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# Saron Musical Instruments to Improve Creative Thinking Skills in Learning the Concept of Sound Waves

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**Abstract**

*Saron* is a traditional musical instrument that is part of the Javanese gamelan which is close to the people of Bekasi, West Java, Indonesia. As a local wisdom, the *Saron* musical instrument is unique and has the potential to be a real example of sound waves in physics learning. Here we report on integrated science, technology, engineering, and mathematics (STEM). We developed a STEM module to support students in learning the concept of sound waves using the analysis, design, development, implementation and evaluation (ADDIE) method. The STEM module was evaluated by several learning media experts, learning design experts, and learning materials experts. The STEM module was piloted on public high school students in several stages including one-on-one evaluation, small group evaluation, and field testing. Based on the results of the summative evaluation.

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## INTRODUCTION

The current era of the creative industrial revolution is closely related to knowledge activities and technological developments. In this sector, the areas of knowledge creation and innovation are important things that must be implemented in performance activities. Therefore, critical thinking skills, creativity, and digital problem-solving skills are important assets that students must have (Purwati, 2019). Referring to creative thinking according to Torrance, creative thinking is divided into four aspects, namely fluency, flexibility, originality, and elaboration. The results of a preliminary study to determine the level of creative thinking skills carried out in three public high schools in Bekasi, West Java Province, Indonesia. Our preliminary study found that: fluency aspect 63%, flexibility aspect 44%, originality 35%, and elaboration 42.37%. Based on the results of a preliminary study on the level of creative thinking of students, the creative thinking ability of students in Indonesia still needs to be improved.

Steps that can be taken in training students to think creatively and continuously through learning modules that are integrated with Science, Technology, Engineering and Mathematics (STEM). The module is a form of teaching material as a result of printed media arranged systematicallywith language that is easily understood by students, so that students can measure their abilities without the intermediary of the teacher. Research conducted at US Universities focuses on core science and math modules in STEM learning. By using the STEM module, it is hoped that students can make careful plans, and students can manage their needs, one of which can complete their studies more quickly and in a short time (R.L.van der Merwea, 2020). The world organization in the field of education UNESCO revealed that the integration between Science Technology Engineering and Mathematics known as STEM is an aspect that grows in developed and developing countries (Nadlir, 2014). STEM learning leads to the individual's ability to apply an understanding of how intense competition work life that is interconnected amongst the four existing domains, namely science, technology, engineering, and mathematics. In recent years, many countries have started to implement STEM in learning integration. Research in developing countries estimates the effect of student academic performance outcomes, distinguishing between STEM and non-STEM fields. The results found that the effect was found to be greater in STEM subjects (Robert, 2009).

The low ability of student's creative thinking, especially on sound wave material, can be seen from the results of teacher interviews conducted during the preliminary study. In 2017 data for the Indonesian national high school examination showed that 44.67% of students were able to answer the physics exam correctly (Puspendik Kemendikbud). Therefore, it is necessary to improve students' physics learning achievement, especially with sound wave material. Sound wave material can apply STEM which is supported by local wisdom by using local musical instruments. A good study was reported by Nayif and Moshe 2014 that there was an increase in students' learning motivation in studying sound wave material using STEM. The findings of this study indicate that students can successfully study in the integration of STEM subjects including physics, electronics, computer science, or mathematics. The choice of topics that meets students' needs such as sound amplification systems and digital sound are key factors in creating motivation in studying theory and preparing for final exams. This method contributes greatly to students' motivation at school (Rodriguez, 2016).

The application of learning to improve students' abilities in sound wave material, one of which is by integrating a musical instrument in the form of a *Saron* incorporated in a gamelan musical instrument. Javanese Gamelan is one of the traditional musical instruments from Java Island which is currently known internationally as an ancestral cultural heritage inherent in Javanese society. Developed in the era of the Hindu-Buddhist kingdom, the gamelan became a percussion instrument used to accompany various traditions on the island of Java that would give the

distinctive beat of this gamelan (Fathoni A, 2020). Most Javanese people often hold gamelan performances at every celebration or event they organize.

Overall, gamelan is a set of musical instruments that are played by hitting. Gamelan musical instruments are thought to have been known to the general public on the island of Java since 404 BC, as well as the depiction of gamelan games at that time on the reliefs of Borobudur and Prambanan temples. A gamelan set consists of several musical instruments, including a set of musical instruments in the form of drums, xylophone, bonang, fiddle and *celempung*, xylophone, gong, bamboo flute, *siter*, *kempul*, *kethuk*, *kempyang*, *gender*, *Saron*, *slenthem*, *demung*, *manak*, and clay. The main components of the gamelan instrument are bamboo, metal, and wood. Each musical instrument has its function in gamelan music performances. One part of the gamelan instrument is the *Saron*. *Saron* has a function as a regulator of high and low notes in gamelan music performances (Elif Karaa, 2021).

One of the challenges is to keep gamelan in Indonesia so that it can be preserved (Riri, 2017). Re-introducing to students the values of local wisdom in schools, as well as efforts to maintain culture against changing times, maintained and used as teaching materials as well as forming human character. Local wisdom functions as a filter and controller of foreign cultures. To continue to be preserved, the Indonesian government proposed gamelan as an Indonesian cultural heritage, and finally, in 2014, the gamelan was officially recognized by UNESCO (A. Fathoni, 2020).

In developing this STEM learning tool using the ADDIE model,this model is an approach that helps teachers to design efficient and effective teaching by applying the ADDIE model process to learning products. So that the ADDIE model can be used to develop teaching materials in the form of modules that can be used by students in learning independently (Sugiyono, 2008). The ADDIE model is not only used for module development but also the development of sound wave learning media. Research developed by Bambang, *et al.*. Sound resonance training kit 2020 for high school students. This device is designed to analyze the phenomenon of sound resonance and calculate the speed of sound in the air. Research and development are carried out using the ADDIE model (Analyze, Design, Development, Implementation, Evaluation) as a development research method. The device consists of a resonant tube, a piston, (Kristanto A. , 2010).

Bambang, *et al.*. reported sound resonance training devices for high school students. This device is designed to analyze the phenomenon of sound resonance and calculate the speed of sound in the air. Their studies on devices built through research and development through analysis, design, development, implementation, evaluation (ADDIE) models. The device consists of a resonant tube, a piston, (Kristanto A. , 2020). The ADDIE model is not only used to develop learning tools but also to learn modules such as sound wave material. The ADDIE model is an approach that helps teachers design efficient and effective teaching. So that the ADDIE model can be used to develop teaching materials in the form of modules used by students in learning independently.

We developed our STEM module for the concept of sound wave learning in *Saron* instruments as an improvement based on the shortcomings found in the previous development of other researchers. The integrated STEM module of *Saron* instruments is feasible, practical, and effective for learning the concept of sound waves for students. In addition, their creative thinking skills also improved well.

## METHODS

Our *Saron* instrument STEM module is the kind of product development concept that can apply the ADDIE development model (Dick, W. and Carey, L. 1996). The purpose of applying the ADDIE concept here is to build performance-based learning. The educational philosophy for this

ADDIE application is that learning must be student-centered, innovative, authentic, and inspiring (Prasetya, 2012).

In product development research, the product must be developed through 3 stages, namely the validity test phase, effectiveness test, and practicality test. Data obtained through interviews will be processed qualitatively. Data were obtained through a questionnaire with questions using a rating scale with 5 categories of assessment, namely: 5, 4, 3, 2, 1. (Nurlaela, 2019). The data will be converted into quantitative data.

This module, after being developed, was then validated by 9 experts including 3 media experts with IT and physics education lecturer backgrounds, 3 learning design experts with physics education lecturers and physics teachers backgrounds, and 3 material experts with physics lecturer backgrounds. Then the module was tested in a one-to-one evaluation by 3 students with moderate, low, and high abilities. Then the small group was evaluated as many as 9 people with medium, low, and high student abilities. Finally, there were 15 field trials with moderate, low, and high student abilities.

The trial subjects in the implementation of the STEM module for learning *Saron* music were three public high schools in Bekasi, West Java, Indonesia. We chose Bekasi because Bekasi can represent the condition of Indonesian education. Bekasi is a growth area for Jakarta and is part of the Greater Jakarta Area (Jakarta – Bogor – Depok – Tangerang – Bekasi). Most of the Bekasi Regency area is lowland with a hilly southern part. Meanwhile, based on data from the Central Statistics Agency (Biro Pusat Statistik), the population in Bekasi Regency until 2012 was more than 2.7 million people. The population by sub-district is not evenly distributed. The advantages of an economic sector can be seen from its growth. Based on the distribution of the percentage value of GRDP (Gross Domestic Product) of Bekasi Regency from 2007 – 2012 based on current prices, the economic structure of Bekasi City is dominated by the manufacturing sector with a distribution of 77.52% in 2012 (Torrance, 2018). Therefore, Bekasi is good for obtaining a public high school education in Indonesia.

There are three public senior high schools (*Sekolah Menengah Atas Negeri*, SMAN) are: SMAN 1 Cibarusah, SMAN 1 Serang Baru, and SMAN 2 Cibarusah. The sampling technique used by the researcher is purposive sampling. This sampling technique is a data source sampling technique with certain considerations (Lili Herawati Parapat, 2020). The consideration is the suitability of the school location in Bekasi with the research location.

The instruments used in this research are test and non-test instruments which aim to find out information on the feasibility, practicality, and effectiveness of the product being developed. The test instrument used is a test instrument for students' creative thinking skills that have been validated by experts. Then the non-test instrument used interview questionnaires, student responses, and teachers. The interview guide is used as a reference in conducting interviews with physics subject teachers at the preliminary research stage which aims to find out the problems and use of modules in schools. Students' and teachers' responses to questionnaires were used to determine the effectiveness and practicality of the modules made.

## RESULT AND DISCUSSION

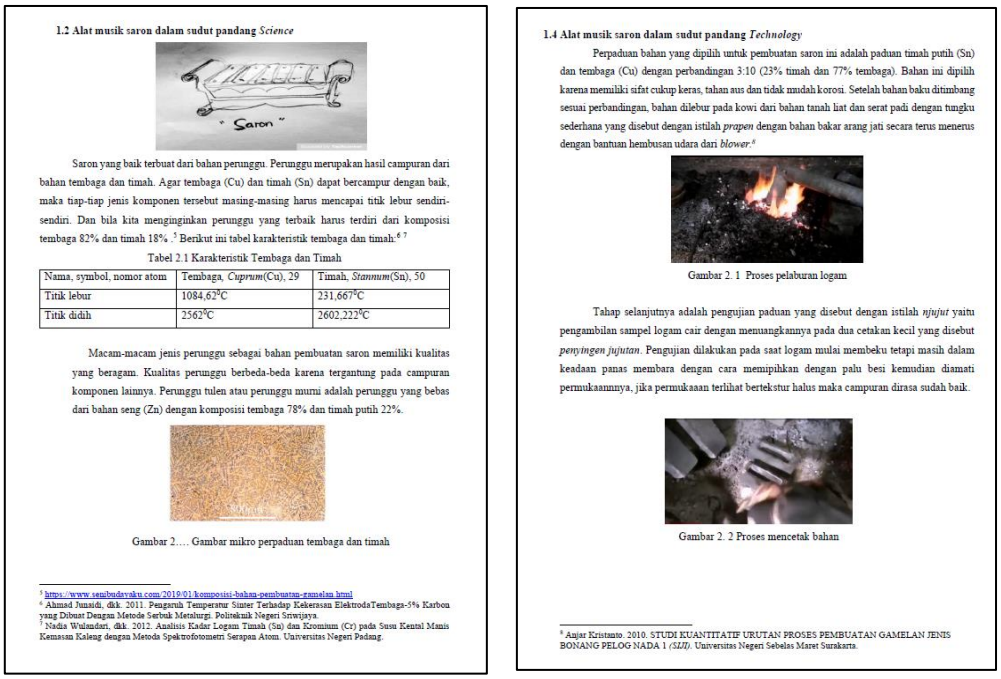
The product resulting from this development research is a STEM learning module that integrates local wisdom, especially in wave material for class XI high school students. The development of the STEM module uses the ADDIE model. The ADDIE model is used for details in the design of student experimental learning. This means a systematic process that helps in creating and developing effective, engaging, and efficient sound wave learning materials in an environment that uses art, science, learning, and instructional theory.

The ADDIE development model has the advantage of having five stages that are interrelated and structured systematically and cannot be done randomly. The following are the stages of the research: the analysis stage, the design stage, the development stage, the implementation stage, and the evaluation stage. The ADDIE model has also been used by other researchers to develop Arduino-assisted voice learning media. The device consists of a resonant tube, piston, sound sensor, Arduino UNO, amplifier, adapter, and cable. Several practices can be tested on this device, including analyzing resonance at room temperature with different frequencies and sound resonance at different temperatures (Kristanto A. , 2010).

The analysis stage is the first stage in developing the ADDIE model. Analysis of learning objectives is done by first analyzing the syllabus and lesson plans to obtain independent learning information about the teaching materials needed by students in learning the competencies that have been programmed.

Curriculum analysis is carried out by considering the characteristics of the curriculum used in schools. These stages are carried out so that the development of STEM modules is based on the existing curriculum. The existing curriculum considers students as inheritors of the nation's creative culture. Through education, we can learn about cultural heritage from the perspective of its culture to create a sense of pride to be applied in everyday life.

The second stage in the ADDIE model is the design stage. The results of the design phase serve to organize the content when the product will be produced so that it can build the knowledge and skills needed by students. The components in the development of STEM modules that are integrated with local wisdom can be seen in Figure 1.



**1.2 Alat musik saron dalam sudut pandang *Science***




Saron yang baik terbuat dari bahan perunggu. Perunggu merupakan hasil campuran dari bahan tembaga dan timah. Agar tembaga (Cu) dan timah (Sn) dapat bercampur dengan baik, maka tiap-tiap jenis komponen tersebut masing-masing harus mencapai titik lebur sendiri-sendiri. Dan bila kita menginginkan perunggu yang terbaik harus terdiri dari komposisi tembaga 82% dan timah 18% .[5] Berikut ini tabel karakteristik tembaga dan timah:[6 7]

Tabel 2.1 Karakteristik Tembaga dan Timah

| Nama, symbol, nomor atom | Tembaga, *Cuprum*(Cu), 29 | Timah, *Stannum*(Sn), 50 |
|---|---|---|
| Titik lebur | 1084,62$^0$C | 231,667$^0$C |
| Titik didih | 2562$^0$C | 2602,222$^0$C |

Macam-macam jenis perunggu sebagai bahan pembuatan saron memiliki kualitas yang beragam. Kualitas perunggu berbeda-beda karena tergantung pada campuran komponen lainnya. Perunggu tulen atau perunggu murni adalah perunggu yang bebas dari bahan seng (Zn) dengan komposisi tembaga 78% dan timah putih 22%.



Gambar 2.… Gambar mikro perpaduan tembaga dan timah

[5] https://www.senibudayaku.com/2019/01/komposisi-bahan-pembuatan-gamelan.html
[6] Ahmad Junaidi, dkk. 2011. Pengaruh Temperatur Sinter Terhadap Kekerasan ElektrodaTembaga-5% Karbon yang Dibuat Dengan Metode Serbuk Metalurgi. Politeknik Negeri Sriwijaya.
[7] Nadia Wulandari, dkk. 2012. Analisis Kadar Logam Timah (Sn) dan Kromium (Cr) pada Susu Kental Manis Kemasan Kaleng dengan Metoda Spektrofotometri Serapan Atom. Universitas Negeri Padang.

**1.4 Alat musik saron dalam sudut pandang *Technology***

Perpaduan bahan yang dipilih untuk pembuatan saron ini adalah paduan timah putih (Sn) dan tembaga (Cu) dengan perbandingan 3:10 (23% timah dan 77% tembaga). Bahan ini dipilih karena memiliki sifat cukup keras, tahan aus dan tidak mudah korosi. Setelah bahan baku ditimbang sesuai perbandingan, bahan dilebur pada kowi dari bahan tanah liat dan serat padi dengan tungku sederhana yang disebut dengan istilah *prapen* dengan bahan bakar arang jati secara terus menerus dengan bantuan hembusan udara dari *blower*.[8]



Gambar 2. 1 Proses pelaburan logam

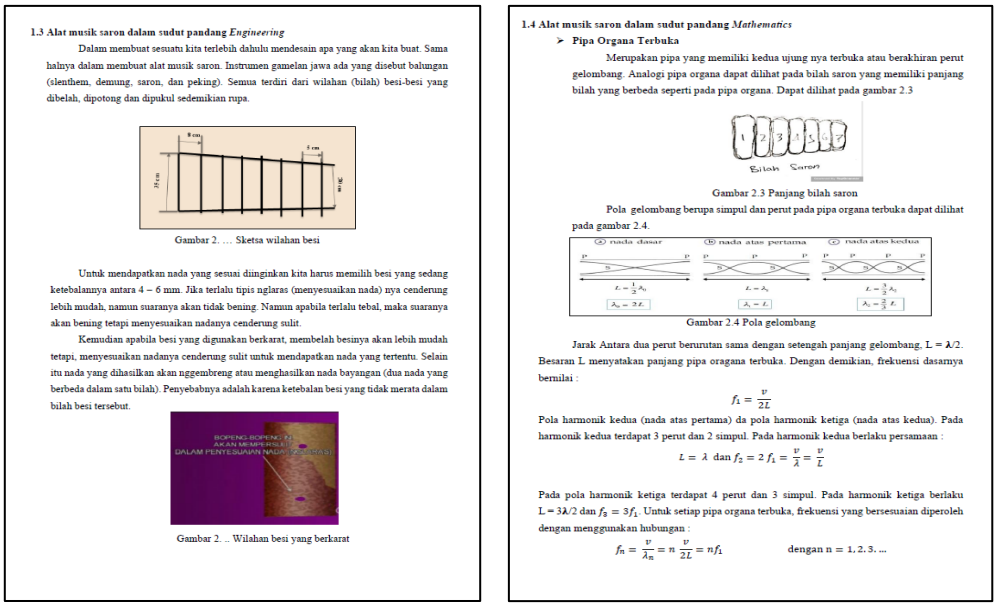
Tahap selanjutnya adalah pengujian paduan yang disebut dengan istilah *njujut* yaitu pengambilan sampel logam cair dengan menuangkannya pada dua cetakan kecil yang disebut *penyingen jujutan*. Pengujian dilakukan pada saat logam mulai membeku tetapi masih dalam keadaan panas membara dengan cara memipihkan dengan palu besi kemudian diamati permukaannnya, jika permukaaan terlihat bertekstur halus maka campuran dirasa sudah baik.



Gambar 2. 2 Proses mencetak bahan

[8] Anjar Kristanto. 2010. STUDI KUANTITATIF URUTAN PROSES PEMBUATAN GAMELAN JENIS BONANG PELOG NADA 1 *(SLJ)*. Universitas Negeri Sebelas Maret Surakarta.

(b)




(c) (d)

**Figure 1**. (a) The science component in the module, (b) The technology component in the module, (c) the engineering component in the module, (d) The mathematics component in the module.

The scientific aspect is the ability to use scientific knowledge and processes to understand the natural world and the ability to participate in making decisions. (Fathoni A, 2020). *Saron* musical instrument in terms of science can be seen from the material of manufacture, namely from copper and tin. They come with different melting point and melting point characteristics,so the resulting quality will be different.

The engineering aspect is the application of science and technology through a project-based design process by integrating several different lessons. *Saron* musical instrument in terms of engineering can be seen from the sketch process or the design of the *Saron* musical instrument. To get the desired tone, we must choose an iron whose thickness is between 4-6 mm. After obtaining the appropriate iron wilahan, first measured and scratched. For the low tone bar size 1 (ji) the length is approximately 35 cm and the width is 8 cm. For the highest note 2 (little ro) 30 cm long and 5 cm wide.

The technology aspect is knowledge of how to use, understand, and analyze new technologies that can affect individuals and society. The *Saron* musical instrument in terms of technology can be seen from the process of making *Saron*. The combination of materials chosen for the manufacture of this *Saron* is an alloy of tin (Sn) and copper (Cu) with a ratio of 3:10 (23% tin and 77% copper). The best quality metal musical instrument products are products made of bronze. Products made of bronze still require a smelting stage to make it (Frendy Purnomo, 2017).

The mathematics aspects are the ability to analyze, reason, and communicate ideas effectively for mathematical problems. The *Saron* musical instrument in terms of mathematics Students understands the formula used to determine the pattern of the harmonic series in an open and closed organ pipe.

The third stage is the development stage which is a combination of the previous two stages, namely the analysis stage and the design stage. The steps that must be taken at this stage are: making the product to be produced, developing the subject matter as a result of input or suggestions, and conducting trials. The material used in this module is sound waves. Sound wave material tends to be difficult for students to understand. Therefore, STEM module learning is needed that can be

integrated with real life. In the module, there are experimental activities and student worksheets. The next stage is the STEM module is validated by lecturers and teachers. Validation is a formative evaluation of students. The validation process uses instruments that have been made in the previous stage. Validation is carried out to assess the validity of the STEM module that will be used.

The first stage of formative evaluation is an expert assessment carried out by several experts consisting of media experts, material experts, and learning design experts. The number of experts involved in media examination is three experts. The number of experts involved in the examination of the material is three experts. The results of the assessment were analyzed in several stages, namely the feasibility of the media and analysis of expert judgment from each aspect and each indicator. The results of the assessment of each aspect by media experts, design experts, and materials experts can be seen in Table 1.

**Table 1.** Assessment results by experts

| No. | Aspect | Percentage | Category |
|---|---|---|---|
| 1. | Media Expert | 95,35% | Very Good |
| 2. | Learning Design Expert | 91,60% | Very Good |
| 3. | Content Expert | 94,74% | Very Good |

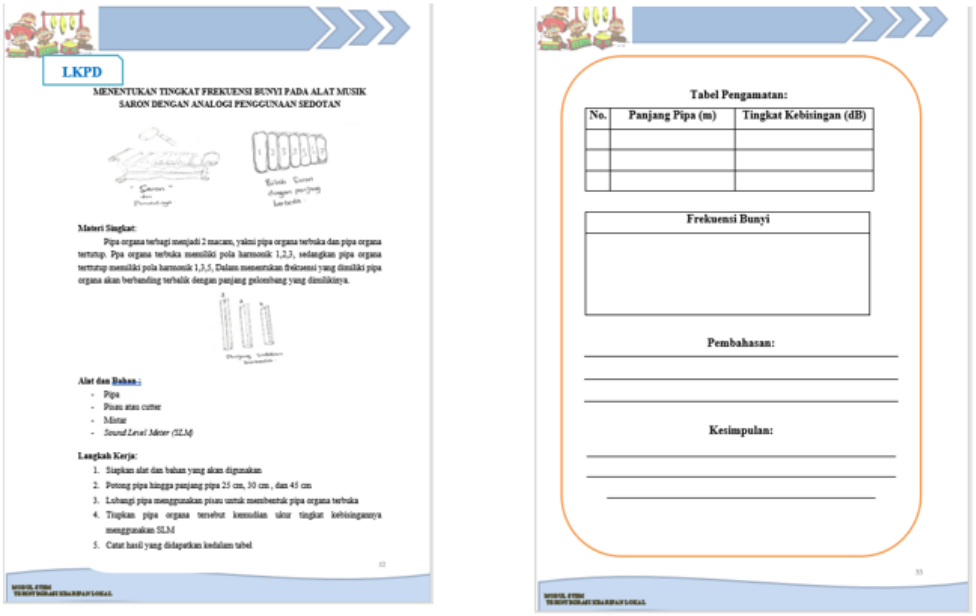
The expert assessment was carried out by 9 experts. They are three media experts, three learning design experts and three material experts whose results are shown in Table 1. The results of student trials on the STEM module before it is implemented can be seen in Table 2.

**Table 2.** Assessment results by experts

| No. | Aspect | Percentage | Category |
|---|---|---|---|
| 1. | One to One | 71,97% | Good |
| 2. | Small Group | 66,39% | Good |
| 3. | Field Experiment | 64,60% | Good |

After the module went through the development stage and was validated by experts, the STEM module which was integrated with local wisdom began to be implemented in three public high schools in Bekasi Regency.

The fourth stage in the ADDIE model is implementation. After the module is validated by the experts, it is time for the module to be implemented in the learning process. The use of Saron musical instruments in physics learning can be applied to sound wave material, especially to the material of sound strength and sound frequency. The application of this learning is still in a pandemic atmosphere which is carried out by distance learning. Therefore, the assessment of students to improve their creative thinking skills is carried out through experiments from home in studying *Saron* in sound wave material. The use of *Saron* is represented as a simple experiment using straws of different lengths then the ends of the strawsform a triangle then blown and will make different sounds. The image of the student worksheet can be seen in Figure 2.




(a) (b)

**Figure 2.** (a) Worksheet students start page and (b) Worksheet students experiment observation table

The following is the students' response to the *Saron* experiment which is represented using straws with different lengths and then compared the frequency values for each different length using a sound analyzer.

Student response 1: "Physics is unique because it is inour environment"

Student response 2: "Theory will be more meaningful if it can be proven by experiment"

Student response 3: "There are many things that can be used in physics learning media, one of which is a musical instrument"

The following is the documentation of students working on *Saron*'s experimental project which is represented using a straw and their worksheets can be seen in Figure 3.


(a) (b) (c) (d)

**Figure 3**. (a) Tools and materials used (b) Work steps (c) Experiment (d) Student worksheets

The following is the value of the N-Gain level of students' creative thinking abilities based on the pretest and posttest scores. The magnitude of the students' N-gain value during implementation can be seen in Table 4.

**Table 4**. *N*-Gain test results of creative thinking skills on the field test

| N-Gain | Score |
|---|---|
| **Average** | 0,65 |
| **Category** | Medium |

The results of the pre-test and post-test assessments after and before being given the STEM module can be seen in Table 5.

**Table 5.** Creative Thinking Ability Results

| Creative Thinking Achievement Percentage | Pre-test | Post-test |
|---|---|---|
| **Average** | 40% | 80,65% |
| **Category** | Not Good | Good |

The results of the pre-test and post-test scores showed differences before and after being given the integrated STEM module of the *Saron* musical instrument. The pretest score of students' creative thinking achievement before being given the STEM module was 40% in the less category and when after being given the STEM module the students' creative thinking level was 80.65% in the good category. So, there is an increase of 40.65%. The results of the STEM module assessment by teachers and students through a summative assessment questionnaire on the effective and practical aspects can be seen in Table 6.

**Table 6.** The results of the summative assessment of the effective and practical aspects

| No. | Aspect | Percentage | Category |
|---|---|---|---|
| 1. | Effectiveness | 97% | Very Good |
| 2. | Practical | 70% | Good |

The results of the assessment of three physics teachers from three different senior high school, the percentage of indicators for achieving learning objectives was 100%, indicators that made it easier for students to learn to get a percentage of 100%, and indicators of STEM modules that could improve creative thinking skills got a percentage of 91.67%.

*Saron* musical instrument is part of the gamelan instrument that can explain the concept of physics in terms of explaining the strength of sound and the high and low sound. High sound intensity comes from large sound amplitude and conversely low sound intensity comes from small amplitude. Strong and weak sound depends on the amplitude (Nursulistyo, 2019).

By raising the *Saron* musical instrument as Bekasi local wisdom discussed in the STEM module and study native Indonesian arts, it is integrated into physics learning, it is hoped that students can be appreciative to the environment andthe characteristics of the Indonesian nation as a national identity. Following the results of research conducted by Elif Kara, *et al.* (Elif Kara. 2021) there are differences in results between students who study with STEM learning and those who do not. These results have a stronger influence on student achievement in STEM learning compared to non-STEM learning. New findings were obtained in the STEM field for students with higher achievement to improve subjects such as engineering, mathematics, and natural sciences (Elif Karaa, 2021).

The indicators of students' creative thinking skills improved in this study were indicators of flexibility, originality, and elaboration. The fluency indicator was not improved because at

worksheets students time of the initial preliminary study the students' fluent thinking ability or fluency was already good, so only 3 indicators had to be improved because they were still low. Based on the results of the graph of students' creative thinking abilities for each indicator at the pretest and post-test. The flexibility indicator increased by 27.78%, the originality indicator increased by 36.73%, the elaboration indicator increased by 47.67%. The highest increase occurred in the elaboration of indicators, namely 47.67%.

An indicator of flexibility is building ideas from different points of view. In this flexibility indicator, students are trained by presenting the problem of the *Saron* musical instrument made of brass and bronze, then comparing the materials or constituent materials which when the *Saron* is hit it will produce a pleasant sound when viewed from the speed valueof wave propagation. The second indicator is originality, which is producing a new or different final answer in solving a given problem. In this case, students are trained when working on the worksheet students in Figure 2. Students can understand why the length of the straw can produce different frequency values. The third indicator is the elaboration indicator, which describes the factors that influence and add detail to the idea or ideas so that they are more valuable. In this elaboration indicator, students are trained by sketching a simple musical instrument from West Java, along with the materials used in making the instrument.

The implementation of learning is done through online and offline learning. The lesson is divided into three meetings. Online learning was carried out once, namely to strengthen students' understanding by practicing flexibility indicators, building ideas from different perspectives on the integrated sound wave material of the *Saron* musical instrument. Offline learning is done twice by giving worksheet students. Students are trained with indicators of originality by experimenting with making simple musical instruments from simple items using different straws as a substitute for *Saron* music with different blade lengths. in addition, the students' elaboration indicator makes a simple musical instrument sketchso that students get more meaningful learning. In line with other research, it is suggested that educators can use project-based learning to improve creativity and student learning outcomes (Ni Wayan Rati, 2017). Meanwhile, during the learning process, students tend to be more interested in experimental activities, and elaborate in making simple musical instrumentsso that students are more enthusiastic about doing these activities. In line with the research of Ai Nurlaela, *et al.*. that the indicator of creative thinking has the highest value compared to other creative thinking. This is because students can explain in detail, coherently, and by explanation procedures or work steps (Nayif, 2014).

## CONCLUSION

This research succeeded in developing an integrated module of science, technology, engineering, and mathematics (STEM) of *Saron* musical instruments on sound wave material, especially on the material of strong and weak sounds and sound frequencies studied by high school students with analysis, design, development, implementation, and evaluation (ADDIE) development method. STEM modules can be implemented in the learning process based on the results of trials, practicality, and effectiveness.

The STEM module is successfully used to improve students' creative thinking skills because when they study sound waves using the STEM module, students are invited to think by paying attention to the culture around them, for example, the *Saron* musical instrument. In addition, students are invited to make simple musical instrument products from used goods, so that students can increase their creativity by making products from their designs. The results of the development of the STEM module is included in the practical category, student responses to the practicality aspect score 76% and are included in the good category.

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