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STEM Integrated Approach in Improving Students' Physics Conceptual Understanding

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ABSTRACT

The study on the Science, Technology, Engineering and Mathematics (STEM) integrated approach in improving students' physics conceptual understanding in Indonesia was conducted following the quasi-experimental research design. Samples were determined using purposive sampling involving 30 students. The study sought to determine whether the STEM integrated approach can improve students' physics conceptual understanding. Based on the findings, students *agreed* that the STEM integrated approach can improve physics conceptual understanding. Further, a significant difference in the scores of the students before and after the conduct of STEM integrated approach was observed and a significant relationship was obtained between students' test scores and students' level of agreement in the implementation of STEM integrated approach. Thus, the STEM integrated approach improved students' physics conceptual understanding. It is recommended that seminars, workshops, and in-service training should be organized for effective implementation of the STEM integrated approach in the classroom.

Keywords
Conceptual understanding, STEM education, interactive simulation.

I. BACKGROUND

Introduction

Economic, civic, and global challenges required the education system to develop skills beyond routine knowledge and memorizing skills (Saavendra & Opfer, 2012). OECD's Programme for International Student Assessment (PISA) is conducted to measure the ability of 15 years-old students' to use their reading, mathematics, and science knowledge and skill to solve real-life problems. In general, Indonesian students' performances are very low among 78 countries participating in PISA 2018, with a score of 396 in science, while the international average score is 498 (OECD, 2019). In Indonesia, the national curriculum has undergone significant changes since it was first established in 1947. The recent curriculum, namely Curriculum 2013, emphasizes the importance of conceptual understanding as one of the basic competencies in science learning (Widiyatmoko & Shimizu, 2018).

Conceptual understanding is the main objective of science education. However, teaching instruction is often directed to standardized tests rather than students' conceptual understanding of the subject. Students' achievements are determined from their scores on the standardized test, which does not necessarily reflect their deep understanding in science. Depending on the nature of the test, some students who are good at memorizing might be able to score well although they do not understand the basic concept about the phenomena (Konicek-Moran & Keeley, 2015). Ellis (2013) implies that conceptual understanding enables students to explain and apply their knowledge in new circumstances.

STEM education plays a crucial part in preparing the workforce for the future global economy. As the economic development relies further on science and technology, there will be increasing needs of STEM professionals. Sarı et al. (2018) suggest that problem-based STEM has significantly increased students' interest in STEM disciplines and careers. In addition, STEM education also equipping students with the knowledge and skills needed not only in STEM-related jobs but also for working in other fields. Studies on STEM education show that STEM education effectively improves students' higher-order thinking skills (Wahono et al., 2020) and problem-solving (Suratno et al., 2020).

Extant researches proved that STEM education improves students' learning outcomes and skills. However, more studies on the effect of STEM integration on students' learning outcomes in particular disciplines are needed (English, 2016). This study is intended to investigate the impact of integrating STEM into the standard physics curriculum. Specifically, the effect of STEM integration on physics' conceptual understanding will be explored through the exemplary activity.

Research Questions

This study aimed to determine the effect of STEM in improving students' physics conceptual understanding. Specifically, it aimed to answer the following questions:

1. What is the students' perception of the implementation of STEM integrated approach in physics?
2. Is there any significant relationship between students' perception of the STEM integrated approach and students' improvement in physics conceptual understanding?
3. Is there any significant difference between pretest and post-test scores in physics conceptual understanding?

Theoretical Framework

Implementation of STEM Education

The STEM acronym was initiated in 2001 to replace the acronym SMET (Science, Mathematics, Engineering and Technology), which refers to the career fields or curriculum that integrated knowledge and skills from those disciplines (Hallinen, 2019). Since then, STEM research and education are expanding in many countries around the world. Wahono et al. (2020) define STEM education (enactment) as teaching, learning, and integrating the disciplines and skills of science, technology, mathematics, and engineering in STEM topics, with an emphasis on solving real-world problems. STEM teaching and learning can be implemented in the various form at a different level of integration (see Table 1). A higher level of integration is harder to achieve since it requires more planning, collaboration, and time to execute (Vasquez et al., 2013).

Table 1. Increasing levels of STEM integration (adapted from Vasquez et al., 2013)

Form of integration	Characteristics
Disciplinary	Concepts and skills are learned separately in each discipline.
Multidisciplinary	Concepts and skills are learned separately in each discipline but are linked in a common theme.
Interdisciplinary	Combined concepts and skills from two or more disciplines are learned to enhance knowledge and skills.
Transdisciplinary	Knowledge and skills from two or more disciplines are employed to solve real-world problems or projects to help in shaping the learning experience.

Many studies have been done to identify effective STEM education. STEM enactments are more effective when supported by an approach, learning model, or other methods (Wahono et al., 2020). STEM lesson accompanied by other approach or learning strategies improves students' 21^{st}-century abilities and affective engagement and significantly increases students' interest to pursue STEM-related career (Chen & Chang, 2018; Lee et al., 2019; Sarı et al., 2017). Moreover, Srikoom, Faikhamta & Hanuscin (2018) revealed four dimensions for effective STEM teaching practice and their characteristics for long-term learning (Figure 1). Further, emphasizing the growing role of technology in human life, the U.S. Department of Education, Office of Educational Technology (2019) highlighted nine important aspects of STEM learning. With the support of digital technology, STEM learning provides dynamic representations, collaborative reasoning, immediate and individualized feedback, science argumentation skills, engineering design processes, computational thinking, project-based interdisciplinary learning, embedded assessments, and evidence-based models.

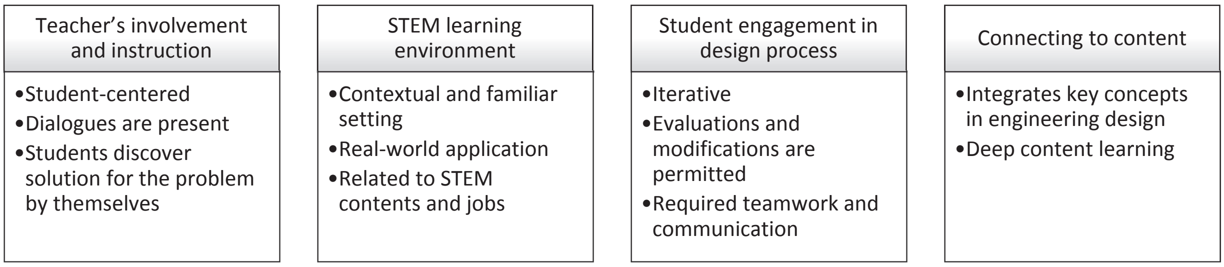

Figure 1. Four dimensions of STEM teaching practice (adapted from Srikoom et al., 2018).

Conceptual Understanding in Science

Conceptual understanding is the main objective of science education. Learning is not merely memorizing facts and formula, but to understand what they are learning. Teaching for understanding prepares students for further learning and perform their role effectively. In his article, David Perkins implies that,

> "*Knowledge and skill in themselves do not guarantee understanding. People can acquire knowledge and routine skills without understanding their basis or when to use them … Understanding something is a matter of being able to carry out a variety of 'performances' concerning the topic …*" (Perkins, 2003, p.2, 6)

Perkins (2003) further explains that 'understanding performances' required critical thinking and analysis, that allow students to apply what they have learned in new situations.

Science is known to be a difficult subject to learn. The nature of science itself, which involves multilevel of conceptual learning, has made it difficult to understand (Johnstone, 1991). For example, in physics there are the macroscopic (phenomena), the invisible (e.g. forces, reactions, electrons), and the symbolic (math, formulae, etc.). Moreover, the methods used, the facilities available, the nature of the learners present further obstacles for students' understanding. Moreover, Gabel (2003) suggests that there is excessive information in the textbooks for the students to grasp. Therefore, teachers and curriculum designers need to examine both the concepts included in the classroom and suitable teaching approach. Several teaching strategies can be integrated to build students' conceptual understanding (Gabel, 2003), which are the learning cycle approach, science/technology/society, real-life situations, discrepant events, analogies, collaborative learning, wait-time, concept mapping, inquiry, and mathematical problem-solving.

The study of Taşlıdere & Eryılmaz (2009) suggests that compare to traditional teaching, conceptual learning effectively improves students' understanding of the main concept, promote critical thinking, and established more positive attitudes toward the lesson. Students become aware of their surroundings by using real-life examples and connecting physics and technology in learning physics. Moreover, the integration of technology has shown positive impacts on conceptual learning. Ellis (2013) recognized that students' conceptual and visual understanding has greatly improved using supplemental web-based software.

II. METHODOLOGY

Research Participants Selection

The study was conducted at Immanuel Christian High School in Pontianak, Indonesia. The school implements the K-13 National Curriculum. The researcher used purposive sampling in the selection of the research participant. No randomization since the study utilized a quasi-experimental research design. There were 30 researchers selected participants in this study. The participants were a class of tenth-grade students (15-16 years old), comprised of 14 male students and 16 female students. All of which have undergone pretest, intervention, and post-test to assess students' improvement in their conceptual understanding in physics. Further, the same participants were subjected to a survey questionnaire to explore students' level of agreement (perceptions) towards the STEM integrated approach in improving conceptual understanding in physics.

Research Instruments

This study utilized a quasi-experimental one-group pre-/post-tests method for this study. This quasi-experimental research design is appropriate to study exploring the effectiveness of a certain intervention. The main instruments utilized in this study were the pretest/post-test test questionnaire and the researcher-made survey questionnaire. Specifically, the pretest/post-test test questionnaire was used to collect students' test scores and statistically evaluate if there is a significant increase in the scores. It contains 10 questions that assess students understanding on the chosen lesson for this study, wherein the maximum score for the tests is 10. On the other hand, the survey questionnaire intends to gather quantitative responses on students' perceptions of STEM approach. Additionally, the said survey questionnaire employed a 5-point Likert type scale, namely; (5) Strongly agree, (4) Agree, (3) Neutral, (2) Disagree, and (1) Strongly disagree and it also contains the four indicators of STEM integrated approach according to U.S. Department of Education, Office of Educational Technology (2019) namely, dynamic representation, immediate and individualized feedback, science argumentation, and engineering design processes.

Further, both instruments were subjected to validation and enhancement to suit the rationale of the study. As part of ensuring the external validity, three external validators validated/enhanced the instruments, and then suggestions and comments were taken and incorporated in the final draft of the instruments. Moreover, the revised test and survey questionnaires have undergone pilot testing to ensure the reliability of the instrument using Cronbach alpha.

Data Collection Procedures

The researchers developed an activity according to the school syllabus in physics. A lesson plan was also crafted containing the STEM integrated approach and how it will be carried out during the experimentation. As shown in Table 2, the lesson was conducted to integrate STEM disciplines to explore the basic concepts and solve real-life problem. The activity was designed for one meeting of approximately 90 minutes. Due to the pandemic, the intervention was regulated online on September 16, 2020.

Table 2. STEM integration in the study

STEM integration	Task Description
Technology	Task 1: Perform on how to build electrical circuits (simple, series, parallel and complex circuits) using the Circuit Construction Kit DC simulation provided by PhET Colorado. Task 2: Measure the currents and voltages at different points in the circuit.
Science	Task 1: Discover how to use ammeter and voltmeter to measure current and voltage in a circuit. Task 2: Compare the characteristics (current and voltage) of series and parallel circuits.
Mathematics	Formulate rules/equations about voltage and current in series and parallel circuits.
Engineering	Design, build, and test a model of electrical system in a house, which incorporates series and parallel circuits, using the simulation.

Data Analysis Procedures

The following data analysis procedures were utilized to obtain the purposes of the study. The determination of students' perception of STEM approach was based on students' responses in the survey questionnaire. The gathered data were statistically treated using mean and standard deviation.

In the quantitative data analysis, raw data of the students' responses on the survey questionnaires and posttest scores were encoded as an excel data format and transferred to IBM SPSS Statistics 21 software for data analysis. The objective of the study is to measure the improvement of students in terms of conceptual understanding in physics using the STEM integrated approach. Thus, a correlation test was utilized in this study. A correlation test was carried out using the Kendall rank correlation coefficient to determine the significant relationship between students' level of agreement and post-test scores.

The main objective of this study is to whether students' conceptual understanding in physics improves using STEM as a teaching approach, therefore the study employed a t-test for paired samples. Further, the t-test for paired samples is a hypothesis test that tests the null hypothesis that the means for both groups are equal, versus the alternative hypothesis that the means are not equal (2-tail) or that the mean for one of the groups is larger than the mean for the other group (1-tail).

III. RESULTS AND DISCUSSION

The Implementation of STEM in Physics

Table 3 shows students' level of agreement on the different indicators for the STEM implementation. The dynamic representation reveals an average mean of 4 or *Agree* in the descriptive equivalent which means that majority of the students agreed that STEM learning using simulation can improve learning especially difficult topics on physics that are impossible to observe in a real setting. The result corroborated with the study conducted by National Research Council (2011) that computer simulations and games have great potential to promote a learning avenue where students can observe and manipulate physical phenomena which are impossible to observe in an actual setting, thus allow them to develop accurate scientific concepts about these phenomena. Also, Choi & Gennaro (1987) argued that simulations may be used to assist the learning of those students that have the low ability on imagining relatively difficult concepts that are critical to understanding the dynamics of systems under observation. Moreover, the implementation of simulation is timely for today's pandemic since it can be used in distance education and as an alternative to hands-on lab activities (Lara &Alfonseca, 2000). Further, the study of Forinash & Wisman (2001) suggested that distance science laboratories are safe and accessible to a student at any time.

The immediate, individualized feedback shows an average mean of 4 or *Agree* in the descriptive equivalent which means that in general students agreed that STEM learning enables them to evaluate their initial responses and misconceptions. National Research Council (2011) suggested that students are motivated in their science learning since simulations allow instant feedback according to their interests and concerns. Further, the study also implied that simulations help them to review their misconceptions and reconstruct scientifically correct explanations. Additionally, the study conducted by Finkelstein et al. (2005) demonstrated that the deficiency in observation provided by simulation can be advantageous since students are focusing attention on certain attributes. Therefore, students are not distracted by the unconstrained environment, which results in productive learning.

Scientific argumentation skills are related to conceptual understanding and critical thinking skills and scientific literacy (Noviyanti et al., 2019). The result of the current research reveals an average mean of 4 or *Agree* in the descriptive equivalent, indicating that students acknowledged the STEM integrated approach enables them to develop their argumentation skills. In this study, students constructed DC circuits and measured the electric current and voltage using an interactive simulation. In addition, they analyzed patterns and differences in series and parallel circuits and formulated scientific explanations about the physical phenomena. Research has shown that students' science argumentation skills can be enhanced through computer-based learning (Office of Educational Technology, 2019). The study of Ellis (2013) showed that web-based software has significantly improved student conceptual and visual understanding of dimensional analysis.

Table 3. Students' level of agreement in the implementation of STEM in physics

No.	Statements	Mean	SD	Descriptive Equivalent
	Dynamic Representation			
1.	I enjoyed learning science using interactive simulation.	4	0.76	Agree
2.	Interactive simulation helped me construct more accurate scientific concepts that would otherwise be difficult or impossible to observe.	4	0.65	Agree
3.	I was able to recognize and evaluate misconceptions through simulation-based learning.	3	0.76	Neutral
4.	I learned science/ physics better using simulations than activities that did not involve simulations.	4	0.86	Agree
	Average	4	0.76	Agree
	Immediate, individualized feedbacks			
5.	The goals of the activity were clear and directed my actions and effort accordingly.	4	0.53	Agree
6.	I was able to evaluate my initial answers for the preliminary questions when using interactive simulation.	4	0.76	Agree
7.	The interactive simulation provided immediate feedback about my responses or misconceptions.	4	0.63	Agree
	Average	4	0.64	Agree
	Science argumentation			
8.	I needed to think critically to present and defend evidence that explains an idea about scientific phenomenon.	4	0.97	Agree
9.	I analyzed ideas that seemed correct but lack supporting evidence.	3	0.83	Neutral
	Average	4	0.90	Agree
	Engineering Design Processes			
10.	In the activity, I designed solution for real-world problem.	3	0.85	Neutral
11.	Digital tools (e.g. interactive simulation) enabled me to test, modify, and improve my design.	4	0.94	Agree
	Average	4	0.90	Agree

The engineering design processes shows an average mean of 4 or *Agree* in the descriptive equivalent which means that students generally agreed that STEM integrated approach incorporates the engineering process for problem-solving. STEM education provides more contextual and relevant learning for students. Vasquez (2015) argued that STEM learning allows students to apply the skill and knowledge they have learned or are in the process of learning to solve real-life problems. In this study, students were involved in an activity using an interactive simulation to build DC circuits. Through the simulation, they discovered the concepts of series and parallel circuits and subsequently design a house's electrical system. Moreover, the Office of Educational Technology (2019) suggested that digital tools are powerful to support the engineering design process. The study of Li et al. (2015) showed that engineering design-based implementation in science learning using Lego bricks has significantly improved students' problem-solving skills.

STEM Integrated Approach and Conceptual Understanding

Figure 2 shows the correlation between students' level of agreement towards the STEM integrated approach and their test scores. It further shows that after the conduct of the said approach one student who responded 5 or strongly agree/favored with the approach obtained a score of nine. Moreover, 14 students who responded 4 or agree/favored in the survey gained six to nine scores. However, 15 students who responded neutral or agree on the approach obtained a score below six. These findings agree with the study of Lee et al. (2019) and Chen & Chang (2018) that the integration of STEM into the educational curriculum has increased students' affective engagement in the lesson. In addition, as cited by Wahono, Lin, & Chang (2020) the duration of the implementation of the STEM integrated approach has considerable effect on the learning achievement. Further, the study recommended that to promote better learning outcomes, it is necessary to employ considerable amount of time towards the application.

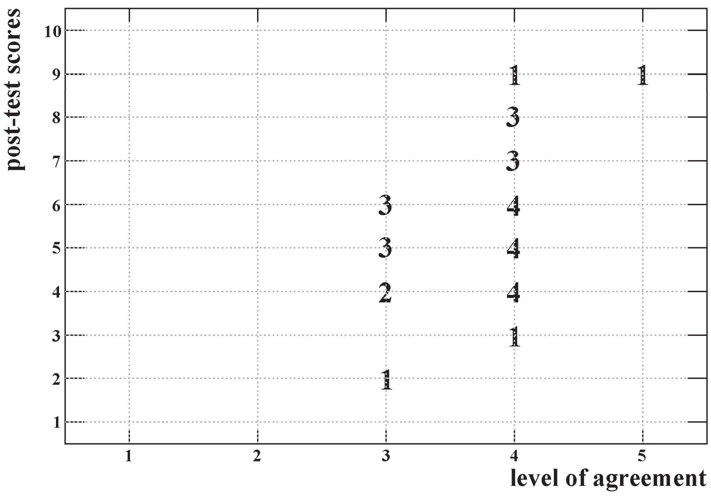

Figure 2. Correlation of the level of agreement and post-test scores

The correlation between students' perception of the STEM integrated approach and the improvement in physics conceptual understanding were analyzed. As shown in Table 4, the *p-value* in sig. (2-tailed) is 0.051 or the correlation coefficient is 0.316 at 0.05 alpha. It means that students' perception of the STEM integrated approach and students' improvement in physics conceptual understanding has a low or slightly significant relationship. The research of Finkelstein et al. (2005) suggested that students acquire benefits from computer-based activities and simulations, such as direct and visualization of the concepts, which presumably hindered when using real equipment. However, the study also argued that students might be impeded by several problems with the operation of new tools, such as computers.

Table 4. The correlation between students' improvement and level of agreement on STEM

		Level of agreement on STEM	Interpretation
Students' improvement	Correlation Coefficient	.316	Low or slight relationship
	Sig. (2-tailed)	0.051	
	N	30	

Students' Improvement in Physics Conceptual Understanding

The study of Wahono, Lin, & Chang (2020) revealed that STEM enactment in Asia effectively improves students' higher-order thinking skills, academic learning achievement, and motivation. It is evidently shown in Figure 3 that the students' scores concentrated above the normal line, which means that after the implementation of the STEM integrated approach, it improves the scores of the students, i.e. conceptual understanding in physics.

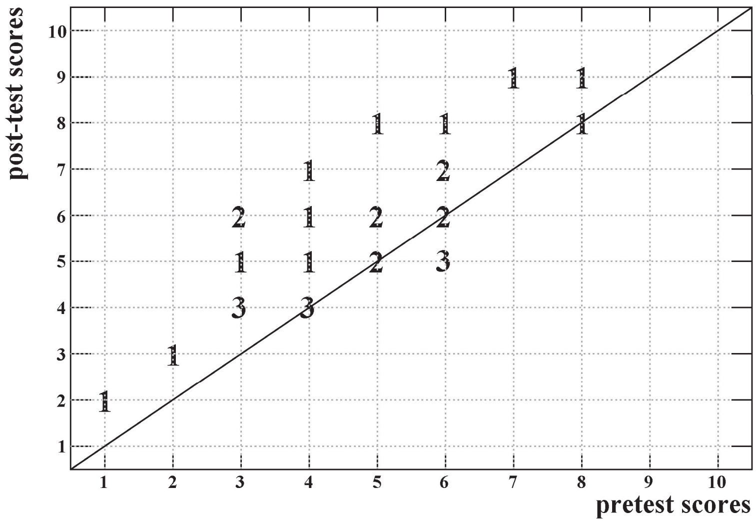

Figure 3. Mapping of pretest and post-test scores

The data in Table 5 shows that there is a significant difference between students' pretest score and posttest score in the implementation of STEM, since the p-value in sig. (2-tailed) is 0.000 which is lower than 0.05 alpha. Thus, the implemented STEM integrated approach improves students' conceptual understanding of physics. The result is congruent with the study conducted by Komarudin, Rustaman, & Hasanah (2017) that STEM-based e-book has great potential to promote students' understanding in science. In addition, the study of Taşlıdere & Eryılmaz (2009) suggested that the integration of technology has shown positive impacts on conceptual learning. They further suggested that conceptual learning effectively improves students' understanding of the main concept, promote critical thinking, and established more positive attitudes toward the lesson. Lastly, students become aware of their surroundings by using real-life examples and connecting physics and technology in learning physics.

Table 5. t-Test of students' improvement in physics conceptual understanding

Description	Pretest	Post-test	Computed t-value	p-value Sig. (2-tailed)	Df
Mean score	4.70	5.63	-4.360	0.000	29

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the findings of the study, the following conclusions were drawn and considered.

1. An average mean of 4 or *Agree* as an overall level of agreement of students in the implementation of the STEM integrated approach in improving conceptual understanding in physics;

2. The improvement of students' conceptual understanding in physics was manifested due to the implemented STEM integrated approach as it showed a low or slightly significant relationship; and
3. There was a significant difference between the scores in the pretest and post-test observed before and after the implementation of the STEM integrated approach. Thus, the STEM integrated approach introduced improved students' conceptual understanding in physics.

Recommendations

Based on the results obtained in the study, it is recommended that:

1. Utilization of STEM integrated approach and explore how it works in a certain subject/discipline is highly encouraged. Moreover, teachers are advised to participate trainings on how to deliver the subject content, teaching style, approach, and the learning materials following this approach. This will allow the teachers to be able to meet the learning competencies especially abstract topics in physics;
2. Conducting similar studies covering different competencies in physics and other abstract lessons in science; and
3. Repeating the same study but bigger number of respondents and longer duration of the experimentation to validate claims.

REFERENCES

Chen, Y., & Chang, C.-C. (2018). The impact of an integrated robotics STEM course with a sailboat topic on high school students' perceptions of integrative STEM, interest, and career orientation. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(12), 1614. https://doi.org/10.29333/ ejmste/94314.

Choi, B. S., & Gennaro, E. (1987). The effectiveness of using computer simulated experiments on junior high students' understanding of the volume displacement concept. *Journal of Research in Science Teaching*, 24, 539-552.

Ellis, J. T. (2013). Assessing the development of chemistry students' conceptual and visual understanding of dimensional analysis via supplemental use of web-based software. *Journal of the Chemical Education*, 90, 554-560.

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(1), 1-8. https://doi.org/10.1186/s40594-016-0036-1

Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P. B., Perkins, K. K., Podolefsky, N. S., Reid, S., & LeMaster, R. (2005). When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment. *Physical Review Special Topics – Physics Education Research 1,* 010103 (2005). DOI: 10.1103/ PhysRevSTPER.1.010103

Forinash, K., & Wisman, R. (2001, September). *The viability of distance education science laboratories*. T. H. E Journal Online. https://thejournal.com/Articles/2001/09/01/The-Viability-of-Distance-Education-Science-Laboratories.aspx?Page=1

Gabel, D. (2003). Enhancing the conceptual understanding of science. *Educational Horizons*, 81(2: Winter), 70-76.

Hallinen, J. (2019, June 28). *STEM*. Encyclopædia Britannica. https://www.britannica.com/topic/STEM-education

Johnstone, A. H. 1991. Why Is Science Difficult to Learn? Things Are Seldom What They Seem. *Journal of Computer Assisted Learning7:* 75-83.

Komarudin U., Rustaman, N.Y., Hasanah, L. (2017). Promoting students' conceptual understanding using STEM-based e-book. *AIP Conference Proceedings* **1848**, 060008 (2017). https://doi.org/10.1063/1.4983976

Konicek-Moran, R., & Keeley, P. (2015). *Teaching for conceptual understanding in science.* NSTA Press, National Science Teachers Association.

Lara, J., & Alfonseca. M. (2001). *Using simulations and virtual reality for distance education*. In Ortega. M., Bravo. J., (Eds.), Computers and Education, Towards an Interconnected Society. Kluwer Academic Publishers, 199-206.

Lee, Y., Capraro, R.M. & Bicer, A. Affective Mathematics Engagement: a Comparison of STEM PBL Versus Non-STEM PBL Instruction. *Can. J. Sci. Math. Techn. Educ.* **19,** 270–289 (2019). https://doi.org/10.1007/s42330-019-00050-0

Li, Y., Huang, Z., Jiang, M., & Chang, T. W. (2016). The effect on pupils' science performance and problem solving ability through Lego: An engineering design-based modeling approach. *Educational Technology & Society,* 19(3), 143-156.

National Research Council. (2011). *Learning Science Through Computer Games and Simulations*. Committee on Science Learning: Computer Games, Simulations, and Education, Margaret A. Honey and Margaret L. Hilton, (Eds.), Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

OECD. (2019). *PISA 2018: Insights and interpretations.* Retrieved from https://www.oecd.org/pisa/PISA%202018%20 Insights%20and%20Interpretations%20FINAL%20PDF.pdf

Office of Educational Technology. (2019). *Innovation spotlights: Nine dimensions for supporting powerful STEM learning with technology*. U.S. Department of Education. https://tech.ed.gov/files/2019/10/stem-innovation-spotlights-research-synthesis.pdf

Perkins, D. (1993). Teaching for understanding. *American Educator*, 17(3: Fall), 8, 22-35.

Saavedra, A.R, & Opfer, V.D. (2012). *Teaching and learning 21st century skills: Lessons from the learning sciences*. Rand Corporation.

Sarı, U., Alıcı, M., Şen, Ö. F. (2018). The Effect of STEM Instruction on Attitude, Career Perception and Career Interest in a Problem-based Learning Environment and Student Opinions. *Electronic Journal of Science Education*, 22(1) 1-21.

Srikoom, W., Faikhamta, C., Hanuscin, D. L. (2018). *Dimensions of effective STEM integrated teaching practice*. K-12 STEM Education, 4(2), 313-330.

Suratno, Wahono, B., Chang, C-Y., Retnowati, A., & Yushardi. (2020). Exploring a direct relationship between students' problem-solving abilities and academic achievement: A STEM education at a coffee plantation area. *Journal of Turkish Science Education, 17*(2), 211-224. https://doi.org/10.36681/tused.2020.22

Taşlıdere, E., & Eryılmaz, A. (2009). Alternative to traditional physics instruction: effectiveness of conceptual physics approach. *Eğitim Araştırmaları-Eurasion Journal of Educational Research,* 35, 109-128.

Vasquez, J. (2014/2015). *STEM: Beyond the acronym*. Educational Leadership, Dec./Jan.,10-16.

Wahono, B., Lin, P-L., Chang, C-Y. (2020). Evidence of STEM Enactment Effectiveness in Asian Student Learning Outcomes. *Journal of STEM Education*, (2020)7:36, https://doi.org/10.1186/s40594-020-00236-1

Widiyatmoko, A., & Shimizu, K. (2018). An overview of conceptual understanding in science education curriculum in Indonesia. *J. Phys.: Conf. Ser.* **983** 012044

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