and post-test through a significant level between before and after the use of the Science module based on the STEAM approach. The results of the paired sample t-test analysis showed the value of sig. (2-tailed) = 0.000. Sig value (2-tailed) <0.05, then H0 is rejected, and Ha accepted, so that the data concluded that the IPA module-based approach include games biotechnology STEAM effect on improving student learning outcomes.

The Science module based on the STEAM approach equipped with biotechnology games is said to be effective if student learning outcomes have increased with an average N-gain score of 0.3 ≤ g <0.7 in the medium category. This is consistent with the average N-gain of a large group of 0.67 so that the module developed can be said to be effective. While learning can be said to be successful if the percentage of individual student learning outcomes reaches 65% and learning is said to be successful classically if student learning outcomes reach ≥ 85% (Kuo et al., 2019). In line with previous research that the application of the STEAM approach can improve students' mastery of concepts (Firat & Koksal, 2019; Millan, Mauri, & Casey, 2014; Thuneberg et al., 2018). This is because, in the preparation of modules, students are given space to explore the knowledge learned and involved in practical activities so that the knowledge obtained is inherent to students. The composition of the module content is in accordance with Conner et al (2017), which gives students the opportunity to engage in exploration rather than memorizing, have the chance to discuss their ideas and communicate with others. In addition to helping students understand the STEAM approach material can also help build ability, creative students and characters. According to Land (2013) during STEAM-based learning students are trained with questions that require students to solve problems, critical and creative thinking also collaborate with fellow students.

The use of the biotechnology game in the modules also supports the effectiveness of the STEAM-based science module developed. Game in learning can provide a pleasant environment, motivating, and increasing creativity (Abualrob & Shah, 2012; Jun & Ping, 2008; Kulldel, 2007; Loeb et al., 2018; Madden et al., 2013). When students feel happy at the beginning of learning by using biotechnology games, students also become motivated to understand the material. This is in line with research by Quigley and Herro, (2016), which states that using mobile games increases student motivation in learning, which then helps in the achievement of learning objectives. Flexible game access allows students to repeat the material being studied.

Meanwhile, to disseminate the effectiveness of modules, dissemination was carried out, and varied N-gain results were obtained with medium, high, and high categories. This is in line with Georgette and Hyonyong (2012) that teaching using modules must be widely used in classrooms at various levels of education to find out student performance improvement. The results of the distribution showed consistency in the effectiveness of learning using STEAM-based biotechnology science modules equipped with biotechnology games. In accordance with a research by Bartel and Hagel, (2014) that modules are teaching materials that can improve the effectiveness and efficiency of learning in schools. The use of modules in the learning process can activate students so that learning is no longer teacher-centered. Students are able to learn independently with modules because their use is not difficult, delivery in modules is easy to understand, presentation of interesting material, drawings and STEAM activities as well as test comprehension and practice questions that are accompanied by answer keys enable students to assess their own level of understanding. According to Pablos, Pozo, and Repiso (2017) adds that the module is effectively applied to science learning.

CONCLUSION

STEAM-based science modules equipped with biotechnology games based on the validation results obtained at 87.17 with a very valid category. The effectiveness of the module based on N-gain from the pretest and posttest is categorized very effectively with an N-gain value of 0.72 and sig. 0.00 <0.05. So it can be concluded that the STEAM-based science module is equipped with biotechnology games that are feasible and effective to be used in improving the learning of Biotechnology Science.

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