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STEM literacy in growing vocational school student HOTS in science learning: A meta-analysis

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ABSTRACT

The low higher order thinking skills (HOTS) of vocational students is shown from the approaches and models used in learning that are not specific, learning activities are limited to methods that have not been able to grow HOTS. One of the approaches offered in science, technology, engineering, and mathematics (STEM). The research objective was to analyze STEM in growing HOTS through literature studies. The data collection method used a STEM systematic review from 2016-2020 based on the indexed findings of Google Scholar and Scopus (Database: Elsevier, Scopus, and Science Direct). Qualitative descriptive data analysis technique was employed on inductive deductive patterns. Based on data analysis, there are findings of 18 Google Scholar indexed articles and 20 Scopus indexed articles according to the inclusion criteria. The results showed that: i) STEM integration patterns in growing HOTS obtained six STEM literacy patterns of 28% on Google Scholar and four STEM integration patterns by 65% in Scopus; ii) The trend of STEM and HOTS research from 2016-2020 has increased the most in 2020 by 56% on Google Scholar and 40% on Scopus. Most of the methods used are research and development (R&D) with data analysis techniques in the form of t-test on Google Scholar data and survey methods with descriptive analysis on Scopus data. The difference in the publication trend on the integration pattern, the number of samples used is greater in the Scopus data. The method used is more dominant in the survey than R&D, but whatever the research design in STEM literacy is, in principle, it can empower HOTS to increase learning activities.

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1. INTRODUCTION

Higher order thinking skills (HOTS) generate new ideas that can adapt to different conditions, think flexibly, creatively, think critically, and be tolerant of ideas [1]. Vocational school (*SMK*) science learning is oriented towards applied science studies that can apply to the world of work and industry. Global challenges require learning patterns that empower HOTS through a science, technology, engineering, and mathematics (STEM) approach. HOTS are an important part of learning skills [2] which are cognitive activities in finding solutions to solve problems [3], finding ideas to help students develop HOTS in the form of critical thinking, and creative thinking. Indication of the ability to train students with the dimensions of thinking processes which include the domains of analyzing (C4), evaluating (C5), and creating (C6) [4].

The low HOTS are caused by lack of media and learning models that can maximize students' HOTS effectively [5]. Conventional and question and answer methods still dominate science learning so that students become passive and students' thinking activities are weak. Some teachers only consider HOTS as a process that can only be done individually. Teachers do not know the right way to increase student HOTS in the learning process in the classroom [6]. The learning approach used to develop HOTS is too difficult for students who have limited creative thinking knowledge and skills. The low HOTS is triggered by some teachers perceiving HOTS as a process that is only done individually. Teachers do not know the right way to increase students' HOTS in the learning process in class. Meanwhile, the purpose of science education is to educate students to adapt to different conditions, think flexibly, ask questions, be creative, think critically, respect society, and be tolerant of ideas. Several things have been done to increase HOTS by applying a science learning approach that aims to the future and compete globally, namely STEM. STEM aims to develop students' HOTS [7]. STEM education provides educators with the opportunity to show students how concepts, principles, and techniques from science, technology, engineering, and mathematics are used in an integrated manner in the development of products, processes, and systems used in their daily lives [8].

Science as a process is nothing but a scientific method, the activity of giving divergent questions in every aspect in the form of open-ended questions and having HOTS. Decision-making through convergent thinking activities is an indicator of high-order thinking students [9]. Indicators analyze ideas that are quite well developed through the ability test instrument that characterizes HOTS. The problem solving studied has not been driven by standard indicators, only based on the assumptions of researchers and conditions in the field [10]. The purpose of ethnoscience learning is to analyze profiles and is proven to contribute to scientific publications on the discussion of local and scientific knowledge in basic formal education can equip students' character and high-level skills. STEM learning refers to the ability to apply an understanding of how intense competition works. Ability is meant by understanding people's native knowledge as a science learning approach that equips students' HOTS. One of the approaches used is ethnoscience-based learning is very important to develop in vocational school science teaching materials, especially it can be integrated into the STEM learning model. Learning by finding your concept through high-order thought processes without leaving culture as a form of environmental care is needed in the 21st century with STEM literacy. Analysis of STEM learning outcomes, type of integration, education level, and year of publication shows that the use of STEM integration of project-based learning (PjBL) in higher education can be done as a preliminary analysis and a basis for research in the STEM field. STEM learning outcomes are integrated to equip students in work readiness and career skills [11].

The STEM model to updating topics in the 21st century to compete globally and solve life issues through STEM literacy. STEM literacy shows the integrated multidisciplinary of science, technology, engineering, and mathematics used in living systems, the condition of qualified STEM career skills is getting lower based on TIMSS and PISA results [12]. The integrated STEM approach in learning has the potential to equip students' 21st-century work skills through learning outcomes. Assessing the integration of STEM in learning to map the results of STEM research at the science education level undertaken. Researchers are limited in studying it because of the large number of STEM areas covered. The STEM domain is limited to information on growing student HOTS and the contribution of STEM integration. Based on the identification of research problems, it is necessary to have a solution in using STEM that can grow student HOTS through literature reviews. The research objectives are: i) Analyzing the research process based on the integration pattern, methods, analysis techniques, and findings resulting from STEM in growing vocational high school students' HOTS; ii) Analyzing the findings of research publications on Google Scholar and Scopus in 2016-2020 regarding STEM in growing vocational high school students' HOTS.

2. RESEARCH METHOD

This type of literature study used a systematic review approach [13]. Accountable sources to build a reliable evidence base for research recommendations. Sources of data are taken based on articles published by Google Scholar, Elsevier, Scopus, and Science Direct in 2016-2020. The steps used in this research are presented in Figure 1. A systematic review has been defined as a scientific process governed by a set of explicit rules and demonstrates the completeness, immunity from bias, transparency, and accountability of inclusion and exclusion techniques. The systematic review process is carried out based on crucial inclusion questions in the research objectives, namely: i) Analyze the STEM integration pattern in growing vocational high school students' HOTS; ii) The important contribution of STEM which can grow HOTS of vocational school students. The keywords used in the search for sources are: HOTS, vocational school, STEM, and natural science. The seven steps of a systematic review began with inclusion criteria, then filtered out relevant sources and mapped them out based on research objectives. The synthesis of literature study findings provides conclusions and research recommendations.

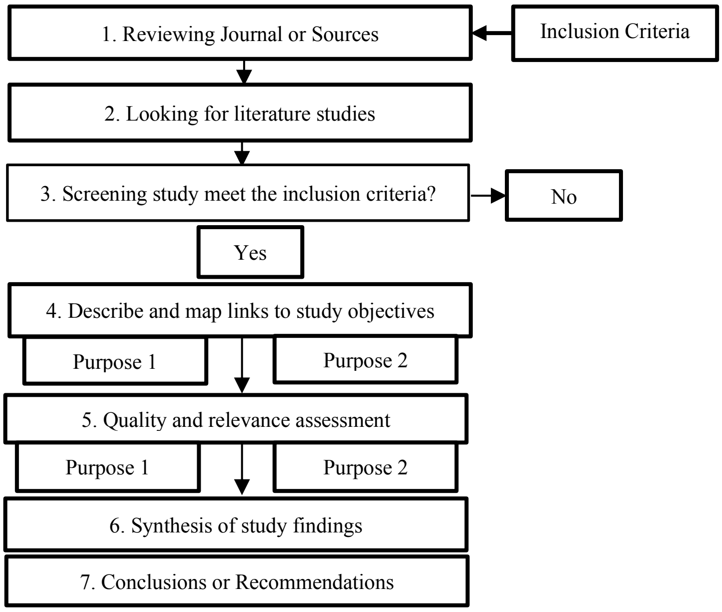

Figure 1. Systematic review process [13]

3. RESULTS AND DISCUSSION

The results of a systematic review show the STEM model as a solution to train students in scientific work and be directly involved in the learning process and produce products. Learning activities to develop HOTS that are not fixated on one solution to the problems they face. However, by bringing up many alternative answers to solving problems on the HOTS indicator. Based on the purpose of the literature review, the importance of HOTS in science learning, the potential of the STEM model to grow students' HOTS, and the relationship between the components of STEM model and the HOTS indicators. Figure 2 presents data findings on Google Scholar publications in 2016-2020.

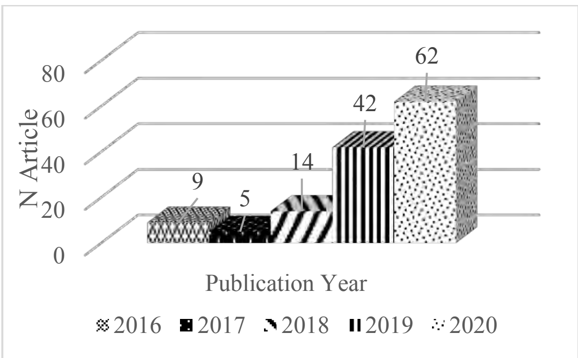

Figure 2. Google Scholar data search results

Furthermore, identifying the inclusion criteria based on the research objectives as shown in Figure 3. Based on the search results for a total of 136 articles, there are 18 articles discussing STEM literacy and HOTS of vocational students, which are presented in Figure 3. Table 1 shows the contribution of STEM in establishing student HOTS based on a review of the integration pattern of the research methods used, data analysis techniques and STEM findings in HOTS.

Table 1 reveals the data source inclusion criteria can be categorized in accredited and non-accredited journals. Accredited journals are journals indexed in the Science and Technology Index (SINTA) to assess journal performance based on accreditation and citation standards. Indexation of national journals that have been accredited by the National Journal Accreditation Institute (ARJUNA). SINTA as the official portal of the Ministry of Research, Technology and Higher Education which contains the measurement of science and technology performance including the performance of researchers, writers, journals, and science and technology institutions is presented in Figure 4. STEM-integrated publication categories, there are differences in the research trends presented in Figure 5. The highest percentage is obtained by the STEM integration pattern in empowering students' HOTS without any special modification with other models or approaches. Furthermore, Table 2 presents the results of the STEM review in the Scopus indexed findings in 2016-2020.

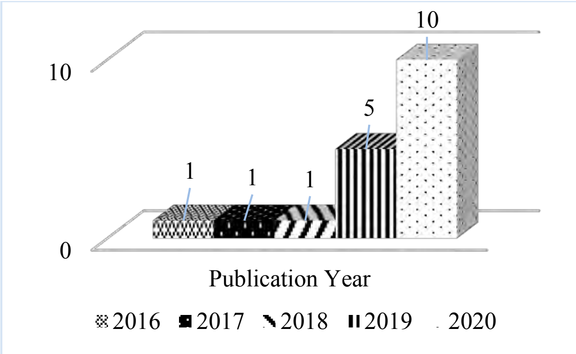

Figure 3. Trend of STEM and HOTS publication based on inclusion criteria

Table 1. Student literature reviews on STEM and HOTS on Google Scholar publication articles (2016-2020)

Data source code	Research methods 1	2	3	4	5	6	Data analysis technique	Research findings	Integration pattern
2016-1	X						Independent t-test	The STEM-PjBL model can improve learning abilities in the form of student HOTS [14]	STEM-PjBL
2017-1		X					Descriptive analysis	Contextual video technology literacy can foster positive student responses and learning outcomes [15]	Technology literacy
2018-1			X				t-test	The responses of students and teachers are very interesting to the STEM module in growing HOTS [16]	STEM
2019-1				X			Descriptive analysis	The teacher's perspective that STEM is very important to be applied to the development of thinking skills and to compete globally [17]	STEM
2019-2	X						t-test	PBL model can add HOTS to students [18]	STEM-PBL
2019-3					X		Descriptive analysis	HOTS empowerment through a scientific framework [19]	Non STEM
2019-4			X				Independent t-test	STEM model in developing process skills in learning [20]	STEM
2019-5			X				Descriptive analysis	HOTS assessment in growing learning outcomes is needed by teachers [21]	Non STEM
2020-1			X				Quasi experiment	The STEM integrated ethnoscience model can cultivate student HOTS [22]	STEM-ethnoscience
2020-2						X	Descriptive analysis	STEM-PjBL can grow student HOTS [23]	STEM-PjBL
2020-3						X	Descriptive analysis	The STEM model in developing students' problem-solving abilities [24]	STEM
2020-4					X		Descriptive analysis	STEM-PjBL teaching materials can grow students' 4C [25]	STEM-PjBL
2020-5					X		Descriptive analysis	HOTS needs analysis using Four Tier Test [26]	Non STEM
2020-6	X						t-test and Gain score	The STEM-PjBL model in cultivating 4C skills [27]	STEM-PjBL
2020-7		X					t-test	PBL model in growing student HOTS [28]	STEM-PBL
2020-8	X						Gain test	Project-based STEM model in cultivating student HOTS [29]	STEM
2020-9			X				Descriptive analysis	The HOTS characteristics of students are in the medium category in science learning [30]	Non STEM
2020-10			X				Validity and reliability test	HOTS-based LKPD development in good category [31]	Non STEM

Information: 1) Experiment; 2) 4D; 3) R&D Borg and Gall; 4) Survey; 5) Qualitative; 6) Library research

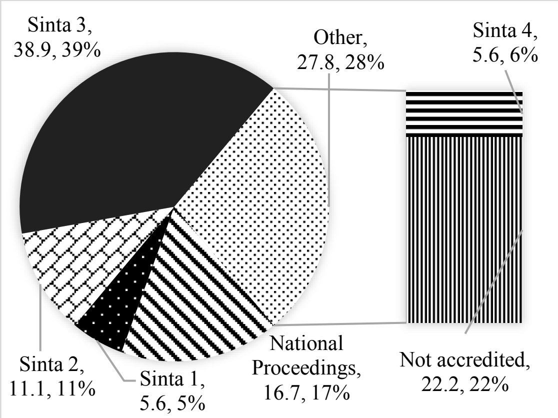

Figure 4. Publication categories based on Google Scholar's indexed findings inclusion criteria

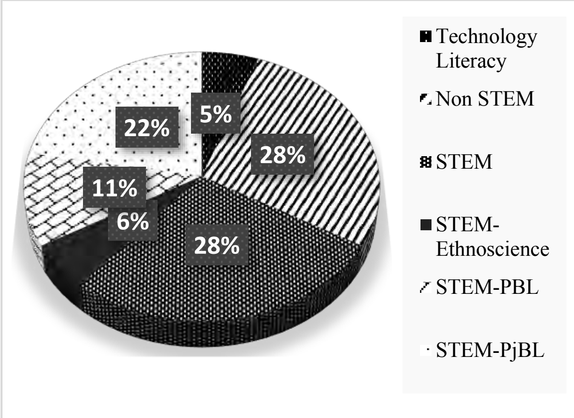

Figure 5. STEM and HOTS integration pattern (Scopus indexed findings)

Table 2. Literature review results for STEM and HOTS in Scopus indexed publication articles (2016-2020)

Data source code	Research methods 1	2	3	4	5	6	Data analysis technique	Research findings	Integration pattern
2018-1	X						Thematic	STEM literacy is implemented in effective learning for student thinking activities [32]	STEM
2018-2			X				Literature narrative	Problem-based STEM literacy can improve thinking skills. [33]	PBL-STEM
2018-3	X			X			Descriptive analysis	Relationship between learning outcomes and STEM learning [34]	STEM
2018-4					X	X	Descriptive analysis	STEM can give students the ability to take initiative [35]	Technology literacy
2017-1	X						Qualitative	Teachers need to implement integrated STEM in learning [36]	STEM
2018-5				X	X	X	Qualitative	STEM education is part of the initiative to improve learning abilities [37]	STEM
2016-1	X						Qualitative	STEM integration is an embryo for advancing curriculum development and student learning outcomes. [38]	STEM
2016-2				X			Qualitative	The integrated STEM framework is a solution to solving problems in learning science and mathematics [39]	Science and mathematic literacy
2018-6	X						Statistic descriptive	STEM can increase student motivation [40]	STEM
2018-7				X			Qualitative and Quantitative	STEM provides opportunities for professional academic performance [41]	STEM
2020-8					X		Qualitative	The importance of teachers implementing STEM in improving the professionalism and thinking skills of students [42]	
2020-7	X						ANOVA test	There is a significant change in students' HOTS [43]	Mathematic literacy
2020-4	X				X		Descriptive analysis	There are differences in learning outcomes between STEM and Non STEM [44]	STEM
2020-5	X			X			t-test	There are differences in students' understanding and analysis in understanding science concepts using STEM literacy [45]	STEM
2020-6	X	X		X		X	ANOVA test	Student responses to STEM careers in increasing interest involving science, technology, engineering, and mathematics [46]	STEM
2019-1				X			Quantitative Descriptive	STEM can increase students' higher order thinking through Nurture through Nature (NtN) [47]	Technology literacy
2019-2			X				Quantitative Descriptive	STEM has a big effect on thinking skills when integrated with technology [48]	Technology literacy
2020-1	X						Descriptive analysis	Technology can develop students' pedagogic competences, creative thinking and critical thinking [49]	Technology literacy
2020-2						X	Descriptive analysis	HOTS can be increased through STEM literacy [50]	STEM
2020-3	X						t-test	There is an increase in students' understanding of use STEM [51]	STEM

Information: 1) Survey; 2) Test; 3) Questionnaire; 4) Observation; 5) Interview; 6) Documentation

3.1. STEM literacy model in growing HOTS

Table 1 and Table 2 show that the form of STEM integration is used differently in growing the HOTS of vocational students. STEM integration is carried out with various research methods and various data analysis techniques so that the information obtained in the literature review gives an idea that the publication trend obtained on STEM and HOTS of vocational students is very complex. A critical review of the findings will provide research recommendations. Furthermore, it explains the contribution of STEM in growing HOTS. There is a similarity in the results obtained by 28% and 65% on the use of STEM and non STEM in growing HOTS (Figure 4 and Figure 5). There is 6% technological literacy part of S-T-E-M literacy, with STEM integration different in principle, because S-T-E-M literacy has its respective roles in growing HOTS. STEM-based science learning is learning science subject matter that integrates system designs and the use of technology for real problem solving, but only a few use technology literacy separately from STEM [16], [17]. The research finding is that technological literacy can increase student positive responses and learning outcomes, not in the realm of developing student HOTS [15]. Furthermore, it is explained in detail about the integration pattern of STEM with the learning model in growing student HOTS as a consideration in recommending further research.

3.2. STEM-PBL integration in growing HOTS

There are 11% and 10% integration of STEM-PBL (Figure 5) showing that the superiority of the problem based learning (PBL) model will occur meaningful learning. Students learning to solve problems will apply knowledge or try to find the knowledge needed [28]. In the PBL model situation, students integrate knowledge and skills simultaneously and apply them in the relevant context. The PBL model can improve critical thinking skills, foster students' initiative in work, internal motivation in learning, and can develop interpersonal relationships in group work. The PBL model is believed to be able to improve the quality of education through the HOTS of vocational students [18]. STEM integration has the potential to give students the opportunity to practice HOTS because it provides problems that must be resolved through STEM literacy with the PBL learning phase.

3.3. STEM-PjBL integration in growing HOTS

STEM-PjBL integration gained 22% indicating practice-based learning as student-centered instruction that occurs over a long period of time, where students choose, plan, investigate and produce products, presentations, or performances that answer real problems. PjBL facilitates the development of communicative competences by collaborating and 'learning by doing'; development of cognitive, metacognitive strategies, and increased motivation, which results in increased language proficiency [27]. PjBL trains students to develop creativity and allow balance in independent learning, as well as problem-solving abilities and carry out effective learning. PjBL encourages the achievement of critical thinking skills, responsibility, collaboration and being able to interact with the world around them [14]. PjBL provides students the freedom to plan learning activities, carry out projects collaboratively in solving problems, and produce work products that can be presented to others that can be used as recommendations in solving their problems. Students work together in groups for long periods of time, looking for various information resources and creating authentic products that are ultimately used as recommendations for problem-solving. Initial problems in learning as the main capital PjBL to collect new knowledge based on real experience through learning activities [27].

3.4. Integration of STEM and ethnoscience in growing HOTS

There is 6% integration of STEM with the ethnoscience approach (Figure 5). The ethnoscience approach is a process of reconstructing original science that develops in society to be transformed into scientific science. Science is the study of natural phenomena that develop in society. It is very relevant if the ethnoscience approach is explained through an integrated learning model with technology, engineering, and mathematics. the reason is that scientific science cannot stand alone. There is a need for further explanations to provide students with comprehensive and holistic skills from various learning domains [22]. The case in the field is that there is a gap between the need and availability of expertise. Referring to the data from the Central Statistics Agency in 2010, Indonesia's 88 million human resources are still dominated by unskilled workers, and it is predicted that in 2020 there will be a 50% shortage of labor. Without efforts to develop basic skills, soft skills (collaboration, communication, creativity, problem-solving), and prerequisite values for entering the STEM profession, it is very difficult to expect young people who are motivated and ready to pursue STEM fields which can be the key to creating a generation in the global arena. Therefore, STEM education needs to be a frame of reference for the education process in Indonesia in the future [8]. The importance of ethnoscience learning for special exploration in empowering student knowledge that has been embedded in students to develop native knowledge in a community and is studied towards formal science as a learning study in schools [52] with packaging integrated learning models, namely use of a modified STEM learning model with an ethnoscience approach (E-STEM).

3.5. Findings of STEM literacy publications in growing vocational school student HOTS

Furthermore, the trend of STEM and HOTS research according to the inclusion criteria in the findings of Google Scholar and Scopus has increased each year in 2016 by 6% and 10%, in 2017 as much as 6% and 5%, in 2018 as much as 6% and 35%. In 2019 as much as 28% and 10%, and in 2020 as much as 56% and 40%. Increasing publication, there are several considerations on learning objectives with STEM literacy. STEM literacy development is not an easy matter. It takes at least a decade to develop STEM education in a country [12]. The development of STEM education requires the participation of science teachers to contribute to the development of STEM-based science learning models. The effectiveness of learning based on classroom-based scientific research includes the development stage in analyzing the content of the subject matter and the field test stage in initiating innovative STEM-based science learning content. The contribution of vocational school in advocating the importance of integrating STEM education into curriculum policies and preparing vocational school graduates must be ready to work with all their skills. Based on the data in Table 1 and Table 2, the use of research methods centered on research and development (R&D) and surveys by developing integrated STEM models and teaching materials that are effective in growing student HOTS. Sample size considerations vary widely depending on the objectives and data analysis. The contribution of HOTS indicators based on the Bloom taxonomy is presented in Figure 6.

Figure 6 shows the activities of developing ideas, connecting different ideas, and formulating ideas to solve certain problems. Students' thinking skills will develop well if done intentionally. Students who have creative thinking skills will easily understand the concept of learning. The HOTS empowerment in STEM learning that is offered can maximize creative thinking process skills through a process of inquiry which ultimately can realize maximum creativity. STEM aims to product learning by integrating. So that the research recommendations on the use of STEM literacy are very important in growing HOTS, but the form of STEM integration used has not been effective, so innovation is needed in the learning model by examining student HOTS indicators. Recommendations have the potential for an integrated STEM ethnoscience approach considering that the HOTS aspect indicator emphasizes the ability to think through complex learning resources. The characteristics of vocational school applied science learning are that students look for other learning resources by exploring their surroundings listed in learning phase, learning outcomes, learning activities, material or subject matter, learning strategy methods and assessment techniques.

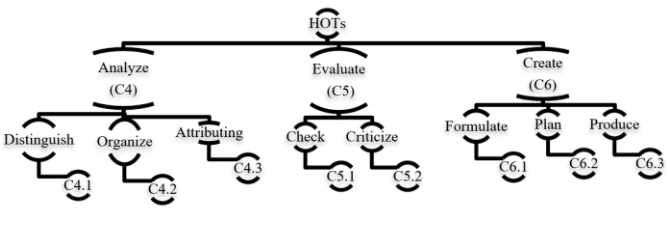

Figure 6. Cognitive process dimension [4]

4. CONCLUSION

The results of the Google Scholar indexed findings from 2016-2020 based on the inclusion criteria were only 18 STEM literacy articles in growing the HOTS of vocational students. The STEM integration pattern in growing the greatest HOTS was obtained by 28% STEM and non-STEM literacy, 22% STEM-PjBL integration, 11%, STEM-PBL, 6% STEM-Ethnoscience, and 5%Technological literacy. Most of the methods used are R&D with data analysis techniques was t-test. Meanwhile, for the Scopus indexed data, most of the data collection methods used a survey with a large sample size of more than 1,000 samples with qualitative analysis techniques. Based on the two sources indexed by Google Scholar and Scopus, it shows differences in publication trends on the integration pattern, the number of samples used is greater in the Scopus data, the method used is more dominant in the survey than R&D. Whatever the research design in STEM literacy is, in principle, it can empower HOTS to increase learning activities, thinking habits, and students' independence through complex learning resources.

The lack of STEM integration pattern with other approaches or models to maximize the increase in HOTS is an important reason to be used as a research recommendation. Integrated STEM will be able to facilitate students in higher-order thinking activities and equip vocational school graduates to be work-ready and globally competitive according to the goals of STEM literacy.

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