Learning design for the natural resonance concept of the rope system with a "Gambo"

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Abstract. Gambo as a traditional stringed musical instrument from Mbojo tribe (NTB) is increasingly missing its existence among the younger generation. This instrument has never been used as a media for learning physics, even though it can show the phenomena of vibration, waves and sound. This paper aims to explain the learning design of construction the concept of natural resonance using a gambo system and involving advanced spectrum applications of smartphone and evidence the effectiveness of its implementation based on student understanding about the concept and its responses. The learning activity is guided inquiry which involves 28 senior high school students of Kota Bima grade XI. Data was collected through document studies and concept understanding tests. The results of test were analyzed using descriptive statistics and using the normalized gain test, while the analysis of student responses to learning activities used a likert scale. Based on studies and research results, it was concluded that the learning of the natural resonance concept of the string system using Gambo has been well designed and can be implemented easily and effectively. Understanding of students' concepts increases significantly, and gets a good response from students.

1. Introduction

Understanding the concept of waves of senior high school students is still relatively low [1, 2, 3]. Therefore physics learning innovations must continue to be developed, especially the use of contextual media and digital technology devices, considering physics as a field to develop of skills and knowledge [4]. Contextual learning media such as traditional musical instruments need to be applied in physics learning activities so that students feel they are learning directly from real phenomena in their daily lives and their existence is maintained as a local resource.

The use of traditional musical instruments such as the Sundanese flute to study a concept of sound beat has been carried out by [5] and a physics perspective on the Sundanese flute has also been carried out by [6]. However, concentrations on gambo musical instruments as a learning media for physics have been carried out by [7] who examined the relationship of wave propagation velocity to string temperature, while also revealing that college students can learn the phenomena of sound beat through signal analysis generated from gambo with sampling method uses Adobe Audition software and FFT analysis in Matlab program.

Therefore, to enrich the study of gambo as a learning media for physics, then do the learning design for concept of natural resonance system of the string system uses "Gambo" through the
implementation of guided inquiry learning methods to improve understanding of the basic concepts of vibration, waves and sound for high school students.

2. Method

The syntax design learning of concept of natural resonance string system using a gambo with the orientation of the guided inquiry method is done through case studies and literature studies. Students as research subjects were 28 pupils from Senior High School (SMA N 1 Kota Bima) grade XI. The research method uses quasi experiments in one group pretest-posttest design. The research data was collected using documents to analyze the structure of learning material that can be done with Gambo, while to collecting data of understanding concepts used 14 multiple choice concept test, as well as using a questionnaire to capture students' perceptions about learning that has been implemented.

The result of concept understanding test were analyzed statistically descriptive and used a normalized gain test $g = \frac{SkPr - SkP_{pre}}{SkP_{max} - SkP_{pre}}$ with the categories as show in Table 1 [8], while the analysis of student responses (positif/negative) about learning activities using likert scale analysis with criteria as show in Table 2 [9].

| Classification | Gain Score ($g$) | Category |
|----------------|------------------|----------|
| $g \geq 0.70$  |                  | High     |
| $0.70 > g \geq 0.30$ |                  | Moderate |
| $g < 0.30$     |                  | Low      |

| Respons (+) | Criteria                        | Respons (-) |
|-------------|---------------------------------|-------------|
| 5           | Strongly Agree (SA)             | 1           |
| 4           | Agree (A)                       | 2           |
| 3           | less agree (LA)                 | 3           |
| 2           | disagree (dA)                   | 4           |
| 1           | strongly disagree (sdA)         | 5           |

3. Result and Discussion

3.1. Learning Design

The design of learning objectives, steps, and learning indicators developed for investigation activities of the traditional music instrument (gambo) and the Advanced Spectrum(pro) application are shown in Table 3.

| Learning objectives: | Learning Steps: | Learning Indicators: |
|----------------------|-----------------|----------------------|
| Build on the concept of natural resonance string system that is bound at both ends, through the investigation of the gambo | Create a gambo string vibration event that is bound at both ends and record the sound waveform generated using the Advanced Spectrum(pro) application of smartphone. | Pupils can: Determine the harmonic frequencies contained in the gambo tone wave. |
|                      | Observe and analyze the string vibration pattern, determine the wavelength, to compare the harmonic frequencies. In addition to direct observation of string vibration patterns, analysis of harmonic frequencies | Determine the ratio of the frequency of the overtones to the fundamental pitch. |
|                      |                  | Predict the natural wavelength or |
Learning objectives:

- Instrument and using a smartphone application [3,7,9,16,17].

Learning Steps:

/overtones is determined by the FFT (Fast Fourier Transform) method using the Advanced Spectrum application by observing the dominant spectrum peaks, analyzing and comparing the values of the fundamental frequencies and overtones that appear, to predict other harmonic numbers.

Learning Indicators:

- Natural fundamental frequency of each harmonic vibration mode of the gambo string tied at both ends and illustrate the prediction pattern.

As an operational step to achieve the learning objectives described in Table 3, several tools and materials are needed as the main components in learning activities namely the Gambo musical instrument, computer or Android smartphone and the Advanced Spectrum\(^{(pro)}\) application, the ruler, and calculator.

The first thing students do is choose one of the gambo strings and tune it to a certain standard tone. The string that is picked (can be done without pressing the string or by pressing the string at a certain point along string) will produce a sound wave tone, then the tone wave will be captured by the Advanced Spectrum\(^{(pro)}\) application so that you will see the frequency spectrums that make up the tone wave. This process is shown in Figure 1.

**Figure 1.** Shape of a Gambo and Advanced Spectrum\(^{(pro)}\) Application

Determination of the fundamental/first harmonic frequency value, second harmonic, third harmonic, and so on is given by the coordinates of the spectrum. Spectrum data with frequency and amplitude coordinates read by the Advanced Spectrum\(^{(pro)}\) application are determined by "double clicking" the smartphone screen until a "two hands and cursor" sign appears and then shifts and places the cursor at the peak point of the spectrum you want to know the coordinates of. For example if the cursor is placed at the top of the first spectrum then it will be seen in tools with the code: M1 = 1002.23 Hz; -37 dB (this information is called the fundamental frequency \(f_0\) and with the amplitude \(A_0\)). At the peak of the second spectrum M2 = 2005.76 Hz; -50 dB (called the 2nd harmonic frequency \(f_1\)), and so on.

After all the harmonic frequency values are obtained, proceed with calculating the ratio of the frequency of the overtones to the fundamental frequency, so that it will be completely collected as in Table 4.
Table 4. Harmonic frequency spectrum and harmonic ratio.

| Gambo string/Tone source | $f_{harmon}(Hz)$ | Ratio harmonic |
|--------------------------|------------------|---------------|
|                          | $f_0$  | $f_1$  | $f_2$  | $f_3$  | $f_4$  | $f_5$  | $f_6$  | $f_{7}$  | $f_{8}$  | $f_{9}$  | $f_{10}$  | $f_{11}$  | $f_{12}$  | $f_{13}$  | $f_{14}$  | $f_{15}$  | $f_{16}$  | $f_{17}$  | $f_{18}$  | $f_{19}$  |
| Gambo string-I           | 1002.23 | 2005.76 | 3003.52 | 4000.45 | ......  | 1    | 2    | 3    | 4    | ......  |

Based on the calculation of the harmonic ratio, students can find the characteristic natural resonance produced by stationary waves in the strings that are bound at both ends as round multiples of the fundamental frequency $f_0$: $f_1: f_2: f_3: ... = 1: 2: 3: 4: ...$. This shows that the vibration of the waves in the string system that is bound at both ends will occur resonance at frequencies: $nf_0$ (with harmonic number $n = 1, 2, 3,...$).

The next activity is to observe the vibration pattern of the string just after it is picked, draw the pattern, and determine the number of waves ($m$) formed along the ($L$) of the vibrating string. It should be understood by students that no matter how long and strong the string junction and the rigors of the stringed passages, stationary waves on the gambo string will always occur in a state of basic resonance. The vibration pattern will look like Figure 2.

![Figure 2. String Vibration Pattern in a State of Basic Resonance.](image)

As long as the string ($L$) only forms $\frac{1}{2}$ waves so that it can be written in the form $L = \frac{1}{2}\lambda_0$, this pattern is the basic resonant mode (first harmonic). The second harmonic/1st overtone ($n = 1$) resonance pattern was not observed because no harmonic vibration pattern was formed on the gambo instrument string system. However, it can be predicted based on information on the ratio of the overtone frequency to the fundamental frequency.

Based on the general relationship of the traveling wave $v = \lambda_0 f_0$, the speed of wave propagation in the gambo string system is length $L$ (m), mass density $\mu$ (kg/m), and tension $F$ (N) which is set with a fixed condition will produce a constant wave velocity as $v [7]$, so that the predicted number of waves ($m$) formed at the $n$-harmonic resonance state is determined by comparing each harmonic state to the basic state according to the formula $\frac{f_n}{f_0} = \frac{v/\lambda_n}{v/\lambda_0} = \frac{\lambda_0}{\lambda_n} = \frac{2L}{\lambda_n}$, so that the predicted wavelength and image of the harmonic resonance pattern the $n^{th}$ overtone ($n = 1$) the resonance analysis is $\frac{f_1}{f_0} = \frac{\lambda_0}{\lambda_1} \rightarrow 2 = \frac{2L}{\lambda_1} \rightarrow L = \frac{2}{3}\lambda_1 \rightarrow L = \lambda_1$.

![Figure 3. Prediction of the String Vibration Resonance Pattern in the Second Harmonic State.](image)

And so on is carried out with the same process for each other $n^{th}$ harmonic state so that successively will form $L = \frac{1}{3}\lambda_0, L = \frac{2}{5}\lambda_1, L = \frac{1}{6}\lambda_2, L = \frac{4}{9}\lambda_3,...$ which eventually students will mutually confirm and conclude the results of their investigation, such as: waveform characteristics and gambo tone wave spectrums arranged by complex tones, spectra the frequency of the composition of the sound of the gambo tone consists of the basic frequencies and the overtone harmonics, the ratio of the overtone...
frequencies to the fundamental frequency is \( n f_0 \) to express the general form of the relationship between the length of string and the natural resonance wavelength of the string system as

\[
L = (n + 1) \frac{\lambda_n}{2}.
\]

3.2. Profile of Understanding the Concept of Waves.

The wave concept understanding test consists of 14 questions covering four cognitive levels, namely C1 to C4 with the topic of stationary waves on a rope vibration system. Based on the results of the pretest, students' knowledge is generally very low where students are only able to answer a maximum problem of 7 out of 14 questions or classically can only answer an average of 3-4 problems. This is because there are still many students who have not had the wave material learning experience.

After applying the learning process, the achievement of each student seems to change significantly to be able to answer 13 problems and at least 8 problems (or the classical average has been able to answer 10 problems), in addition all students have increased understanding. Visualization of the explanation can be seen in Figure 4.

![Figure 4](image)

**Figure 4.** Comparison of Cognitive Achievements (Pretest and Posttest) for Each Student.

Judging from the \( g (N_{gain}) \) each student there were 10 pupils who experienced an increase with a high category namely students with serial numbers 1, 4, 5, 8, 11, 13, 15, 21, 23, and 24 while seventeen other students were in the medium and one pupil with serial number 28 in the low category. Based on this reason for pedagogical purposes, the designed learning (Learning steps, use of the gambo, and smartphone applications) shows good effectiveness in terms of achievement and increased student mastery of concepts. The increased achievement of learning outcomes is due to students being able to observe directly using all their senses in real terms the vibration of the gambo strings, the vibration patterns of the strings, the recording of the waveforms, and the series of harmonic frequencies so that students can use the patterns of information/data that appear to train oneself in predicting a phenomena. The carrying capacity of contextual media and technological devices to improve student learning outcomes is also stated in ref. [1, 6, 7, 9, 17].

Classically achievement at each cognitive level of pretest and posttest after implementation of learning is shown in Figure 5.
Figure 5 shows that each cognitive level has increased, and the increase that is in the high category \((g = 0.82)\) is "Understanding (C2)", while the cognitive levels of Remembering (C1), Applying (C3) and Analysis (C4) are in the medium category. Classically the average gain of students cognitive knowledge achievement is in the moderate category \((g = 0.63)\). Increasing students understanding of the concept of wave resonance because students have mastered the principles and physical meaning of the resonance phenomena that occur in the string [1, 2], the physical meaning of harmonic frequencies, wavelengths, and their relationships [5, 6, 16, 17], and are able to apply formulas to solve problems [7, 9].

As an example of resolving the natural resonance problem of a string system in the Melde experiment where the rope is stretched with a certain weight then vibrated with a vibrator that can be set to its frequency [7], the vibration of the rope can be forced to vibrate with a certain frequency which is in the natural frequency range of the rope [7]. Even though the procedure is different from the string system on the gambo musical instrument which cannot be vibrated with various frequencies, but almost all students are still able to understand that at its natural frequency basically the wave pattern formed consists of one node and two antinode \((1/2 \text{ wave})\), then when the vibrator vibrating frequency is increased to 2 times the initial frequency \((f_1 = 2f_0)\) then the wave pattern can form 2 node 3 antinode \((1 \text{ wave})\) and so on. In a state of frequency with multiple integers even, the natural resonance of the string system will form certain stationary wave patterns that show the natural characteristics of the vibration. Students can understand that only certain frequencies (multiples of even integers from the base frequency) can form a resonance in the string system that is bound at both ends, this is explained also in ref. [7, 9, 16, 17].

3.3. Student Perceptions of Learning Design
Information on student attitudes obtained by closed questionnaire was assessed on a likert scale with five categories. The recapitulation of students responses to learning design is shown in Figure 6.
Based on Figure 6 the majority of students' responses to the learning design applied can be well received. Seen with the response "disagree" if the wave learning that uses the method of guided inquiry and traditional musical instruments gambo less attract the attention of students, there is no connection with things in the daily life, learning material becomes difficult because it also involves a smartphone application, and activities learning is very time-consuming and concentration, but on the contrary, the students actually felt that learning activities that were designed using gambo music instruments and advanced spectrum inquiries were useful, creating a comfortable and pleasant learning atmosphere because they were in line with the expectations and desires of student learning at this time.

The learning steps that are designed can give students knowledge about the working principles of strings musical instruments (gambo), gain reinforcement and feedback so that students feel understanding of the concepts and basic principles of waves can be increased. On the other hand the activities of investigating scientific phenomena formed on traditional musical instruments and smartphone applications can train a variety of student skills as a scientist such as observing skills, making tables, making drawings and graphs to conclude and communicate a phenomenon, as expressed by [12, 13, 15, 16]. Furthermore, learning the concept of waves associated with traditional musical instruments can increase students motivation, creativity and interest in getting to know more about the local potential of the region, this is in line with the view by Robinson in ref. [14] that knowledge of science and creativity can be obtained through the integration of art and science.

4. Conclusion
Learning that has been designed can improve students understanding of concepts about the phenomena of vibration, waves, and sounds, and get a good response from students. In addition, the natural resonance concept learning design of the string system using gambo and smartphone applications can be declared successful because it can be implemented easily and effectively.

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References

[1] Maria E 2011 A Simple experiment to explore standing waves in a flexible corrugated sound tube Journal the Physics Teacher 49

[2] Erin M K, and Jhon R de Bruyn 2011 Understanding of mechanical waves among second-year physics major Can. J. Phys. 89 1155–1161

[3] Apisit T et al 2011 Consistency of student’s conceptions of wave propagation: findings from a conceptual survey in mechanical waves Physics Education Research 7 020101.2011

[4] Wenning C J 2012 The Levels of Inquiry Model of Science Teaching Journal of Physics Teacher Education Online: http://www.phy.ilstu.edu/jpteo [30-01-2013]

[5] Khairil A, Dadi R, Ida K., and Sparisoma V 2017 Study of Sound Beat using Sundanese Flute and Adobe Audition™ 13 Bengkulu International Conference on Science and Education (BICSE 2017)

[6] Ika Mustika S, Khairil A, Engkur K, and Nuryani R 2016 Sundanese flute: from art and physics perspective Advances in Social Science, Education and Humanities Research (ASSEHR) 1st International Conference of Mathematics and Science Education (ICMSEd 2016) 57 Published by Atlantis Press (http://creativecommons.org/licenses/by-nc/4.0/).

[7] Khairil A, Dadi R, Ida K., and SparisomaV 2018 Construction of Basic Concepts of Waves through a “Gambo” (Traditional Musical Instrument) The 8th Annual Basic Science International Conference. AIP Conf. Proc. 2021 040003-1–040003-9; https://doi.org/10.1063/1.5062747

[8] Jhon S, and Gay S 2010 Correcting the normalizet Gain for guessing Journal of The Physics Teacher, 48, p.194-196

[9] Khairil A., Dadi R, Ida K., and SparisomaV 2020 Teaching wave concepts using traditional musical instruments and free software to prepare prospective skillful millennial physics teachers

[10] Hake, R 1999 Analyzing Change/Gain Score USA: Dept. Of Physics Indiana University.

[11] Riduwan, S 2012 Pengantar Statistik Bandung: Alfabeta

[12] Yelensii, Y, Wiyono, K., & Andriani, N 2020 Efektivitas Penggunaan Video Pembelajaran Materi Usaha Dan Energi Berbasis Permainan Tradisional Jurnal Pijar Mipa, 15 (1), 1-6

[13] Setiawan B, Innatesari D K., and Sabtiawan W B 2017 Jurnal Pendidikan IPA Indonesia The Development Of Local Wisdom-Based Natural Science Module To Improve Science Literation Of Students 6(1), 49–54. https://doi.org/10.15294/jpii.v6i1.9595

[14] Robinson, K 2017 Out of our minds: The power of being creative West Sussex: John Wiley & Sons Ltd.

[15] Subali B, Rudsiana D, Firman H, Kaniawati I, & Eillianawati E 2017 Computer-Based Experiment of Free Fall Movement to Improve the Graphical Literacy Jurnal Pendidikan IPA Indonesia, 6 (1)

[16] Jaafar R, Nazihah A, Daud M, & Hon K. K 2018 Harmonic series experiments : length correction of the Malaysia pan flute.

[17] Jaafar R, Ayop S K., Tarmimi A., Illias I, Hon K. K., Nazihah A, and Daud M 2016 Visualization of Harmonic Series in Resonance Tubes Using a Smartphone The Physics Teacher, 54 (9) 545-547 1–4. https://doi.org/10.1119/1.4967895