# STEAM-Integrated Problem-Based Learning: Traditional Indonesian Music on Sound Wave Concepts

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**Abstract:** Conceptual understanding is the level of a student's ability to understand a certain concept and explain it without altering the original meaning. This research aims to determine students' conceptual understanding by using STEAM-integrated Problem-Based Learning on sound wave material. "Mix methods" are used in this research, which is accompanied by an embedded experimental design. The research subject consists of 37 students in 11th grade at SMA Salatiga. Based on the results, it can be concluded that Problem-based learning (PBL) can increase students' conceptual understanding of sound wave material. This is proven by the results of the analysis on their conceptual understanding; where previously it consisted of the partial understanding category (5.41%), partial misconception category (10.81%), specific misconception category (48.65%), and no understood category (35.14%) – and after using STEAM integrated PBL – it consists of sound understood category (35.15%), partial understanding category (48.64%) and partial misconception category (16.21%). In the future, STEAM-integrated PBL can be implemented in other skills, especially the ones needed in the 21st century; such as critical thinking, creativity, communication, and collaboration.

**Keywords:** Conceptual understanding; Misconceptions; Problem-based learning; STEAM

## Introduction

Physics which studies natural phenomena (which are not alive) or matter within the scope of space and time. The interaction between matter and energy will form a natural phenomenon (Darman et al., 2018). An example in our daily lives is sound wave. Although sound is a phenomenon which can be found daily, several students still fail to understand the material regarding this particular topic. This fact is strengthened by Laily's statement (2020) in her research on sound wave, where it argues that 53.28% of students have misconception on that topic. It usually happens since students consider the sound's loudness will affect its frequency, hence the harder an object is hit, the higher its propagation speed will be. Based on this statement; it can be seen that students' intuition regarding amplitude and frequency is still incorrect, in which they cannot differentiate between strong and weak sounds (amplitude) with high and low sounds (frequency)

(Tumanggor et al., 2020). In sound wave, the level of conceptual understanding of $v=\lambda f$ is still low. This is similar with what Adelina et al., (2017) state in her research, where it concludes that based on the data distribution of answers and the level of conceptual understanding, the relationship of $v=\lambda f$ is still not fully understood yet by students who have studied mechanical wave material (Amina et al., 2017). The problem which is often faced in the learning process is misconception. It can be caused by several things, one of which is student's own pre-conceptions; which later will result in their low understanding on the aforementioned concept in physics (Anggara, 2012; Izza, 2021).

The level of ability where students are expected to understand known facts and concepts, as well as for them to explain it with their own words (based on what they know) without altering the original meaning is known as conceptual understanding (Nurlina et al., 2020). In planning and providing solutions for a problem, it is necessary to have a good conceptual

understanding. However, most teachers only focus on solving mathematically rather than on conceptual understanding. Based on the data of PISA in 2018, Indonesia's score on science performance has decreased, namely from 403 to 396 (Tohir, 2019). 35% of students in Indonesia are in the competency group level 1a, while 17% are in the lower level. At the former, students can choose the best scientific explanation in the general context of the data presented (OECD, 2017; OECD, 2019). Most of their conceptual understanding of sound wave is still low. This is similar with what Nindri et al. (2020) has stated in her research on the 11th graders at SMA Tampan Pekanbaru, which argues that the level of students' understanding in sound wave and light wave material is in the very low category (Nova et al., 2020). A research done by Arfiyan et al. (2018) also supports this statement, where in that research; it concludes that most of the students' conceptual understanding is in the low category. It means that they still fail to understand the concept of the relationship between wavelength, speed and frequency (Widiyanto et al., 2018). This problem must be dealt with, one of which is through the development of learning models which are appropriate for the skills needed in this 21st century, which is Problem Based Learning (PBL) (Pratiwi et al., 2019).

Problem-Based Learning is a learning method which presents authentic and meaningful situations or problems to students, which can serve as a start for an investigation (Pratiwi et al., 2019). Its strategy, which represents real world situations, aims to develop students' knowledge and skills in solving a certain problem. It consists of five stages, which are orienting students to problems, organizing students to learn, guiding students to solve problems, Developing and presenting students' wor, Analyze and evaluate problem solving process (Yennita & Zukmadini, 2021). Today, physics learning emphasizes cognitive improvement. It must not only provide concepts, instead it needs to provide skills which lead to physics processes (Sawitri et al., 2021). There has to be a guarantee that each student possesses the skills to innovate and learn, utilize information technology and media, as well as has readiness to work and survive with those skills (Nurlina et al., 2020). Therefore, the implementation of Problem Based-Learning in physics learning is expected to ease students' problem solving process, namely by using a series of scientific methods; since during the learning process, they will be given some phenomena which are often occur in their daily lives (Makrifah, 2017). An approach which is appropriate for this learning model is STEAM. It is important for the students in Indonesia in preparing and training them so as to fulfill the demands of the 21st century curriculum and skills development (Saddhono et al., 2020).

Science, Technology, Engineering, Art, and Mathematics (STEAM) is a learning approach designed with five aspects - which encourage students' curiosity to explore their knowledge (Rahmawati et al., 2020). Those aspects aim to train students to think critically and to possess techniques or designs for problem solving based on the knowledge which they have. In learning process, information is formed through collaboration and creativity. It means that students must hone their skills and learning processes of science, technology, engineering, art and mathematics in thinking and solving problems (Saddhono et al., 2020). In the special case of STEAM, art is used to introduce complementary approaches to creativity (Andreotti & Frans, 2019). The art used in this research is a part of Indonesian culture. Indeed, a culture which can be brought up in sound wave material is no other than Indonesian traditional musical instruments. Students are asked to create Indonesian traditional musical instruments from strings. Researches which focus on STEAM (with aspects of art) combined with local culture to increase students' conceptual understanding are still so few. Therefore, the researcher wants to conduct this research. In this research, musical instrument is chosen since each has its own artistic elements which can be mixed with Indonesian culture. Moreover, it relates to the discussed material, which is sound wave. By using STEAM integrated Problem Based Learning, it is expected that students' conceptual understanding on sound wave material can increase. This research aims to determine students' conceptual understanding using STEAM integrated Problem Based Learning.

## Method

This study uses mixed methods research, with an embedded experimental design. This research focuses on sound wave (strings and organ pipes) implemented to Indonesian traditional musical instruments, and the subject consists of 37 high school students in Salatiga. The data are collected through conceptual understanding test with Cronbach's alpha reliability of 0.75 (in the high category). The test instrument is developed with indicators adapted from a research done by Anderson et al. (2010), which includes cognitive processes; namely interpreting, exemplifying, classifying, summarizing, inferring, comparing and explaining. Furthermore, the researcher also interviews several students (as the qualitative data) to confirm the answers and explore their knowledge on conceptual understanding on sound wave material, as well as takes documentation during the data collection. As for the steps of learning, they are done through STEAM

integrated Problem Based Learning; which can be seen in figure 1.

| Steps | Activities | STEAM Connections |
|---|---|---|
| Orienting Students to Problems | Teacher gives two problems, which are problems related to the learning topic (in order for the students to focus on the concepts being studied) and problems related to the project to be worked on (in order to serve as the start to build students' STEAM skills). | Technology Science |
| Organizing Students to Learn | Teacher divides the students into groups of 4-5 to discuss tools and materials, as well as to discuss product design which will be used to solve a given problem | Science |
| Guiding Students to Solve Problems | Teacher gives student worksheets to guide them to work on products and solve existing problems during product work. | Science |
| Developing and Presenting Students' Work | Teacher assigns students to determine the tools and materials to be used, as well as to design the product to be made. Product work is done outside learning hours. After finishing the product, a group presentation will be conducted, in which students must explain the followings: 1. The concepts and principles of the developed project 2. The reason(s) for using the tools and materials used 3. The difficulties faced while working on the product | Science Technology Engineering Art Mathematics |
| Analyze and Evaluate the Problem Solving Process | Teacher assigns students to criticize the results of the discussion by analyzing, evaluating, as well as drawing conclusions on the concept and principle of the project made. After that, students will receive questions to determine their level of conceptual understanding after the learning process is done. | Science Mathematics |

**Figure 1.** Learning steps of project based learning

The data obtained from this study will be analyzed quantitatively and qualitatively. Quantitative data were obtained from students' conceptual understanding test scores during the pre-test and post-test, the results of the test scores were analyzed using the statistical description test, the normality test, the different test scores of pre-test and post-test, N-Gain score and effect size, While the qualitative data were obtained from the results of student interviews after completing the pre-test and post-test, the results of the interviews were analyzed by category of level of understanding of the concept according to Abraham (1992), as in figure 2.

| Understanding Category | Characteristics of Student Answers |
|---|---|
| Sound Understood (SU) | The answers are correct and contain all scientific concepts |
| Partial Understanding (PU) | The answers are correct and contain at least one scientific concept, and do not have a concept error |
| Partial Misconception (PM) | The answers already provide several correct information, but they still have a conceptual error in the explanation |
| Specific Misconception (SM) | The answers show a basic misunderstanding of the concept being studied |
| No Understand (NU) | Wrong/irrelevant answers, merely repeating the question, empty answer |

(Abraham (1992))

**Figure 2.** Category level of conceptual understanding

## Result and Discussion

The data on students' conceptual understanding are collected from the results of the pre-test, post-test and interviews on the students. The whole data are analyzed qualitatively and quantitatively to determine students' conceptual understanding before and after they utilize STEAM integrated Problem Based Learning. Based on the quantitative analysis, the average score on the pre-test and post-test of students' conceptual understanding of sound wave are 27.51 and 74.54. It shows that there is an increase in students' conceptual understanding after they utilize STEAM integrated Problem Based Learning in their learning process. Furthermore, the data are analyzed using Paired Samples Test, N-Gain and Effect Size to determine the category of students' conceptual understanding. Based on the results of the Paired Samples Test analysis; Sig. (2-tailed) 0.20c,d is found. This shows that STEAM integrated Problem Based Learning can increase students' conceptual understanding. The N-gain and effect size results found are 0.65 (upper medium category) and 0.93 (medium category). This shows that there is an increase in students' conceptual understanding after they utilize STEAM integrated Problem Based Learning in their learning process. The results of the data analysis by using Paired Simple Test, N-Gain and Effect Size also show that there is an increase in students' conceptual understanding after they utilize STEAM integrated Problem Based Learning in their learning process. This result can be seen in Figure 3.
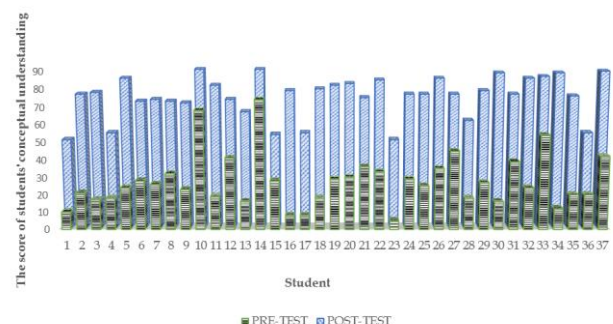
**Figure 3.** Students' increased conceptual understanding after pre-test and post-test

It shows that student's conceptual understanding has increased after they utilize STEAM-integrated PBL in their learning process. During the learning process and when doing projects, they manage to actively interact in class and invoke new ideas to solve problems. This is supported by the results of the research, which shows that there is an interaction between STEAM-integrated PBL and students' conceptual understanding

on their creative thinking skill. By involving students to solve problems, it will ease them to understand the concept being studied (Budiyono et al., 2020). The researcher also conducts interviews with the students on the effectiveness of using this particular learning model in class. Based on the results, students mostly think that learning with STEAM-integrated Problem Based Learning can help them to understand the concept being studied, since they can directly examine the processes. Learning with STEAM integrated Problem Based Learning gives a series of problem solving activities in a real world context - combined with science, technology, engineering, art and mathematics - therefore students will certainly be helped to be more creative in dealing with every challenge. During learning process, teacher must act as a facilitator, and students are hoped to be more active in expressing their thoughts on the problems given (Suwardi & Farnisa, 2018).

In this research, students' conceptual understanding is categorized into several levels based on Abraham's (1992), which are Sound Understood (SU), Partial Understanding (PU), Partial Misconception (PM), Specific Misconception (SM) and No Understood (NU). The percentage of students' conceptual understanding in each category during the pre-test and post-test can be seen in figure 4.



Sound Understood (SU)   Specific Misconception (SM)
Partial Understanding (PU)   No Understand (NU)
Partial Misconception (PM)

■ Pre-test   ■ Post-test
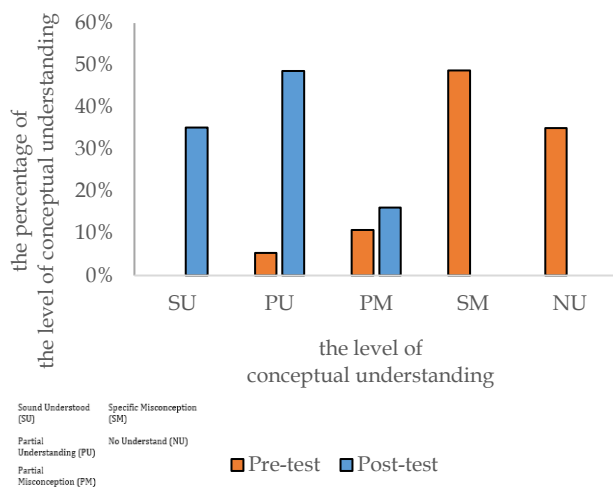
**Figure 4.** The Percentage of the level of students' conceptual understanding in each category

During the pre-test or before the implementation of STEAM integrated PBL, students' answers are in 4 categories, namely no understood (35.15%), misconception (48.64%), partial misconception (10.8%), and partial understanding (5.4%). In the first category, most students only answer the questions provided with short answers and write incorrect results (Winarmi, n.d.). Students can be in this category due to several causes, one of which is the knowledge which they get

during the learning process is not helpful for conceptual understanding of sound wave and its application (Shalihah et al., 2016). Students' answers in the second and third categories have several correct results. However, they still use their own understanding in describing the answers to each question; meaning they have not used the appropriate concept yet. One of the causes of it is that they still maintain their intuition about previously accepted concepts. This causes them to experience difficulties in implementing the concept to their answers (Istiyani et al., 2018). Finally, for the last category, which is partial understanding; most students have answered correctly. However, there are still some errors in determining the variables. This is in accordance with the explanation in the category table, where students manage to answer correctly and contain at least one scientific concept, and do not have a concept error.

After the students utilize STEAM-integrated Problem Based Learning in their learning process, there is an increase in their conceptual understanding, namely from 4 categories to 3 categories (which consist of sound understood-35.15%; partial understanding- 48.64%; and partial misconception-16.21%). During the post-test, most students are in the first category, where they manage to answer correctly and in accordance with the concept learned. It is apparent that they can explain the physics concept which they have learned, which is the relationship between string length and frequency. They are able to explain that the value of the length of the rope with frequency is inversely proportional. The examples of the students' answers in each category contained in the post-test results (namely sound understood, partial understanding and partial misconception) can be seen in figure 5.

Based on the table, students in the first category manage to answer the questions based on the right concept, as well as to use the equations which they have learned. They also compare the frequency results obtained based on the instructions. Now, based on the interviews results, students in this category state that the frequency value and the length of the rope are inversely proportional; hence the longer the rope, the smaller the frequency value will be. Furthermore, their statements are also in accordance with the results of the research, which state that the frequency value will be smaller - since the resulting wavelength value is greater - due to the increase in the length of the rope (Jumini, 2015). Since they manage to answer the questions correctly, it is clear that they belong into the sound understood category. This is similar with the opinion of Uno et al. (2016), in which the competency shown by students in conceptual understanding and in conducting procedures in a flexible, accurate, efficient and precise manner is also a conceptual understanding (Argawi et al., 2021).

Question

5. Lidya dan Kinan memiliki senar gitar dengan bahan yang sama. Senar dipasang pada tegangan yang sama. Panjang senar milik Lidya adalah 100 cm, dan panjang senar Kinan adalah ½ dari panjang senar Lidya. Berapa besar perbandingan nada dasar yang dihasilkan oleh senar milik Lidya terhadap senar milik Kinan?

Sound Understood



Partial Understanding



Partial Misconception



**Figure 5.** The examples of the questions and students' answers in each category

Meanwhile, students in the partial understanding category also answer based on the correct concept and use the equations which they have learned. However, in their final answer, they still include the speed value (v) - which should have been omitted since it has the same value between v1 and v2. Based on the interview results, the students manage to explain the relationship between the frequency of the fundamental note and the length of the string. However, they still cannot explain that the value of v in the same medium has a fixed value; hence they still write the variable v in their final answer. Their statements are in accordance with the research results of Kameo et al. (2020) which show that students' conceptual understanding on wave propagation

through the same medium with different frequencies is still low. The wave velocity value should have been constant, since it is in a fixed medium (rope) when the frequency is increased, and the only thing that will change is the wavelength value (it will decline) (Kameo et al., 2020). Students are considered to be in the partial understanding category if they manage to answer the questions and explain the relationship between frequency and string length correctly. This is in accordance with the opinion of Uno et al. (2016) concerning the first category (Argawi & Pujiastuti, 2021). However, since there is still a slight error in differentiating one of the variables, those students cannot be included in the sound understood category yet, instead they are still in the partial understanding category.

Furthermore, students in the partial misconception category answer the questions based on the concepts and equations being studied. However, in the equation used, there is a variable error. They calculate by entering the variable l or string length into the value n (level of tone sought). Meanwhile, the equation $fn=v/\lambda$ with a value of n actually indicates the tone level sought instead of the known string length. Since there is still a misunderstanding on the concept in the use of equations, it can be considered that these students belong to the partial misconception category. Based on the interview results, they argue that the value of n in the equation $fn=(n+1)(v/2l)$ is the known length of the rope, where the actual value of the fundamental tone frequency (f0) is shown by the equation $f0=v/2l$, with $n=0,1,2,\ldots$ harmonic sequence. Their statements are in accordance with the results of Sutopo's research (2016), which indicate that there are still difficulties in implementing this concept to solve problems, since most students still fail to understand the relationship of $v=\lambda f$ - and many even have signs of misconception (Sutopo, 2016) .

## Conclusion

Based on the data and results of the research analysis, it can be concluded that the students' conceptual understanding has improved thanks to STEAM integrated Problem Based Learning. This research is therefore considered successful. For further research, it is advised for the researchers to explore students' conceptual understanding on other topics by implementing STEAM-integrated PBL.

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