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The Validity and Practical Test of STEM@Home Learning Design to Empower Student's Science Literacy

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Abstract: The science, technology, engineering, and mathematics (STEM) approach is one of the approaches to teaching integrative science contextually and to promote science literacy, which is identified to remain low among Indonesian students. Applying STEM projects to grade 8 students has been challenging during the pandemic. Thus, there is a need to develop an online STEM project that accommodates learning at home or distance learning, is suitable during the pandemic, and incorporates training to improve science literacy. Therefore, we developed a STEM@Home Learning Design by adopting the Flower STEM-Approach Design using the topic of vibration, wave, and sound. This study aims to reveal the validity of the learning design by involving 44 reviewers (lecturers and teachers), followed by the practical test run by 117 reviewers of lecturers, teachers, and student teachers majoring in science education. A questionnaire consisting of 30 items on learning design, instructional setup, and student competencies was distributed online. On average, the respondents scored 4 to 5 on a 5-point scale of the STEM@Home Learning Design in each indicator (86.3%). It can be concluded that the STEM@Home Learning Design is feasible to proceed to the empirical study.

Keywords: distance learning, science literacy, sound wave vibration, STEM education

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INTRODUCTION

One of the benchmarks used today for indicating the nation's progress is the literacy level of a country's population. Facts about the science literacy of junior high school students in Indonesia can be identified from the results of PISA measurements. In PISA 2022, the science literacy score of Indonesian students was 383, while the OECD average was 485. The score could place Indonesia in 63rd position out of 81 participating countries. These scores increased a bit in the next round of measurement (OECD, 2019) . However, the science literacy of Indonesian students cannot be categorized as high. About 34% of Indonesian students achieved Level 2 of science literacy, and around 76% of students from other OECD countries were at this level. This level describes the lowest competencies in science literacy, in which students show abilities to recognize the correct explanation of familiar phenomena in science, and to identify problems and choose the correct conclusion based on the data provided. Almost 0% of Indonesian students achieved Levels 5 to 6, which indicates the ability of students to apply their science knowledge independently and creatively to a wide variety of problems, including unfamiliar cases.

Science literacy has become a term used to express the broad goals of science education (Bybee, 2009). It is defined as the ability to think critically and creatively, solve problems, and be sensitive to natural phenomena and the environment. Science literacy is categorized into four: a way of investigating, a body of knowledge, a way of thinking, and the interaction of science, technology, and society (Chiappetta et al., 1991). Science literacy is a competency that is trained through the implementation of the scientific method which generally focuses on observing, questioning, gathering information, conducting experiments, processing and analyzing data, and conveying results through the data that have been collected. There are five definitions released by scholars and institutions that generate the definition of science literacy as related to several components, including 1) understanding of science and its applications, 2) understanding the nature of science and its relationships, 3) ability to identify, 4) ability to think scientifically, and 5) ability to produce arguments (Almeida et al., 2023).

According to PISA, science literacy is the ability to engage with science phenomena, the concepts or ideas of science, as a reflective citizen (OECD, 2018). It also covers the ability to explain scientific phenomena, evaluate and design scientific inquiry, and interpret data and evidence scientifically. The important issue in science literacy according to PISA is the ability to apply scientific knowledge in the real context. In other words, science literacy may be categorized into three domains, i.e. science knowledge or understanding, scientific process skills, and scientific attitude. To measure this literacy, PISA develops an instrument consisting of six levels: Level 1b as the lowest level, and Level 6 as the highest competency. These instruments are adopted in this research.

The low score of science literacy achievement of students in Indonesia on PISA measurements is influenced by several factors: (a) the use of books as a guide to teaching materials that are not yet appropriate, (b) learning that is too focused on books, (c) low reading ability, (d) learning environment and climate (Suparya et al., 2022). These issues are also related to the gap between science learning applied in schools and the demands of PISA (Fuadi et al., 2020). Research on science literacy in Indonesia has been carried out by several researchers by retesting a PISA standardized test to the students, but it has not been satisfactory (Rini et al., 2021). The research to determine students' mastery of science literacy by (Saptaningrum et al., 2023) showed that the mastery of science literacy of junior high school students in Semarang, which was assessed based on the PISA framework, was categorized as moderate. Research was also run by (Maulina et al., 2022) on same-age participants in Lampung and the result showed low literacy among students. Some internal and external factors are argued to influence science literacy (Jufrida et al., 2019). Psychological factors, which are interest and motivation to learn, family factors (parental background and guidance in the family), and school factors (teaching methods and learning outside school), are on the list.

Meanwhile, some teaching improvements have also been introduced to challenge the science literacy of students, one of which is the science, technology, engineering, and mathematics (STEM)-based teaching approach (Herlanti et al., 2019; Jin & Bierma, 2023). The STEM-based teaching approach can be relied upon to improve students' science literacy. Wicaksono (2020) mentions that teaching science using the STEM approach is one of the supports that can meet the demands of the Industrial Revolution 4.0 by using innovative learning media (Grahito Wicaksono, 2020). It is rational since the STEM approach aims to build curiosity, creativity, critical thinking, and collaboration (Sandi, 2021). These aims are along with the definition of science literacy that is to be nurtured in this research through the STEM@Home Project. The concepts of science literacy were referred to in the definition and measurements of PISA.

The term STEM education refers to teaching and learning which integrates science, technology, engineering, and mathematics proportionally. STEM can also be interpreted as an approach to teaching and learning that consists of two or more STEM components integrated by other disciplines (Haryati et al., 2020). The STEM approach is one of the learning approaches that integrate the four aspects (science, technology, engineering, and mathematics) to solve problems in life by involving creative, critical, and collaborative thinking processes to create 21st-century skilled learners (Dwita & Susanah, 2020).

Some of the advantages and benefits of the STEM approach in thematic science learning at the junior high school level include improving learning outcomes (Wahyuni, 2021); students' critical thinking skills (HACIOĞLU & GÜLHAN, 2021; Rizkika et al., 2022); collaborative skills (Nurwidodo et al., 2022); analytical thinking skills (Sartika et al., 2022); inquiry skills (Chaerunisa et al., 2023; Hidayah et al., 2023), and students attitudes toward science (Toma & Greca, 2018).

The STEM approach as one of the approaches in science education generally is applied as a face-to-face project-based activity. However, introducing STEM projects as distance learning activities by providing students with online sources become common. Some free access websites may be mentioned as examples, NASA STEM, Go Science Kids, Science Buddies, and National Geographic Kids.

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Distance learning is one of the alternatives to learning when access to the school is restricted. Moreover, providing the activities of STEM as a sort of online source allows students: (1) to study anywhere and anytime, (2) to have the flexibility to choose, and (3) to save time. However, indeed there are some disadvantages of distance learning, such as (1) no social interaction, (2) a high chance of distraction, and (3) complicated technology. At the same time, the STEM approach needs more monitoring and guidance from teachers when it is applied. Thus, it seems impossible to accommodate it. However, (Tezer et al., 2021) have successfully revealed the effectiveness of the STEM approach in distance learning, though it has been applied at the undergraduate level. For the same reason, it becomes a big challenge to implement STEM approach-based learning for middle school students, which can be applied independently at home and still can be monitored by the teachers.

STEM learning requires an integration that incorporates its building blocks. One of the STEM learning models initiated by (Wichaidit et al., 2019) is the Flower Designing Model shown in Figure 1.

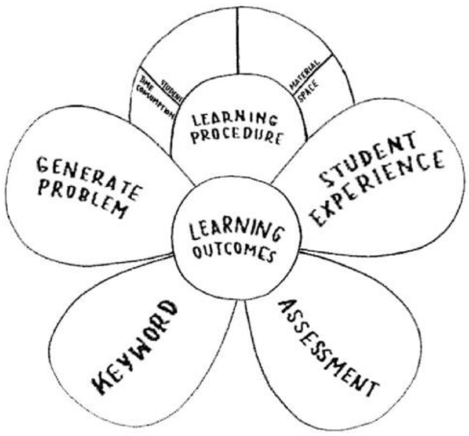

Figure 1. Flower Designing Model (Wichaidit et al., 2019)

The learning design of the STEM approach varies, but three main designs have been adopted widely, i.e., engineering design process (Lin et al., 2021; Shahali et al., 2017; Ting, 2016), design thinking (Henriksen, 2017; Simeon et al., 2022), STEM Quartet (Tan et al., 2019; Teo et al., 2021) However, those designs do not describe the steps that teachers must follow to design the STEM-based lesson. The engineering design process consists of steps that are followed by the engineer to design a product, while the design thinking step is the step used by the designer to design a prototype. Meanwhile, the STEM Quartet design is also equipped with the procedures that must be followed by teachers to design a lesson plan of STEM approach, but in a simple way.

Thus, in this research, we adopt a more detailed procedure for designing the lesson plan, i.e. the Flower Design. This design tool could present all the vital elements of a lesson in one place, empowering teachers to plan their lessons with a deeper understanding of how each piece fits together. It allowed for nonlinear lesson design. Teachers could begin planning their lessons by starting with either learning outcomes or a real-world problem. Also, it was adaptable to individual teaching styles and instructional needs.

It is not clear yet the impact of the online STEM approach activities on the science literacy of students. Based on the problem described above, it is important to develop a STEM Learning Design that may accommodate distance learning, and through this learning design, students may improve their science literacy. Thus, by following the steps of the Flower Design, this research has developed the STEM@Home Learning Design on the topic of wave, vibration, and sound which addresses the learning needs in the middle school science subject. To be implemented effectively, the design needs to be validated and reviewed. This article aims to report the procedure and results of the validity test of the developed STEM@Home Learning Design through the expert judgment review and the practical review from the users' perspectives.

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RESEARCH METHOD

The research followed the 4D stages (define, design, develop, disseminate) of (Thiagarajan, 1974) to develop the product. However, the dissemination stage was skipped, and the stage ended with the validation of the design. The research team developed a STEM Learning Design that was supposed to be applied in online classes by adopting the Flower Designing Model (Wichaidit et al., 2019). The learning design was made on the topic of vibration, wave, and sound which is learned at grade 8 of middle school in Indonesia.

The validity of the design was measured in two stages. The first draft was validated by 44 experts (70.5% science teachers and 29.5% lecturers of science education) who attended the Seminar on STEM Education held by the Department of Biology Education, Sebelas Maret University. The respondents were invited to fill out a 30-item questionnaire. They were also given the draft of STEM@Home Learning Design, consisting of a table of activities, lesson plan, assessment sheet, and video of guidance to develop a simple guitar as the product of STEM activity. The questionnaire was distributed virtually. Another assessment was also carried out to determine the level of agreement of respondents based on certain categories of respondents, i.e. gender, profession, major or expertise, and working period in teaching. The percentage of the feasibility level applied the method of (Widoyoko, 2009) by finding the ideal standard deviation and then converting it into a qualitative score. The conversion of the percentage score into qualitative is described in Table 1.

Table 1. Percentage of Qualitatively Converted Score

Range of score	Category
$25\% \leq X \leq 43.75\%$	Not Feasible
$43.75\% < X \leq 62.5\%$	Poorly Feasible
$62.5\% < X \leq 81.25\%$	Feasible
$81.25\% < X \leq 100\%$	Very Feasible

The result of the first stage of validation was used to improve and revise the first draft of the STEM@Home Learning Design. Furthermore, the second validation stage was the practical test, conducted by sending the revised version of the STEM@Home Learning Design, the lesson plan, the video of guidance to make a simple guitar, and the assessment sheet to 121 respondents of science-relevant lecturers (10.25%), and science teachers (35.89%). The other respondents were university teacher students (53.84%) who have accomplished the teaching internship at school. As many as 117 out of 121 respondents completed the validation.

The instrument of validation was a 30-item questionnaire using a four-point Likert scale questionnaire (1 =disagree, 2=somehow agree, 3=agree, 4= strongly agree). There are three main indicators of the validation instruments, i.e., 1) the content and design, 2) the instruction, and 3) the trained competencies. The first indicator consists of the validity, logic, and clarity of the concepts; the clarity of the competencies; the validity of interdisciplinary STEM elements; the correct coverage of the materials; and the completeness of the learning design. The second indicator consists of the clarity of the guidance, instructions, order, student tasks, procedure of work, time allocation, and assessment. The third indicator measures the competencies that may be trained in the STEM@Home Learning Design, especially science literacy.

FINDINGS AND DISCUSSION

STEM@Home Project Learning Design

In the first step or the *define* step, the researchers decided on the topic of STEM@Home Learning Design, which was vibration, wave, and sound, and then adopted the learning design based on The Flower Design by (Wichaidit et al., 2019). In addition, it also applied learning steps following the indicators of science literacy competencies initiated by (Setiawan, 2018) which adopted the science literacy of PISA.

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At the *design* stage, were determined the learning outcomes as the basic competencies and subject matter indicators, as well as the keyword that was used during the learning process. The learning procedure was the process and order of learning steps. The student experience was the learning activities that students will get during the learning process. An assessment is a measurement of the student's performance that teachers should do during the learning process.

The STEM@Home Learning Design according to the Flower Designing Model is displayed in Table 2. The topic for basic competencies taken in this study is vibration, wave, and sound materials studied by grade 8 students of junior high school. In STEM@Home Learning Design, students will be directed to make a product, namely a simple guitar. This learning requires several meetings with students. However, with distance learning conditions, learning may be carried out face-to-face using applications, such as Zoom or Google Meets. The application of the STEM Learning Design begins by giving a general problem, namely how a guitar can produce sound, and then a statement is drawn to find vibration, wave, and sound material. Then it is continued by making learning procedures until the evaluation stage of making student products.

An example of the products that students may create from the STEM@Home Project on vibration, wave, and sound is shown in Figure 1. The product is a handmade guitar using the used material, such as cardboard boxes, cutters, racket strings/bracelets/hair ties, rulers, and push pins. The difference in the use of guitar strings, or rubber bands is done to find out the difference in waves and sounds produced from each object that becomes a guitar string.

Figure 2. Examples of products that students will make

Table 2. STEM@Home Learning Design

Learning Outcome	Cognitive Competencies: Analyze the concepts of vibration, waves, and sound in everyday life including the human hearing system and the sonar system in animals. Skills: Present the results of experiments on vibrations, waves, and sound. Indicators of competencies include the abilities to: 1. explain the meaning of vibration 2. explain the meaning of waves and types of waves 3. explain the basic concept of sound 4. apply the relationship of wavelength, frequency, period 5. analyze the relationship between vibration, wave, and sound 6. present the results of observations of the surrounding environment about the phenomena of vibrations, waves, and sound 7. present the design of the product/prototype that has been made 8. communicate the finished product
Keywords	frequency vibration, guitar, period, sound, wave, wave propagation speed
Generate Problems	Playing music is one of the hobbies that many people have. Musical instruments that are quite in demand are very diverse. Musical instruments have different sounds, depending on how to sound them.

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	One of the musical instruments that attracts enough attention is the guitar. The guitar sounds by plucking the strings. Various tones of sound can arise from the plucked strings. For students, the guitar is a costly musical instrument. Many students have an interest in guitar but cannot own it because it is quite expensive. To fulfill the desire to play the guitar without buying, the teacher asked the students to make guitars from items that could be found around them. Although the guitar is simple, the challenge is to make a guitar that has a graduated tone and is pleasing to the ear. The tone of a simple guitar can be affected by the type of guitar body used and the size of the guitar body. The hole in the guitar body also affects the tone that will be produced, the object used as a guitar string, the tension of the strings used, and the determination of the guitar key so that the sound produced can be high and low tones
Learning Procedure	**Time allocation:** 12 lesson hours / five meetings **Target Students:** grade 8 students of junior high school **Material:** cardboard boxes, cutters, racket strings/ bracelets/hair ties, stationery, cellphones, laptops, rulers, push pins, styrofoam. **Space:** Each student's home (design@Home) by using online platforms such as WhatsApp, zoom meeting, or Google form. **Learning steps:** 1. The teacher divides students into small groups of 3-4 people. In the group, students can discuss through the online platform to solve the problems, but still, students will make the guitar prototype at home independently. 2. Students read articles: about vibration, waves, and sound in the surrounding environment. 3. The teacher discusses with the students how the guitar can make a sound. 4. The teacher and students discuss what components will be needed in making the guitar. 5. The teacher reads out the task/problem that the students have to solve, namely: a. search for information about various musical instruments, especially plucked ones. b. Students determine objects that will be used as guitar bodies (snack boxes, plastic boxes, shoe boxes, etc.). c. The teacher and students determine the size of the hole that will be made in the guitar body. d. The students find information about the effect of the types of strings on the sound that will be produced. The students determine the objects that will be used as strings (rubber bands, raker strings, hair bands, etc.) e. The students make a guitar design that has been planned with explanations. f. The students make a product from the design that has been made. g. The students care for and observe the results obtained and link them to the material of vibration, waves, and sound. h. The students write the results of all experiments that have been made by making a short video. 6. The teacher and students discuss the results of the products and conclude vibration, waves, and sound.
Students Experience	1. Students understand the relationship between the existing concepts of vibration, vibration, and sound. 2. Students can determine the things that affect the sound produced on a guitar instrument. 3. Students can observe with the help of their science literacy. 4. Students can explain existing STEM concepts. 5. Students practice communicative spirit through discussion. **STEM Breakdown** **Science:** 1. Students recognize the concepts of vibration, wave, and sound. 2. Students know how vibrations, waves, and sound are related in life. **Technology:** 1. Students make a product by using the design that has been made. 2. Students use the Internet technology to find information on possible solutions. **Engineering:** Students find a solution, namely how they make a guitar according to the prototype to solve the problem. **Mathematics:** Students understand the concept and measurement of frequency and waves that affect sound.

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Assessment	1. Assessing the scientific understandings or science phenomena using the cases of vibrations, waves, sound, units, and quantities through pre and post-tests. 2. Assessing the science process skills (basic and integrated science process skills) through student work steps during the learning process. 3. Assessing the scientific attitudes, such as conscientiousness, responsibility, and respect for the data.

The next step was the *development* stage, in which researchers validated the STEM@Home learning design in two stages of validations, i.e. as explained in the above methodology. Furthermore, an assessment was taken to see whether or not the STEM@Home Learning Design was suitable for further large-scale effectiveness tests.

The results of the feasibility value assessment are on three indicators: (1) STEM@Home Learning Design, (2) instructions on STEM@Home Learning Design, and (3) skills trained on STEM@Home Learning Design activity. The initial score was assessed by respondents by providing four answer options, namely *strongly agree, agree, slightly agree,* and *disagree*. The feasibility value on each indicator is presented in Table 3, Table 4, and Table 5 respectively.

Table 3. Feasibility value on Indicator 1

Item No	Total Items	Score	F	Average Score	Percentage (%)
1-10	10	SS(4)	604	2416	60
		S (3)	501	1503	37
		KS (2)	64	128	3
		TS (1)	1	1	0
Total			1170	4048	100
Max. Score			4680		
Average Percentage (%)			86		
Category			Very Feasible		

Table 4. Feasibility value on Indicator 2

No Item	Total items	Score	F	Average Score	Percentage (%)
11-20	10	SS (4)	635	2540	62
		S (3)	465	1395	34
		KS (2)	68	136	3
		TS (1)	2	2	0
Total			1170	4073	100
Max. Score				4680	
Average Percentage (%)				87	
Category				Very Feasible	

Table 5. Feasibility value on Indicator 3

Item No	Total Items	Score	F	Average Score	Percentage (%)
21-30	10	SS(4)	639	2556	63
		S (3)	469	1407	34
		KS (2)	61	122	3
		TS (1)	1	1	0
Total			1170	4086	100
Max. Score				4680	
Average Percentage (%)				87	
Category				Very Feasible	

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Tables 3, 4, and 5 show that the average percentage of each indicator is above 85%. Thus, it can be stated that the STEM@Home Learning Design can be declared very feasible, and the indicators assessed by the respondents can be fulfilled.

Another analysis was to determine the level of agreement among respondents by separating the percentage of strongly agree, agree, and disagree levels according to the categories raised by the researcher, namely gender, profession, field of expertise, and the respondent's teaching period. The level of agreement according to the gender category is in Table 6. Table 7 shows the level of agreement of respondents based on the profession category. Table 8 shows the level of agreement of respondents in terms of expertise category. The level of agreement based on the teaching period category is figured out in Table 9.

Table 6. Percentage of agreement on gender category

Answer option	Male		Female	
	Total	Percentage (%)	Total	Percentage (%)
Strongly Agree	14	63.63	55	57.89
Agree	8	36.37	38	41.30
Disagree	0	0	2	2.11

The research conducted by (Tantri & Roseline, 2021) shows that men and women have different responses, due to the different levels of emotions that they have. Women are more easily hesitant when there is pressure, including in answering questions even though it is carried out online, in contrast to men who feel satisfied when the work can help them get results (Novianti & Syarkowi, 2021).

Table 7. Percentage of agreement on profession category

Answer Option	Lecturer		Teacher		College Student	
	Total	Percentage (%)	Total	Percentage (%)	Total	Percentage (%)
Strongly Agree	9	69.23	29	69.05	31	50
Agree	4	30.77	12	28.57	30	48.39
Disagree	0	0	1	2.38	1	1.61

In the Republic of Indonesia Law No.14 of 2005 is explained the duties of lecturers and teachers. The duties of teachers are listed in Article 20, which are to plan teaching, implement a quality teaching and learning process, and assess and evaluate teaching and learning. Meanwhile, in Article 60 of the same law, it is stated that lecturers are obliged to carry out education, research, plan the teaching-learning process, and improve and develop academic qualifications and competencies on an ongoing basis.

Students who became respondents were teacher students who had carried out teaching internships at schools so it was assumed they had sufficient knowledge of teaching, as well as experience, and had trained and developed the competencies needed in their fields (Meha & Bullu, 2021). According to (Pelita Ansara & Yemmardotillah, 2022), students who have carried out internships have understood the world of education and have implemented pedagogic competence and professional competence, so the voices of students in this study cannot be ignored.

Table 8. Percentage of agreement on the field of expertise category

Answer Option	Strongly Agree		Agree		Disagree	
	Total	Percentage (%)	Total	Percentage (%)	Total	Percentage (%)
Science	18	60	11	36.67	1	3.33
Biology	16	66.67	8	33.33	0	0
Physics	5	71.43	2	28.57	0	0

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Chemistry	0	0	0	0	0	0
Not	27	48.21	28	50	1	1.79

Science is a subject with the scope of substances and energy, both those found in living and non-living things (Astiti et al., 2020). The science that is studied will find different materials, such as physics, chemistry, and biology.

Table 9. Percentage of agreement on teaching period category

Answer Option	Strongly Agree		Agree		Disagree	
	Total	Percentage (%)	Total	Percentage (%)	Total	Percentage (%)
0 year	26	49.06	26	49.06	1	1.88
< 1 year	6	66.67	3	33.33	0	0
1-5 years	15	78.95	4	21.05	0	0
6-10 years	4	44.44	5	55.56	0	0
11-15 years	6	54.55	5	45.45	0	0
> 15 years	11	73.33	3	20	1	6.67

The working period can affect the performance and experience of workers (Miranti et al., 2016). Gaining experience in the world of education can also be affected by the teaching period that a person has been engaged in. The longer the working period that has been passed, the more knowledge and experience will be gained.

At the development stage was distributed a questionnaire consisting of three indicators, each with 10 statements. Indicator 1 asks about the design of STEM@Home Learning Design with a percentage of 86%, or in a very feasible category. This means that the learning design is feasible to be implemented.

The statement on the STEM@Home Learning Design has concepts that are incorporated into STEM@Home Learning Design, such as the concept of material incorporated into learning, competence in the cognitive, affective, and psychomotor domains, and the sequence of the learning process is clear. The statement is included in the very feasible category, so it is concluded that there are no significant changes to be applied directly to the learning process.

Indicator 2 consists of instructions on the STEM@Home Learning Design with a percentage of 87%, containing statements related to the project to be done. Some examples are instructions for activities, sequences of project activities, work targets for students, and explanations of assessments. The statement is included in the very feasible category, so it is concluded that the STEM@Home Learning Design project can be used without having to make significant design revisions.

Indicator 3 contains the skills developed in STEM@Home Learning Design with a percentage of 87%. The statements are related to understanding, critical thinking skills, problem-solving, creativity, analysis, communication and collaboration, and argumentation skills in students. All of these statements were declared very feasible. Learning to make a simple guitar is stated to be able to train several students' abilities, especially science literacy.

In each category, it is stated that on average more than 50% of each category choose to strongly agree. It is stated that respondents can approve the STEM@Home Learning Design presented and can accept the instructions, stages, and assessments attached to the learning.

STEM research on vibration, wave, and sound materials to empower science literacy has also been studied by (Safitri et al., 2019) with the use of learning modules. The result of the study was an increase in science literacy skills by using guitar objects in the learning process. Thus, based on the validity and practical test of the STEM@Home Learning Design, it may predict that the science literacy of the students will also be nurtured well. However, to ensure the effectiveness of the STEM@Home Learning Design, an empirical study must be conducted starting with a small-scale trial, and followed by a large-scale trial in several science classes at middle schools.

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CONCLUSION

The validity test of STEM@Home Learning Design has shown a valid category related to the product and its stages. Moreover, the practical test also showed that this learning design was rated very feasible by the respondents. Based on both tests, the STEM@Home Learning Design on vibration, waves, and sound materials is recommended to be further tested empirically in a multi locations.

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