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Industrial Competency Based-Mathematics Instructional Materials for Mechanical Engineering in Vhs

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Abstract

Mathematics instructional material in vocational high schools (VHS) should be improved to support students' competencies in the world of work due to numerous mismatches between industrial demands and the material taught in schools. This study aims at determining the scope of Mathematics teaching material needed by vocational students to establish a stronger link and match with industries. This research is descriptive quantitative. The population in this study consisted of experienced industry practitioners, VHS teachers of Mechanical Engineering Study Program, VHS teachers of Mathematics, and VHS students of Mechanical Engineering Study Program. The total sample was 215 respondents with purposive random sampling. The research instrument used a questionnaire that had been tested for its validity and reliability. Based on research, the coverage of Mathematics teaching materials in the current VHS syllabus was 34 materials, while the number of materials that were considered as important and very important categories based on the findings was 36 materials. It means two Mathematics teaching materials should be added to meet the needs of the industry. It is needed Mathematics teaching material in the Mechanical Engineering Study Program needs to be adjusted to enhance the students' expertise based on the world of work.

Keywords: Need Analysis; Mathematics teaching material; Mechanical Engineerin; VHS

INTRODUCTION

Vocational High Schools (VHS) play a crucial role in preparing the workforce and it urges VHS to keep up with the trends of the growing market. Nevertheless, VHS faces many problems related to the work readiness of the graduates in their areas of expertise. It might be caused by different orientations between the world of education and the world of work. Schools emphasize graduates to have high grades with a minimum duration of the study, while the industry demands high technical competencies and good attitudes from graduates instead of their academic scores (Wibowo, 2016).

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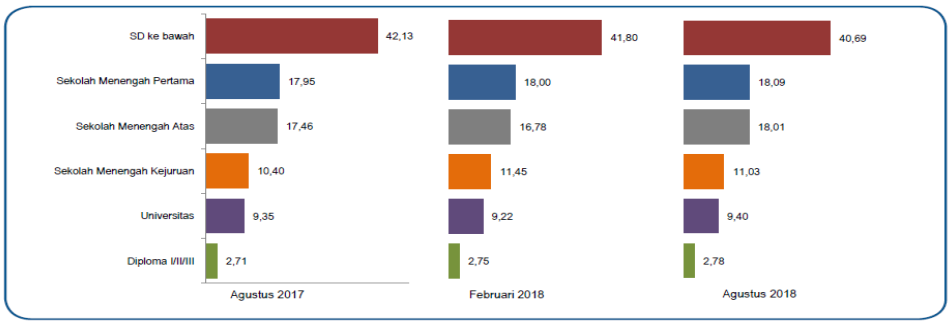

Figure 1. Percentage of Working Population Based on Highest Education 2018
Source: Central Statistic Agency in Labor Force

This problem can be seen quite clearly since the unemployment rate in Indonesia is dominated by VHS graduates. The mismatch skills with industrial needs have been listed as the main reason (Harahap, 2018). The data from Central Statistic Agency in February 2020 shows that the highest level of open unemployment is coming from VHS graduates with a total of 8.49%, followed by 6.77% of high school level and 6.76% of diploma III, respectively. It is a crushing blow to the principles of VHS as work-oriented education with a mission to improve the graduates' quality based on the National Competency Standards to face the globalization era (Hartanto, 2019). Several specific skills including problem-solving skills, analytical skills, human relations, and learning skills must be put forward to enhance students' competencies and to meet industry needs as well as to face the rapid development of technology (Hartanto, 2017).

LITERATURE REVIEW

The teaching and learning process must refer to the demands of the world of work. It means the subjects as part of the secondary school curriculum should be arranged according to the industrial demands. Mathematics is one of the subjects taught in vocational high schools that have not matched the competency requirements from the world of work (NRC, 1989). Mathematics is regarded as a key to success since it will open up opportunities for a brilliant career. It is expected the student to master this subject to plunge into the world of work based on their respective fields. So, Mathematics learning at VHS must be aligned with the expertise program. It means Mathematics teaching materials between one skill program and another must be different to reinforce their respective competencies (Efendi, 2016). In contrast, the curriculum structure (Minister of Education and Culture Regulation No. 69 and 70 of 2013) shows that the duration of Mathematics teaching for all skill programs is declared to be the same including public high schools and vocational high schools. It is quite strange since vocational education is oriented to prepare students for the world of work and it must be future-oriented(Hartanto & Fordiana, 2018), (Hartanto, Handoko, et al., 2019). Similarly, VHS is an advanced secondary education which has the main objective to prepare a skilled, professional, and highly disciplined workforce based on the demands of the world of work (Wulandari, 2013). VHS is required to be able to create human resources who can adapt to

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the advances of science and technology. The main task of VHS is to produce work-ready graduates that have knowledge and skills in accordance with their expertise program (Wibowo, 2016).

The material taught in VHS is presented in the form of various competencies that are considered important for students' future careers. The competencies include the learning process to become smart Indonesians and competent workers by referring to the competency standards set by the industry, business world, or professional association. To achieve the required competencies standards, the learning process is developed into various training courses that are grouped and organized into normative, adaptive, and productive programs. Therefore, it is necessary to conduct a need analysis to clarify the competencies standards based on the demands of the world of work. This needs analysis is basically looking for discrepancies between what is already available and what is expected of which a need assessment is a process of gathering information from gaps to be resolved. The need analysis of Mathematics instructional materials on the competency of Mechanical Engineering expertise in Vocational High Schools is expected to give beneficial impacts in education to develop and maximize the potential of students' competencies. The purpose of this study is to determine the scope of the instructional materials of Mathematics which are needed by the Mechanical Engineering students to match the needs of the world of work.

METHODOLOGY/MATERIALS

This study employed exploratory research of descriptive quantitative without hypothesis testing. It was done with the DACUM approach method. The DACUM is an acronym of Developing a Curriculum which is a method for job analysis utilizing small group studies. This approach was like the introspection approach where experts from the industry were asked to think about the curriculum content without involving any institutional personnel. The analysis by industry practitioners, educators, and consultants was through task identification and related information which is required for jobs and positions. This approach assumes that the curriculum content must have high relevance to the employment needs(Hartanto, 2017).

The population in this study amounted to 464 respondents consisted of experienced industry practitioners, VHS teachers of Mechanical Engineering Study Program, VHS teachers of Mathematics, and VHS students of Mechanical Engineering Study Program. The total sample was 215 respondents with purposive random sampling. The research instrument used a questionnaire with a modified Likert scale in 4 criteria for VP (very important), I (Important), LI (less important), NI (not important). The purpose of using a questionnaire was to determine the scope of Mathematics teaching material needed to be taught to Mechanical engineering students to meet the needs of the world of work. The instrument had been tested its validity and reliability. Based on the results of the expert judgment involving 5 people, this needs analysis instrument was declared valid and reliable.

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RESULTS AND FINDINGS

The analysis of the Mathematics teaching material among students of mechanical engineering was presented in the form of the respondent's achievement level in percent. The decision criteria were stated by using selected Mathematics teaching materials with the respondent's achievement level of more than 50% for the very important and important categories (Hartanto,at.al. 2020).

Below is the comparison of Mathematics teaching materials between the curriculum and the research data which are categorized as important and very important.

No	Mathematics Teaching Material Coverage Indicators	VHS Mathematics learning syllabus	Research data	Explanation	Respondents' Achievement
1	Applying the concept of exponential numbers, root form, and logarithms in solving problems	✓	✓	Ok	93%
2	Applying the equation and inequality to the absolute value of the linear form of one variable	✓	✓	Ok	77%
3	Determining the values of the variables in a two-variable system of linear equations in a contextual problem	✓	✓	Ok	64%
4	Determining the maximum and minimum values for contextual problems associated with a two-variable linear program	✓	✓	Ok	80%
5	Analyzing arithmetic sequences and series	✓	✓	Ok	80%
6	Analyzing geometric sequences and series	✓	✓	Ok	72%
7	Analyzing growth, decay, interest and annuities	✓	✓	Ok	54%
8	Determining the trigonometric ratio of a right triangle	✓	✓	Ok	91%
9	Determining the value of the related angle in various quadrants	✓	✓	Ok	80%

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10	Determining Cartesian coordinates to be polar coordinates and vice versa	✓	✓	Ok	74%
11	Applying trigonometric comparison values to the graph of trigonometric functions	✓	✓	Ok	75%
12	Applying the sine and cosine rules	✓	✓	Ok	87%
13	Finding the area of a triangle in trigonometry	✓	✓	Ok	86%
14	Analyzing the angle value with the formula for the number and difference of two angles	✓	✓	Ok	79%
15	Applying matrix operations in solving problems related to matrices	✓	✓	Ok	77%
16	Determining the determinant, inverse and transpose values in the order 2x2 and the determinant and tranpose values in the order 3x3	✓	✓	Ok	54%
17	Determining the value of the vector quantity in the second dimension	✓	✓	Ok	66%
18	Determine the value of the vector quantity in three dimensions	✓	✓	Ok	64%
19	Determining the value of the variables in quadratic equations and functions	✓	✓	Ok	72%
20	Analyze composition operations and inverse operations on functions	✓	✓	Ok	67%
21	Determining the equation for the circle	✓	✓	Ok	83%

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22	Analyzing contextual problems related to mathematical logic (simple statements, negation of simple statements, compound statements, negation of compound statements and drawing conclusions)	✓	✓	Ok	76%
23	Analyze points, lines and planes in three-dimensional geometry	✓	✓	Ok	78%
24	Defining contextual problems related to geometric transformations	✓	✓	Ok	64%
25	Analyzing counting, permutation and combination rules in contextual problems	✓	✓	Ok	77%
26	Determining the probability of an event	✓	✓	Ok	78%
27	Evaluating statistical studies in contextual problems	✓	✓	Ok	68%
28	Analyzing concentration measures for single data and group data	✓	✓	Ok	75%
29	Analyzing the size of the spread of single data and group data	✓	✓	Ok	75%
30	Determine the limit value of an algebraic function	✓	✓	Ok	73%
31	Determining the derivative of an algebraic function using the definition of the limit function or the properties of the function's derivative and its applications	✓	✓	Ok	74%

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32	Analyzing the relationship of the first derivative of the function with the maximum value, minimum value, and the interval of the monotony of the function, as well as the slope of the tangent to the curve.	✓	✓	Ok	72%
33	Determining the value of an indefinite integral and a certain algebraic function	✓	✓	Ok	73%
34	Determining the surface area and volume of a rotating object using definite integrals	✓	✓	Ok	89%
35	Analyzing binary numbers	-	✓	Recommended	91%
36	Determining the spec in the approximation material	-	✓	Recommended	89%

Based on the research results, there were several materials suggested to be taught in VHS of Mechanical engineering, such as 1) applying the concept of exponential numbers, the form of roots and logarithms in solving problems, 2) applying equations and inequalities of absolute values, 3) determining values variables in SPLDV in contextual problems, 4) determining the maximum and minimum value of contextual problems related to linear two variables, 5) applying arithmetic sequences and series, 6) analyzing geometric sequences and series, 7) analyzing growth, decay, interest and annuities, 8) determining the trigonometric ratio of a right triangle, 9) determining the value of the related angles in various quadrants, 10) determining Cartesian coordinates to polar coordinates and vice versa, 11) applying trigonometric ratio values to the graph of trigonometric functions, 12) applying the sine and cosine rules, 13) finding the triangle area of trigonometry, 14) examining the value of angles with the formula for the number and difference of two angles, 15) applying matrix operations in solving problems related to matrices, 16) determining the determinant, inverse and transposition values in the order 2x2 and the determinant and transposition values in the order 3x3, 17) determining the value of the vector quantity in the second dimension, 18) determining the value of the vector quantity in the third dimension, 19) determining the value of variables in quadratic equations and functions, 20) examining the composition operations and inverse operations on functions, 21) determining the circular equation, 22) analyzing contextual problems related to mathematical logic (simple statements, negation of simple statements, compound statements, negation of compound statements and drawing conclusions), 23) analyzing points, lines and planes in three dimensional geometry, 24) determining contextual problems related to geometric transformations, 25) examining the rules of enumeration, permutation and combination in contextual problems, 26) determining the probability of an event, 27) evaluating statistical studies in contextual problems, 28)

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analyzing the size of the concentration of single data and group data, 29) analyzing the size of the distribution of single data and group data, 30) determining the limit value of algebraic functions, 31) determining the derivative of algebraic functions using definition of limit function, 32) analyzing the relationship of the first derivative of the function with the maximum, minimum, and monotonous interval of the function, as well as the slope of the tangent of the curve, 33) determining the value of the indefinite integral and certain integrals of algebraic functions, 34) determining the surface area and volume of the rotating object using definite integrals, 35) analyzing binary numbers, 36) determining the specs on the approximate material.

The comparison data between the material coverage contained in the current syllabus of VHS and the coverage of Mathematics instructional materials which are considered important and very important by respondents showed that some materials are absent in the current VHS curriculum in Batam City. The vocational school syllabus in Batam city has 34 Mathematics materials, while the very important and important Mathematics materials is 36. It means that two teaching materials need to be added, i.e. approximations and binary numbers. The scope of Mathematics instructional materials will be recommended to the Educational Office as the consideration in preparing the upcoming VHS syllabus.

Based on the research results, the approximation material or tolerance value obtained the respondent achievement level score of 89% from the important and very important categories. It indicates that this material should be taught in vocational schools in mechanical engineering because this material explains the way to determine the minimum and maximum tolerance value of the produced goods. As an example, in a bolt factory employ machine production, the bolts have to be 5mm in diameter and the specifications may allow the diameter between 4.8mm and 5.2mm. The difference between these limits, 0.4mm, is called the tolerance in measurement and is expressed as (5 ± 0.2mm) (Markaban, 2009). If the goods produced are exceeding or less than the tolerance limit, then the goods will be rejected since those do not comply with the standard product specifications. This kind of learning material is needed by students and it must be taught in schools to achieve the skills based on the needs of the world of work (Lubis, 2010), (Hartanto et al., 2020). The good learning experience will support students' competency and this is in line with the basic concept of vocational education.

The material of the binary number obtained high respondents' achievement levels with 91% of the important and very important categories. Binary numbers refer to the numbers based on two, zero, and one (Harjiono, 2011). Computers use binary numbers to communicate among the components (hardware) and intercomputer communication. Computers have been widely applied to machine tools including lathes and milling machines. The combination of computer and mechanical technology is called Computer Numerically Controlled (CNC). Broadly speaking, the definition of CNC is a machine that is controlled by a computer using numerical language (Widarto, 2008). The material of binary numbers is very important to be taught among mechanical engineering students because it is closely related to industrial machining. Vocational education graduates need to have good competence and it urges VHS to produce a competent workforce by enhancing students' productivity, efficiency, and readiness for global competition in the international labor market (Quieng, Lim, & Lucas, 2015), (Hartanto, Huda, & Fordiana, 2019).Students must learn knowledge, skills, attitudes

and do work in accordance with the rules and the real conditions of the world of work, afterwards the learning strategy must be directed according to the needs of the world of work, (Melo, 2013),(Hartanto, Handoko, et al., 2019).Mathematics instructional materials for vocational high schools should be adjusted to current demands, especially for the mechanical engineering department. There are two recommended materials as the foundation to improve students' knowledge and understanding to elevate the link and match with the world of work (Hartanto et al., 2020).

CONCLUSION

Based on the results of the study, it was concluded that the scope of Mathematics instructional material competency in mechanical engineering expertise of VHS has got 34 materials in the current curriculum, while the scope of the teaching material which is considered very important and important based on the needs analysis in the world of work consists of 36 teaching materials. Therefore, it is necessary to adjust the teaching material at least 2 recommended material themes according to the industrial needs.

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