Received : 11 December 2018
Revised : 09 August 2019
Accepted : 27 December 2019
Online : 28 December 2019
Published: 30 December 2019

DOI: doi.org/10.21009/1.05217

Student Cognitive Profile with STEM Based Teaching Material on the Subject of Vibrations and Waves

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Abstract

The results of study Trends in International Mathematics and Science Study (TIMSS) 2011 at the secondary school level showed that the achievement of learning outcomes of Indonesian students in the fields of mathematics and science had not shown satisfactory results. One way to implement effective and enjoyable learning can be supported by teaching materials used in learning. Teaching materials are one of the supporting factors for student learning success. This study aims to produce products and apply teaching materials based on Science, Technology, Engineering, and Mathematics (STEM) to determine the profile of the cognitive process of understanding the concepts of vocational students. The method used in this study is research and development. Characteristics of STEM-based teaching materials that contain material about vibrations and waves associated with STEM aspects and equipped with problems and practical procedures. The results of the analysis of teaching materials can be categorized as feasible, with a percentage of 78.46%. The results of the analysis of student responses after the application of the teaching materials were obtained with a percentage of 83.74% so that it can be concluded that the teaching material included in the category is very practical to use. The results of the cognitive profile analysis of students' understanding of concepts obtained an interpretation percentage of 76.06%; exemplifying 84.44%; inference 67.78%; comparing 62.59%; explain 59.89%.

Keywords: teaching material, STEM, cognitive profile, vibration, wave

INTRODUCTION

Effective and fun learning will produce quality education. A pleasant atmosphere as an absolute requirement for students to love learning. This is stated in Government Regulation No. 19 of 2005, article 19 paragraph 1 states that: the educational process in the education unit is carried out interactively, inspirational, fun, challenging, motivating students to participate actively and provide sufficient space for initiative, creativity, and independence in accordance with their talents, interests, and physical and psychological development of students.

The learning process that is only centered on the teacher directs students to memorize information, remember and collect much information without being required to understand information and relate it to everyday life. As a result, many graduates are rich in theory, but understanding which develops their potential or the potential that exists in the environment is relatively low. This happens because the concept of understanding is still low though the concepts of physics are mostly obtained from observations and experiments experienced by students.

Effective and fun learning can be supported by teaching materials used in learning. Teaching materials need to be developed because they can help teachers deliver the material. Sari's research results (2015), which states that the development of teaching materials that have experiential learning content can improve students' understanding of concepts and minds-on. Furthermore, Satriawan & Rosmiati (2016) stated that the development of contextual-based physics teaching materials by integrating local wisdom can improve the understanding of physics concepts in students for basic physics courses. Then the research of Taqiyyah et al. (2017), proves that teaching materials can improve problem-solving abilities at high criteria with an N-gain of 0.76.

Science, Technology, Engineering, and Mathematics (STEM) is the integration of the four scientific disciplines (science), technology, engineering, and mathematics in an interdisciplinary approach and is applied based on real-world contexts. According to Becker & Park (2011), the integration of the STEM approach in teaching and learning may be carried out at all levels of education from elementary school to university. This can be done because aspects of STEM implementation such as intelligence, creativity, and design ability do not depend on age.

Some developed countries such as America and Belgium have tried to improve the ability of the 21st century through the development of Science, Technology, Engineering, and Mathematics (STEM) education. The ability of the 21st century includes the ability to adapt, think critically, solve problems, self-management, and communicate. According to Bybee (2013), the purpose of the STEM approach is so that students have the literacy skills of science and technology that appear from reading, writing and observing, so that when they enter the community they will be able to develop their competencies to be applied in dealing with the problems of daily life.

STEM brings up many variants to include other disciplines in developing interdisciplinary literacy among students (Copeland et al. 2018). Training on STEM-based learning for teachers can provide insight to adopt innovative and effective learning and act as a guide for students to develop curiosity about science (Siew et al. 2015; Zaniewaki & Reinholz 2016). Murthi'ik et al. (2018), states that the application of the STEM approach is effective for improving self-efficacy and student learning outcomes.

According to Ejiwale (2013), several obstacles can interfere with the successful implementation of STEM education, namely: (1) poor preparation for providing qualified STEM teachers, (2) lack of investment in professional teacher development, (3) lack of support from the school system, (4) lack of content preparation, (5) lack of collaborative research in the field of STEM, (6) Lack of laboratory facilities and learning media, (7) lack of direct training for students. Referring to the research of Ames et al. (2017) states that physics teachers are the readiest to teach the integrated STEM curriculum.

The integration of STEM learning has five main principles, including the integration of STEM content, problem-based learning, inquiry-based learning, design-based learning, and cooperative learning, (Thibaut et al. 2018). According to Afriana et al. (2016), the application of integrated STEM Project-Based Learning to scientific literacy has increased with an average N-gain of 0.36 and 0.31 in the medium category for knowledge and competency aspects. Furthermore, Utami et al. (2017) state that the development of STEM-A (Science, Technology, Engineering, Mathematics, and Animation) based on local wisdom in learning physics can improve students' understanding of concepts.

The cognitive process profile is the process of changing the ability of perception, memory, thinking, individual understanding of symbols to make reasoning and problem-solving. This cognitive process in its development is influenced by factors heredity, environment, maturity, interests and talents, formation and freedom. There is a study of cognitive profiles by Cahyati (2015) applying the Problem Solving learning model that can improve students' understanding of concepts in Energy Material, where the concept of understanding indicators has the highest N-gain value, which classifies with a value of 0.7.

Based on the description above, it can be said that STEM teaching and learning materials can improve students' competencies. STEM-based teaching materials are expected to improve the understanding of concepts and student interest in learning. There are several studies on STEM teaching materials including those by Hapiziah et al. (2015) which states the development of effective STEM Problem Based Learning teaching materials with an N-gain of 0.75. The same thing also expressed by Pangesti et al. (2017) STEM-based teaching materials can increase students' mastery of concept which is characterized by an increase in the value of pretest to posttest. The purpose of this research is to

produce products and apply teaching materials based on Science, Technology, Engineering, and Mathematics (STEM) to determine the cognitive process profile of the concept of understanding vocational students.

METHODS

The method used in this research is research and development. The research was conducted at the State Vocational School in Central Java, which is located at Jalan Brotojoyo No. 1, Plombokan, Semarang Utara. The sampling technique is purposive sampling. The large group trial subjects were class XI TKR, amounting to 30 students. The research procedure was divided into four stages, namely preliminary studies, planning, development, and testing of teaching materials.

Data Analysis Technique

1. Data Analysis of Feasibility Teaching Materials

The developed teaching materials are tested for feasibility by giving an expert feasibility assessment sheet. The feasibility of teaching materials is calculated by finding the percentage using the formula according to (Arikunto, 2013: 272):

$$x = \frac{total\ score}{maximum\ number\ of\ score} \times 100\% \quad (1)$$

Following the eligibility criteria for teaching materials presented by Akbar (2016), the eligibility criteria for teaching materials are presented in TABLE 1.

TABLE 1. Classification Feasibility of Teaching Materials

Score	Level of Feasibility
1% < x ≤ 50%	Not Feasible
50% < x ≤ 70%	Enough Feasible
70% < x ≤ 85%	Feasible
85% < x ≤ 100%	Very Feasible

2. Data Analysis of Student Response Questionnaire

Providing questionnaires to students on the use of teaching materials in physics learning to see the practicality of teaching materials. The data obtained were analyzed using the following formula:

$$practical\ value = \frac{total\ score}{maximum\ score} \times 100\% \quad (2)$$

Interpretation criteria for questionnaire scores according to Riduwan (2009) can be seen in TABLE 2.

TABLE 2. Interpretation Criteria for Questionnaire Scores

Score	Assessment Category
80% < x ≤ 100%	Very Practical
60% < x ≤ 80%	Practical
40% < x ≤ 60%	Enough Practical
20% < x ≤ 40%	Not Practical
0% < x ≤ 20%	Very Impractical

3. Cognitive Profile Analysis

The analysis of items was calculated by the score criteria 4 for correct answers. Calculation of percentage profile understanding of concepts by using formulas according to (Arikunto, 2013: 272):

$$x = \frac{total\ score}{maximum\ number\ of\ score} \times 100\% \quad (3)$$

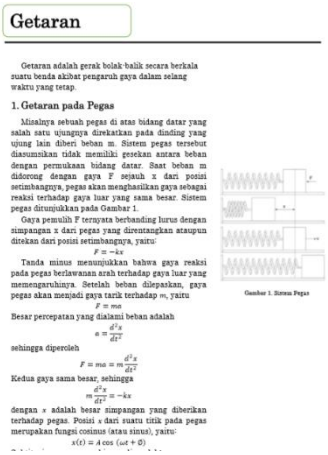
RESULTS AND DISCUSSION

The product developed in this study was physics teaching material based on STEM material for vibrations and waves for grade XI students of SMK. Based on the results of the analysis of the needs of STEM-based teaching materials on vibration and wave material difficult for students to understand. Teaching materials developed to provide direction for students to explore knowledge and carry out independent activities.

The prototype of Teaching Material Based STEM

The prototype of STEM-based teaching materials can be seen in TABLE 3.

TABLE 3. The prototype of Teaching Material Based STEM

Teaching material section	Explanation
	The front cover section of STEM-based teaching materials does not look very interesting, but basic learning competencies are included. The design is indeed too innocent and seems ordinary.
	The STEM-based teaching material is also presented with a concept map of what is in the teaching material. The existence of this concept map makes it easier for students to classify an object to be studied.
	The section that contains aspects of science is explained in detail about vibrational events complete with spring illustrations.

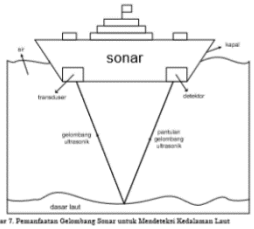
Teaching material section	Explanation

d. Konsep Gelombang dalam Kehidupan Sehari-hari dan Teknologi

1) Gelombang Sonar

Gelombang sonar adalah gelombang yang dapat mendeteksi atau menemukan benda-benda di bawah laut. Ada dua jenis sonar, yaitu sonar aktif dan sonar pasif. Sonar aktif ialah sonar yang mengirimkan suara/sinyal dan menerima kembali gema suara tersebut. Sedangkan sonar pasif ialah sonar yang menerima gema suara, namun tidak mentransmisikan kembali gema suara tersebut.

Sonar sebenarnya memiliki banyak kegunaan, di antaranya digunakan kapal selam untuk mendeteksi kapal lainnya, mendeteksi kedalaman laut, penangkapan ikan, keselamatan penyelaman, dan komunikasi di laut. Proses gelombang sonar untuk mendeteksi kedalaman laut seperti ditunjukkan pada Gambar 7.



Gambar 7. Pemanfaatan Gelombang Sonar untuk Mendeteksi Kedalaman Laut

Persamaan yang digunakan untuk mengukur kedalaman laut adalah

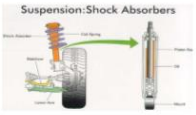
$$h = \frac{v \times \Delta t}{2}$$

dengan: h = kedalaman laut
v = kecepatan gelombang sonar
Δt = selang waktu

The section which contains aspects of technology is explained briefly in the description of wave utilization in the field of technology other than sonar waves, there are several other examples described in teaching materials.

APLIKASI

Gambar di samping menunjukkan salah satu sistem suspensi pada kendaraan bermesin. Cara kerja alat ini adalah sebagai berikut:
Ketika suspensi memperoleh beban atau hentakan dari luar pegas akan memendek. Pegas memiliki gaya pemulih dimana gaya tersebut akan melawan arah gaya yang bekerja padanya sehingga pegas akan mengalami osilasi. Pemberian *shock absorber* dimaksudkan untuk meredam osilasi yang terjadi untuk selanjutnya pegas berhenti (berada dalam posisi setimbang).



Sumber: anjhiflash14area.wordpress.com

The section contains aspects of engineering and is given examples of application techniques in the discussion of vibration, which adds to the knowledge of vocational students about the application of vibration in the automotive field.

4

Dari persamaan dapat menurunkan besaran frekuensi (f) dan periode (T). Hubungan antara besaran sudut ω, periode T, dan frekuensi f adalah sebagai berikut:

$$\omega = 2\pi f = \frac{2\pi}{T}$$

Persamaan dapat dituliskan sebagai berikut:

$$\omega = \sqrt{\frac{k}{m}}$$

berarti,

$$\frac{2\pi}{T} = \sqrt{\frac{k}{m}} \Leftrightarrow T = 2\pi\sqrt{\frac{m}{k}}$$

karena $f = \frac{1}{T}$ maka

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

dengan: T = periode getaran pegas dan beban (s)
m = massa beban (kg)
k = konstanta pegas (N/m)
f = frekuensi (Hz)

SEKILAS INFO

Periode adalah waktu untuk melakukan satu getaran.

$$T = \frac{t}{n}$$

Frekuensi adalah banyaknya getaran yang terjadi dalam waktu 1 sekon.

$$f = \frac{n}{t} \; atau$$

dengan: T = periode (s)
n = jumlah getaran
t = waktu (s)
f = frekuensi (Hz)

The part which contains the mathematics aspect is written clearly and coherently as well as explanations that do not confuse students to understand it.

EKSPERIMEN 1

Tujuan:

Mampu menjelaskan getaran pada pegas

Alat dan bahan:

1. Pegas
2. Statif
3. Penggaris

Langkah kerja:

1. Rangkailah pegas dengan beban pada statif!
2. Ukurlah penambahanpanjang pegas setelah diberi beban!
3. Kemudian tarik pegas sejauh 2 cm dari posisi setimbangnya dan lepaskan!
4. Catat waktu yang diperlukan untuk 10 getaran!

Pertanyaan:

1. Gambarkan sketsa sistem pegas
2. Hitunglah periode dan frekuensi getaran!

Contains experimental steps that students can do to better understand the material presented and students can try it independently.

Teaching material section	Explanation
$TI = 10 \log\left(\frac{I}{I_0}\right)$ dengan: TI = Taraf intensitas bunyi (dB) I = intensitas bunyi (W/m²) I_0 = intensitas ambang = $10^{-12} W/m^2$ **CONTOH** Sebuah bel yang berdaya maksimum 6000 W. Berapakah taraf intensitas bunyi pada jarak 2 km dari sirine? Jawab : *Diketahui* : P = 6000 W r = 2 km = 2000 m *Ditanyakan* : TI? *Penyelesaian* : $I = \frac{P}{4\pi r^2} = \frac{6000\ \text{W}}{4\pi(2000\ \text{m})^2} = 1{,}1943.\ 10^{-6} W/m^2$ Maka, $TI = 10 \log\left(\frac{I}{I_0}\right) = 10 \log\left(\frac{1{,}1943.\ 10^{-6} W/m^2}{10^{-12} W/m^2}\right) = 80{,}771\ dB$	It contains examples of questions that are complete with solutions that students can use as guidelines in understanding the problem.

Feasibility of STEM-Based Teaching Materials

Feasibility of teaching materials in terms of three aspects, namely content, presentation, and language. The results of the feasibility analysis of teaching materials are presented in TABLE 4.

TABLE 4. Results of Feasibility Analysis of STEM-Based Teaching Materials

Aspect	Percentage	Criteria
Contents	80.47%	Feasible
Presentation	78.13%	Feasible
Term	76.79%	Feasible
Average	78.46%	Feasible

Based on the results of the feasibility test analysis of STEM-based teaching materials obtained the percentage r has met the aspect of content feasibility consists of elements of conformity, accuracy, and material updating, STEM characteristics, and cognitive profiles. STEM-based teaching materials consistently present material related to vibrations and waves.

Student Response Questionnaire

Based on the results of the questionnaire analysis of 30 students, the average percentage was 83.74% with a very practical category.

Students Cognitive Profile

Cognitive profile analysis is done to find out which indicators are most prominent. The results of the cognitive profile analysis can be seen in FIGURE 1.

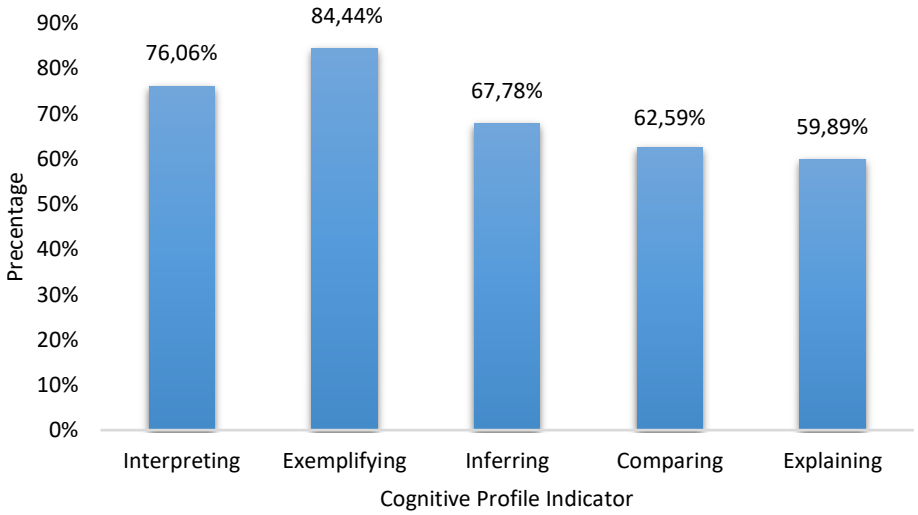


FIGURE 1. Percentage of Student Cognitive Profiles

Based on FIGURE 1, it can be seen that cognitive profile analysis has differences in each indicator. Ability Students' cognitive profiles are measured using delicate instruments in the form of description questions totaling 15 items with each number having a different score depending on the question given. FIGURE 1 presents a comparison of cognitive profiles using STEM-based teaching materials. Indicators of cognitive profile understanding of concepts used as references are indicators of cognitive profile understanding of concepts according to Anderson's taxonomy namely interpretation, example, inference, comparing, and explaining. For indicators to characterize and generalize in previous studies already have the highest N-gain value. So that it is not highlighted on the question made for the test.

In line with the research conducted by Basyari (2015) regarding the Application of Levels of Inquiry at the Interactive Demonstration level to Increase Understanding of Simple Concepts for Junior High School Students, it was concluded that indicators of understanding concepts included in the strong criteria of improvement were classifying. Then the research conducted by Cahyati (2015) applying the Problem Solving learning model can improve the understanding of students' concepts in Energy Material, where indicators of concept understanding have the highest N-gain value, namely classifying with a value of 0.7.

Cognitive profiles on indicators with lower percentages I highlight in the matter of comparing and explaining. Based on FIGURE 1. the results of cognitive profile analysis obtained the highest percentage in the indicator exemplifying 84.44%. On the test questions given, there is only 1 question in the indicator exemplifying and as many as 27 students work even though there are 4 students the value is not optimal, while 3 students do not work. So it can be concluded that almost all students can answer the questions on the indicator exemplifying well.

SUMMARY

Based on the results of the study obtained several conclusions that the STEM-based teaching material contains material about vibrations and waves. The results of the analysis of teaching materials can be categorized as feasible with a percentage of 78.46%. The results of the analysis of student responses after applied teaching materials obtained a percentage of 83.74% so that it can be concluded that the teaching material included in the category is very practical to use. The results of the cognitive profile analysis of students' conceptual understanding obtained the interpretation percentage of 76.06%; exemplifying 84.44%; inference 67.78%; comparing 62.59%; explain 59.89%. Suggestions that can be given for further research are the need for more material related to technology and engineering to enrich students' knowledge and understanding.

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