The Utilization of the Valid Rubric to Improve High School Students' Real-world Problem-solving Skills in STEM Education

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Abstract: Nowadays, students confront challenges with high-level technology. Thus, they need to learn how they can appropriately use technology. Students learn every subject, such as science, technology, engineering, and mathematics at school separately. Then, when they must find a solution that requires to combine two different subject matters, such as engineering and mathematics, they have difficulties to solve the problem because they do not know how to combine two subjects as one discipline. If a school provides Science Technology Engineering and Mathematics (STEM) education in their curriculum, students will learn how to apply their knowledge to solve the problem. Besides, teachers still use the conventional method to teach students and separate every subject as one independent subject. To analyze students' problem- solving skills, teachers use a rubric to assess students' ability in problem-solving. Even though the teachers use a rubric, the rubric is probably not valid because the rubric cannot analyze students' performance continuously. This research explains the usage of a valid rubric to improve students' problem-solving skills in STEM education. The researcher does a comprehensive literature review as a research method by using more than fifteen sources about STEM education, problem-solving, and a valid rubric of problem- solving skills in the results of this study indicate that students can improve their real-world problem- solving skills in STEM education after they getting feedback based on the proposed rubric.

1 INTRODUCTION

High school students learn every subject, such as science, technology, engineering, and mathematics at school separately. When they must find a solution to a problem by applying two different disciplines, such as engineering and mathematics, they are asked to solve the problem by integrating two different subjects. Winarni et al. (in Widya et al., 2019) examine that STEM education is an integrated learning of science, technology, engineering, and mathematics to improve students' problem-solving skill. STEM education has three principles; STEM education should advance the learning, provide a logical and authentic connection between and across the individual STEM discipline and serve as a bridge to STEM careers (Wilson, 2019). One of the STEM education principles encourage students to have problem-solving skills, which is providing a logical and authentic connection. The goal of learning in the K-12 curriculum is to gain students' knowledge and ability to unravel problems by using an integrated concept. Moreover, some researchers use a rubric to analyze students' problem-solving skills. Doctor et al. (2016) said that rubric need a proof of validity because it should be able to give consistent value when used by anyone and at any time. Therefore, this research will explain how to create a valid rubric that the teacher can use in STEM learning to increase students' real-world problem-solving skills.

2 METHODOLOGY

This paper uses the database from google scholar and Milner Library (EBSCO) at Illinois State University and the target is high school teachers. The researcher divides the literature into three groups, such as STEM education, real-world problem-solving skills, and problem-solving rubrics. The keywords that the researcher uses are "STEM education," "problem-solving," "problem-solving rubrics", and "valid rubric." There are five studies about STEM education, one resource describes the STEM education principle, and three types of research of implementation of STEM education, three studies

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explain the problem-solving skills. Eight kinds of research discuss rubric for assessing problem-solving skills. Those groups of papers are combined to make one conclusion of the literature review, which is the criteria of rubrics that teachers can use for assessing students' real-world problem- solving skills.

3 BACKGROUND

Williams (2011) reviewed the STEM education research and produced a literature review about reasons why STEM education has not been implemented yet at school. For example, the teachers already teach all subjects in one class, so integrated STEM education is not essential. The article revealed that STEM education developed from a non-educational rationale. Besides that, elaborating science, mathematics, and technology appears not to be taken seriously. The author mentions that integrating science and mathematics will reduce technology use rather than engineering. In other perspectives, STEM education is not successful because teachers do not understand their content and learning process design, and students cannot transfer one subject to other subjects. Therefore, the teacher should believe that interaction between disciplines will improve students' learning. Other reasons why STEM education is needed today is mentioned by Bell (2016), he examined the need for teachers who has high qualification professional people in STEM is increased. The article explains that an integrated STEM curriculum is needed because students become aware of real-world relations. The author uses phenomenography as a methodology in his research, and it is a method by learning the phenomena. When students learn STEM education, they should understand how STEM is interconnected in the implementation of different STEM disciplines to solve the problems (Ejiwale et al., 2013).

Furthermore, there are three STEM education principles described by Wilson (2019); STEM education should develop learning, provide a logical and reliable connection between and across the individual STEM disciplines, and serve as a bridge to STEM careers. According to those principles, STEM education should provide a logical and reliable connection, which means the technology can engage creative thinking and real-world problem- solving. In addition, integrated STEM education can guide students to get knowledge for a suitable solution for human needs. The researcher recommended some actions, such as starting the STEM education for elementary grades, engage parents' perception of STEM education, implementing project-based or problem-based learning, and encourage students with STEM-focus, in and outside of school practical learning occasions. Those principles can help teachers to develop the learning process, which improves students' real- world problem-solving skills. For instance, English (2016) said that STEM education should encourage students to use knowledge and skills for multiple disciplines. The authors explain STEM integration correlates with Common Core State Standards for Mathematics and Next Generation Science Standards. Besides that, STEM education can be integrated from multidisciplinary to interdisciplinary. The authors describe an excellent development of STEM that can make students get twenty- century skills, such as the inquiry process, problem-solving, critical thinking, creativity, and innovation. Therefore, students are encouraged to create new and productive connections in more than two disciplines. The researcher proves that real- world problem-solving skills can be advanced through STEM education based on its principles.

Meyrick (2011) described STEM education gain students' knowledge, make students learn the topics more in-depth, and increase the skill to solve the problem so that students will be more creative and innovative. Zhang (2017) explained that students could not solve real-life problems routinely, so by involving a problem-based learning process, students can study to solve open-ended problems. In addition, Basu et al. (2015) explained that undertaking the real-world problem can encourage students' problem-solving skills and make them an independent and competent learner. Moreover, Ferreira and Trudel (2012) explained problem-based learning gives an impact on problem-solving skills and a sense of community in the classroom. The authors mentioned that problem-based learning increases students' analytical and reasoning skills to develop a solution to the problem. Euefeuno (2019) described the four steps to do problem-based learning in STEM education, such as identify the problem, design, evaluate, and communicate the solution. It helps students to follow the learning process.

The problem-solving skills can be measured by using a rubric of problem- solving. Docktor et al. (2016) presented an assessment for students' problem-solving skills in Physics. They said that physics is a foundation of STEM education to teach problem-solving. If students want to be an expert on solving the problem, they must integrate their knowledge with the problem- solving framework. Assessing problem- solving skills is needed as a

rubric because it can be used for measuring different scopes of performance and standards of achievement for each of the ranges, and it has consistent scoring rates. The researcher used Minnesota Assessment of Problem Solving (MAPS), which is applied in the classroom activities, such as written problem solutions. There are requirements to make a rubric, such as easy to use, usable in the authentic situation, have evidence for its validity, reliability, and utility. The rubric in their article has five criteria, namely useful description, physics approach, specific application of physics, mathematical procedures, and logical progression. Moreover, Medina, et al. (2013) described the rubric of problem-solving is designed to evaluate four areas that is answer selection, answer prioritization and defense, organization of the respond, and evidence. The results showed that students can improve their problem-solving skills after they get feedback from the teacher based on the problem-solving rubric.

Docktor et al. (2016) used a valid rubric to assess students' problem-solving skills, and it is different from Hull et al. (2013) who studied the development of problem-solving assessment and rubrics which is included physical situation and mathematical description. The article mentions that they continue the global rubric and modifying it by adding mathematical procedures to the rubric. Another possibility is adapting the comprehensive rubric to build a rubric by engaging the conceptual and formal mathematical reasoning. Therefore, this article described that guiding students to blend both theoretical and mathematical reasoning can improve students' problem-solving skills. The problem-solving rubrics can be useful for researchers or teachers to teach students about the problem- solving and how their works are assessed. In addition, the researcher explained the problem-solving strategies, such as visualize the problem, describe a problem, plan a solution, execute the plan, and check and evaluate.

In term of rubric validation, Mustapha, et al. (2016) mentioned that a rubric should present flexibility and consistencies among teachers or raters. Eseryel et al. (2013) designed an article about the validation of assessment for ill-structured problem solving in interdisciplinary STEM education on ninth-grade students. The researcher said that valid assessment for problem-solving skills could improve the progress of learning outcomes. They used two methods for their research, such as problem-solving rubrics and HIMATT (High Integrated Model Assessment Technology and Tools). As a result, both the assessment methods gave significantly difference to student's learning outcomes after the students got the treatment. HIMATT provided the indicator of the quality of ill- structured problem-solving in complex domains, such as STEM education. This article prefers using HIMATT because it is more valid than a problem- solving rubric. Memarian and Mccahan (2018) explained that making the problem-solving VALUE rubrics which presents high achieving descriptor for the indicators through two steps, such as creating the descriptor and mapping the descriptor topics. Six faculty members validate the rubrics, and they made a focus group discussion about revising the description and indicators. The author found that a rubric should have incorporate representation on the problem and solution level, to be more specific to a particular issue and increasing the level of the descriptor.

Dahm (2014) created rubrics to analyze students' outcomes, which has four indicators, and each indicator has four different levels (Figure 1) in STEM education. There was a proof that this rubric has significant consistency for assessing students by different evaluators. Moreover, Gray et al. (2017) developed Quantitative Literacy VALUE Rubric from the Association of American Colleges and Universities to analyze students' works sample in a STEM course. This rubric contains six skills, such as interpretation, representation, calculation, application, assumptions, and communication which has four-point Likert scale each skill. Gray et al. (2017) discussed that there is an issue to assess students' performance because of the possible rater bias and the differences score among rater; thus, there should be a validation for the rubric. The result of their study is the Quantitative Literacy VALUE rubrics gives consistency score in analyzing students' performances.

Indicator	*4*	*3*	*2*	*1*
Formulates appropriate solution strategies	Can easily convert word problems to equations. Sees what must be done	Forms workable strategies, but may not be optimal. Occasional reliance on brute force	Has difficulty in planning an approach. Tends to leave some problems unsolved	Has difficulty getting beyond the given unless directly instructed
Identifies relevant principles, equations, and data	Consistently uses relevant items with little or no extraneous efforts	Ultimately identifies relevant items but may start with extraneous info	Identifies some principles but seems to have difficulty in distinguishing what is needed.	Cannot identify and assemble relevant information
Systematically executes the solution strategy	Consistently implements strategy. Gets correct answers	Implements well. Occasional minor errors may occur	Has some difficulty in solving the problem when data are assembled. Frequent errors.	Often is unable to solve a problem, even when all data are given
Applies engineering judgment to evaluate answers	Has no unrecognized implausible answers	Has no more than one if any unrecognized implausible answers. If any it is minor and obscure	Attempts to evaluate answers but has difficulty. Recognizes that numbers have meaning but cannot fully relate.	Makes little if any effort to interpret results. Numbers appear to have little meaning

Figure 1. Sample rubric for the outcome "students will demonstrate an ability to apply knowledge of mathematics, science, and engineering (Dahm,2014)."

Nevertheless, there are threats to validate a rubric, such as subjective and illogical coding rubrics (Arffman et al., 2015). The distinction between the criteria is uncertain but relied on subtle, subjective difference, illogical, counteractive, and inconsistent standards make biased grading of students' performance. Then, Ge et al. (2011) who said that rubric is needed to investigate the critical thing in the process of problem-solving skills because students have different abilities to solve real-life problems. In the article, the author designed the problem-solving rubric and validated through nine versions of rubrics samples scoring and continuously testing. The rubrics have two or three scoring criteria for two aspects problem representation and generating the solution.

The scoring was done by two professors in the same field and two raters from a different area. When the assessors have different total scoring, which is more than one point, they discussed it and made final scoring. Another research from Lertyosbordin et al. (2019) created a problem-solving rubric for computing science. The author validated the rubrics through five professors in computing science and five raters. The results of grading are discussed and summarized to be some standards, such as best, average, and miserable.

4 DISCUSSION

The previous research describes the improvement of students' problem-solving skills in STEM education, but they did not explain what kind of rubric they used to assess students and how to develop and validate the rubric in different fields. Therefore, this literature review only discusses the connection between the utilization of a valid rubric and the problem - solving skill in STEM education. From this literature review, the reasons why STEM education is not implemented yet at schools is because some teachers do not understand the importance of STEM education and the needed for professional people with high qualifications in the STEM fields. Therefore, it is not only teachers who need to understand STEM education, but also the school administration and students because students will gain their knowledge from integrated subject. Based on the principles of STEM education, which is STEM education logically connect every subject, teachers can advance the learning process in STEM education. Therefore, teachers can improve students' problem-solving skills through the learning process, which is developed by the teacher using appropriate rubrics.

In addition, the literature review explains that teachers should integrate their methodology of teaching students in STEM education. The teachers also should know how to approach students to make students interested in learning and understand the STEM field. The methodology can be problem-based learning. As Ferreira and Trudel use problem- based learning to teach STEM, they use a rubric to know the development of students' problem-solving skills. The result shows significant differences in students who learn with problem-based learning. Therefore, before teachers start to teach STEM education, the teacher should make a rubric to analyze the students' problem-solving skills. Thus, the teacher will know the ability of their students and can increase students' real-world problem- solving skills.

Moreover, the rubric should contain identification of the problem situation, defining problem, evaluation alternative plan, implementation of the solution, communication of the plan. For instance, STEM education uses the VALUE rubric to assess students' performance. VALUE rubric has six skills to be analyzed, which is the same with problem-solving skills, such as interpretation, representation, calculation, application, assumptions, and communication. This rubric is valid because after the rubric is tested for the validation, the results showed that the VALUE rubric gives a consistency score for students.

Furthermore, the rubric should be flexible and consistent because the raters have a different perspective, and it will impact the result of students' performance. According to the literature review, there are some steps to validate the rubrics, such as teachers need more than two experts from the same and different field. After the teacher gets the result of revision from the experts, they test the rubric to know the validity and reliability. If the results say that the rubric is reliable and valid, teachers can use it to analyze students' problem-solving skills.

Teachers can assess students' performance based on the component of their rubric. First, teachers could know how students identify the problem. This component analyzes students' critical thinking skills. Second, the creativity of students could be assessed by how students design the solution for the problem. Then, students evaluate the solution to ensure that the solution can be used to solve the problem.

Communication skills can be assessed when students communicate the solution that they find to solve the problem. In the end, teachers can be more precise in analyzing students' performance and can improve students' problem-solving skills in real-world issues in STEM education.

5 CONCLUSIONS

Students cannot solve real-life problems correctly because they do not know how to integrate multiple disciplines. STEM education can increase students' problem- solving skills by applying integrated multi-discipline concepts. This skill could be perceived by using an assessment that are provided by a rubric. Therefore, the teacher needs to have a valid rubric to improve students' real-life problem-solving skills in STEM education. Thus, the teacher can advance their learning methodology to enhance students' problem-solving skills.

A rubric should contain four components, such as identifying the problem, creating a plan of solution for solving the problem, evaluating the solution, and communicating the solution. The steps of rubric validation are a revision by more than two experts in the same and different fields and testing the rubric. Teachers can use the rubric after the rubric is proved that it is valid and reliable to analyze students' real-world problem-solving skills in STEM education.

In contrast, there is a lack of information about how significant the impact of using a valid rubric in STEM education to improve students' problem-solving. Therefore, there could be future research to measure the improvement of students' real- life problem-solving skills in STEM education. It could be research about the students' interest in STEM education based on the results of the assessment by using a valid rubric. The teacher can analyze whether students can solve the real-world problem step by step based on the correct rubric. After that, teachers can give feedback to the students; then, students will know their ability and increase their skills in problem-solving. Without the rubric, the teacher could not analyze students' problem-solving skills accurately because there is no indicator of problem-solving skills.

REFERENCES

Arffman, I. (2015). Threats to validity when using open-ended items in international achievement studies: Coding responses to the PISA 2012 problem-solving test in Finland. Scandinavian Journal of Educational Research, 60(6), 609–625. doi: 10.1080/00313831.2015.1066429

Basu, S., Kinnebrew, J. S., Shekhar, S., Caglar, F., Rafi, T. H., Biswas, G., & Gokhale, A. (2015). Collaborative Problem Solving using a Cloud-based Infrastructure to Support High School STEM Education. Proceedings of the ASEE Annual Conference & Exposition, 1–21. Retrieved from https://search-ebscohostcom.libproxy.lib.ilstu.edu/login.aspx?direct=true&db =a9 h&AN=116025167&site=ehost-live&scope=site

Bell, D. (2016). The reality of STEM education, design, and technology teachers' perceptions: A Phenomenographic study. International Journal of Technology & Design Education, 26(1), 61–79. https://doi-org.libproxy.lib.ilstu.edu/10.1007/s10798-015-9300-9

Dahm, K. (2014). Combining the Tasks of Grading Individual Assignments and Assessing Student Outcomes in Project-Based Courses. Journal of STEM Education: Innovations & Research, 15(1), 20–31. Retrieved from https://search-ebscohostcom.libproxy.lib.ilstu.edu/login.aspx?direct=true&db=a9h&AN=96381826&site=edslive&scope=site

Docktor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., … Yang, J. (2016). Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. Physical Review Physics Education Research, 12(1). doi: 10.1103/physrevphyseducres.12.010130

Ejiwale, J. A. (2013). Barriers to Successful Implementation of STEM Education. Journal of Education and Learning (EduLearn), 7(2), 63. doi: 10.11591/edulearn. v7i2.220

English, L. D. (2016). STEM education K-12: perspectives on integration. International Journal of STEM Education, 3(1). DOI: 10.1186/s40594-016-0036-1

Eseryel, D., Ifenthaler, D., & Ge, X. (2013). Validation study of a method for assessing complex ill-structured problem solving by using causal representations. Educational Technology Research and Development, 61(3), 443–463. doi: 10.1007/s11423-013-9297-2

Euefueno, W. D. (2019). Project-/problem-based learning in STEM: impacts on student learning. Technology & Engineering Teacher, 78(8), 8–12. Retrieved from https://search-ebscohost-com.libproxy.lib.ilstu.edu/login.aspx?direct=true&db=iih &AN=136066910&site=eds-live&scope=site

Ferreira, M, and Trudel A. R. (2012). The Impact of Problem-Based Learning (PBL) on Student Attitudes Toward Science, Problem-Solving Skills, and Sense of Community in the Classroom. Journal of Classroom Interaction, 47(1), 23–30. Retrieved from https://search-ebscohostcom.libproxy.lib.ilstu.edu/login.aspx?direct=true&db=e ft&AN=83525495&site=eds-live&scope=site

Ge, X., Planas, L. G., & Eseryel, D. (2011). Developing Valid Assessment Methods and Scoring Rubrics to Measure Ill-structured Problem-Solving Performance. American Educational Research Association.

Gray, J. S., Brown, M. A., & Connolly, J. P. (2017). Examining Construct Validity of the Quantitative Literacy VALUE Rubric in College-Level STEM Assignments. Research & Practice in Assessment, 12, 20–31. Retrieved from https://search-ebscohost-com.libproxy.lib.ilstu.edu/login.aspx?direct=true&db=e ric&AN=EJ1149590&site=eds-live&scope=site

Hull, Michael M., et al. (2013). Problem-Solving Rubrics Revisited: Attending to the Blending of Informal Conceptual and Formal Mathematical Reasoning. Physical Review Special Topics - Physics Education Research, vol. 9, no.1, doi:10.1103/physrevstper.9.010105.

Lertyosbordin, C., Maneewan, S., Yampinij, S., & Thamwipat, K. (2019). Scoring Rubric of Problem-Solving on Computing Science Learning. International Education Studies, 12(8), 26. doi:10.5539/ies. v12n8p26

Mustapha, A., Samsudin, N. A., Arbaiy, N., Mohamed, R., & Hamid, I. R. (2016). Generic Assessment Rubrics for Computer Programming Courses. The Turkis Online Journal of Educational Technology, 15(1), 53–68. Retrieved from www.tojet.net/articles/v15i1/1516.pdf

Medina, M. S., Conway, S. E., Davis-Maxwell, T. S., &Webb, R. (2013). The Impact of Problem-Solving Feedback on Team-Based Learning Case Responses. American Journal of Pharmaceutical Education, 77(9), 189. doi: 10.5688/ajpe779189

Memarian, B., & Mccahan, S. (2018). Development and Validation of Descriptors for Universal Problem-Analysis Rubric. Proceedings of the Canadian Engineering Education Association (CEEA). doi: 10.24908/pceea. v0i0.9687

Meyrick, K. (2011). How STEM Education Improves Student Learning. Meridian K-12 School Computer Technologies,14(1). Retrieved from https://meridian.ced.ncsu.edu/archive/summer2011/m ey rick/index.htm

Widya, Rifandi, R., & Rahmi, Y. L. (2019). STEM education to fulfil the 21st century demand: A literature review. Journal of Physics: Conference Series, 1317, 012208. doi:10.1088/1742-6596/1317/1/012208

Williams, P. J. (2011). STEM Education: Proceed with caution. Design & Technology Education, 16(1), 26–35. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&db=vth&AN=83260111&site=eds live&scope=site

Wilson, H.W. (2019). STEM4: The power of collaboration for change. Technology & Engineering Teacher, 78(6), 1–7. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&db=eft&AN=134708005&site=eds-live&scope=site

Zhang, L, et. al. (2017). Can Students Identify the Relevant Information to Solve a Problem? Journal of Educational Technology & Society, 20(4), 288–299. Retrieved from https://search-ebscohost.com.libproxy.lib.ilstu.edu/login.aspx?direct=true&db=eft&AN=125829920&sit eeds live&scope=siteconcer