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An Interesting Way to Learn Vibrations and Sound Waves Using Traditional Musical Instrument "Saron Sasak" for Developing Science Process Skills, Technology Literacy, and Student Creativity

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Abstract –*Developing 21st-century competencies in physics education requires learning approaches that integrate scientific process skills, technological literacy, and creativity through meaningful and contextual experiences. However, vibration and sound wave learning is often presented abstractly, with limited connection to students' cultural environments and minimal use of affordable technology for data acquisition. This study aims to develop and validate vibration- and sound-wave teaching materials using the traditional Sasak musical instrument, saron, integrated with low-cost information and communication technology (ICT) devices to enhance science process skills, technological literacy, and student creativity. The study employed a research and development approach using the ADDIE model, encompassing analysis, design, development, implementation, and evaluation stages. Data were collected through field observations, document analysis, expert validation, and small-scale trials involving 11 prospective physics teachers. The developed teaching materials covered key vibration-wave concepts, including frequency, resonance, waveform analysis, harmonic structure, sound intensity, and creative musical instrument projects, supported by ICT tools such as Adobe Audition, LoggerPro, DaTuner, MacScope II, Advanced Spectrum, and intensity meter applications. The results indicate that the teaching materials were highly feasible, with an average validation score of 81.7% (good–very good), while user responses were very positive, with an average score of 399.91 out of 500. Empirical findings demonstrate that integrating the saron Sasak with ICT-based data acquisition enables students to connect abstract wave concepts with real phenomena, thereby strengthening inquiry skills, digital competence, and creative thinking. The novelty of this study lies in the comprehensive integration of local cultural instruments and affordable digital technologies into vibration-wave teaching materials that explicitly target multiple 21st-century skills within a TPACK-oriented framework. The study concludes that ethnoscience-based, ICT-integrated teaching materials are valid, practical, and effective for physics learning, advancing contextual, culturally responsive, and technology-enhanced physics education.*

Keywords: *learning innovation; physics education; saron Sasak; traditional musical instruments; vibrations and sound waves*

I. INTRODUCTION

The development of 21st-century competencies has become a central priority in science and physics education. These competencies include science process skills, technological literacy, creativity, and cultural literacy, all of which are essential for preparing future teachers to design meaningful, engaging, and contextually relevant learning experiences (Muhali, 2019; Harsh et al., 2019; Oppong et al, 2023; Rahman et al., 2021). However, numerous studies report that these competencies remain underdeveloped among students and prospective teachers, particularly in science learning contexts that emphasize theoretical content while neglecting contextual application and inquiry-based experiences (Tezer et al., 2024; Supratman et al., 2020; Klein et al., 2019; Nurfaizal et al., 2023).

Empirical evidence indicates that students' technological literacy is still relatively low (Tezer et al, 2024), student creativity has not been optimally fostered (Farhan et al., 2021), and science process skills remain weak, as reflected in both classroom-based studies and international assessments such as PISA (Deta et al., 2020; Kurniawan et al., 2021). This problem is caused by the science learning process which only focuses on content without paying attention to context where the teaching material is separated from contextual studies (Juniawan et al., 2024) such as local potential that exists around students, less involvement of students' critical and creative thinking skills (Farhan et al., 2021; Supratman et al., 2020), apart from that, there is less use of technological devices as data acquisition tools (Anwar et al., 2020; Fadhya et al, 2023; Juniawan et al., 2024). However, no learning model integrates theory and practice simultaneously (Kurniawan et al., 2021) to build 21st-century skills holistically (Chusni, 2023). This is in accordance with the results of a field study conducted during the 2023/2024 academic year at several science study program in the province of West Nusa Tenggara, Indonesia which showed that out of 240 respondents, only 1.3% expressed that vibration-wave learning was in the context of the SASAMBO tribe (Sasak-Samawa-Mbojo), only 17% involved software-based technology devices and applications, and 91.7% stated that teaching and learning activities were theoretical, so that 94.2% of respondents expressed that 21st century skills were not trained through vibration-wave learning.

One of the persistent challenges in physics teaching is the gap between abstract theoretical concepts and students' real-world experiences. Conventional wave teaching approaches often emphasize formulas and definitions without providing concrete context, leading to low engagement and limited skill development. The proposed solution in this study, which integrates the traditional Sasak musical instrument *saron* with modern ICT-based measuring instruments, directly addresses this gap (Sriyansyah & Anwar, 2021). By providing culturally familiar media alongside precise, technology-based analytical tools, students are encouraged to connect local wisdom with scientific reasoning. This synergy not only enhances the understanding of wave phenomena but also creates a more inclusive and meaningful learning environment, thereby bridging the gap between theory and practice in physics education.

This study is based on the lack of studies that connect vibration and wave events involving local media of traditional musical instruments and inexpensive ICT devices as teaching materials. Similar studies have been conducted (Anggraeni et al, 2019; Jaafar et al., 2016; Nita & Ramanathan, 2019; Anwar et al, 2020), but the object of the study is not local media from the Sasambo tribe, meanwhile (Anwar et al, 2018; Anwar et al., 2020) and (Kurniawan et al., 2021) only used one type of traditional plucked musical instrument from the Mbojo tribe, whereas the vibrating media of the traditional Sasambo musical instrument consists of a string vibration source, air column, membrane, and plate. However, none of the studies mentioned addressed how to apply it to develop science process skills, technological literacy, and creativity.

The study of waves is a central concept in physics education, yet it is often taught abstractly and disconnected from students' daily experiences. By linking wave phenomena to the traditional Sasak musical instrument, *saron*, students are provided with a tangible and culturally relevant medium to explore vibration, resonance, and sound propagation. This integration not only preserves local cultural heritage but also contextualizes scientific concepts meaningfully. Furthermore, incorporating low-cost ICT tools, such as digital oscilloscopes, spectrum analyzers, and tuner applications, enhances data acquisition and visualization precision, enabling students to bridge traditional knowledge with modern scientific analysis. This approach demonstrates how local cultural resources can synergize with technology to improve conceptual understanding, foster creativity, and promote 21st-century skills in science learning.

Linking the context of traditional musical instruments of the Sasambo tribe to science learning is interesting and meaningful because learning directly through real events using the science process, and teaching materials connected to local resources and technological devices, can improve the quality of learning. Creativity can emerge in the field of science (Farhan et al., 2021), such as through the Ethno-STEAM project-based learning (Juniawan et al., 2024). Likewise, the use of technology (Oppong et al., 2023; Yusuf et al., 2021; Tezer et al, 2024), such as software and smartphone applications, to explore vibration-wave events through signal data collection (Anwar et al., 2020) can improve students' technological literacy (Fadhya et al., 2023). Therefore, science teaching materials must be designed innovatively by internalizing local wisdom and technology. The learning process must be centered on student activities, involving contextual media for students, fostering creative thinking through brainstorming, providing collaborative forums, and simultaneously and holistically orienting activities towards product creation.

In line with this, to support previous research and enrich the vibration-wave teaching materials, this study identifies and characterizes vibration-wave learning materials using only the *saron* Sasak musical instrument and cheap ICT devices, with smartphone applications and efficient computer software serving as the data-acquisition system. Therefore, this study aims to develop and validate vibration-wave teaching materials for the traditional Sasak musical instruments *saron*, integrated with low-cost ICT devices, to enhance prospective teachers' science process skills, technological literacy, and creativity. Simultaneously, research on various musical instruments will continue until 2028, focusing on the creation of a learning syntax grounded in student-centered methodologies that emphasize problem-solving, projects, inquiries, and the integration of STEAM. This will help students become more culturally aware, improve their ICT skills, and foster critical thinking and creativity.

II. METHODS

This study refers to the results of previous studies up to 2028. The method used in this study is Research and Development (R&D) through the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) (Branch, 2010). The information/data to be studied in this study include the definition of vibration waves and physical quantities through the exploration of systems and waveforms, the concept of superposition/interference that forms stationary waves, the speed of wave propagation in a medium, studies of tone quality/sound color (timbre), and natural resonance that occurs through the traditional *saron* musical instrument system. Other data are obtained from ICT devices that can be used to acquire data on vibration-wave phenomena via software and Android smartphone applications. The data collection process is illustrated in Figure 1.

The data were analyzed quantitatively and qualitatively based on laboratory studies. All data from the musical instrument system and ICT were presented as teaching materials, which were then analyzed descriptively to obtain scores from validators (material experts, learning experts, and traditional music artists) against the eligibility criteria. User perceptions/responses to teaching materials were analyzed descriptively to determine the trial's response tendencies.

The participants in this study consisted of 11 prospective physics teachers in the 2024/2025 academic year. These participants were purposively selected to represent the subjects of a small-scale trial of the teaching materials developed to identify practical challenges and refine the design before a wider implementation. Validation was conducted by four experts in the fields of physics materials, instructional design, media, and traditional music. The validation process included assessing content relevance, language clarity, systematic organization, methodological appropriateness, and cultural contextualization of the items. The validation sheet used a 1-5 Likert scale, and the results were analyzed using descriptive statistics to determine the mean scores and categories. This process ensured that the instruments used for development and evaluation met the standards of content validity and practicality. This research was conducted over 10 months, from November 2024 to August 2025.

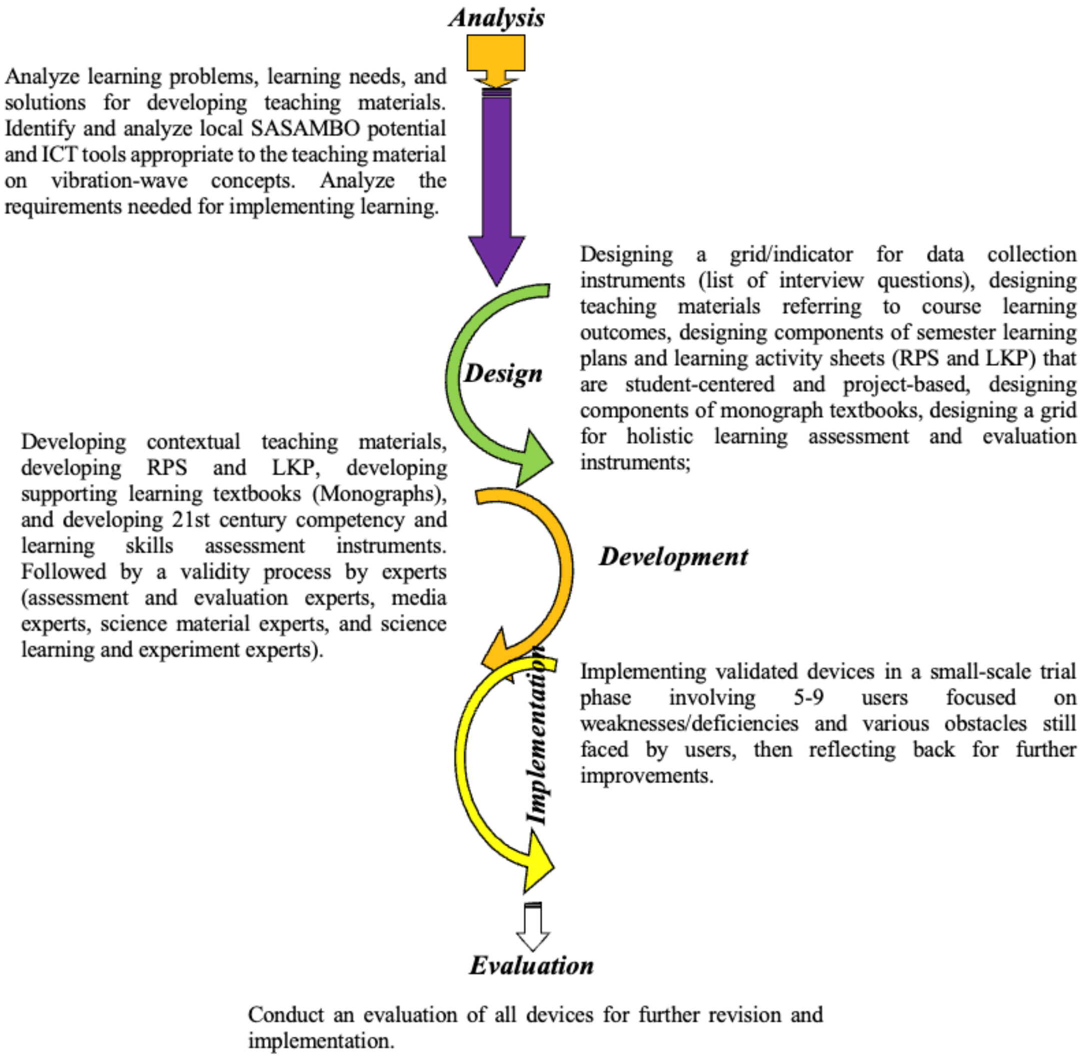

Figure 1. The data collection process

III. RESULTS AND DISCUSSION

1. Shape and type of *saron* Sasak

The *saron* Sasak is generally a plate blade with a slightly curved pattern, and when viewed from the side, it appears slightly trapezoidal. The shape of the *saron* Sasak is shown in Figure 2.

It consists sequentially of a) a blade, b) a saron body (*rancakan*), c) a beater (*tabuh*), d) a resonator (in the form of a bamboo organ pipe that is only closed at the bottom end), and e) a binding rope.

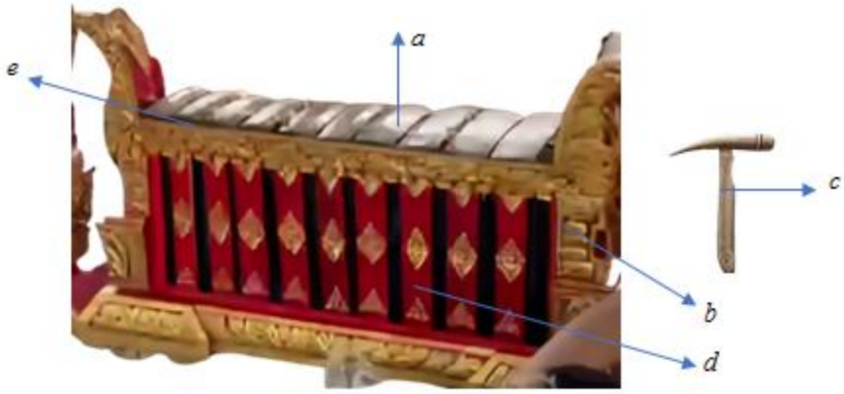

Figure 2. Shape and parts of the *saron* Sasak (Lombok, West Nusa Tenggara, Indonesia)

Various types of *saron* can be grouped based on the number/amount of blades, the length, thickness, and width of the blades, as well as the frequency of the tone produced, which is a function of the sound used in a type of music. Each type of *saron* Sasak is usually arranged in a pair whose dimensions are identical but differ slightly in producing the tone's frequency. The local community usually names a pair of similar *sarons* as *saron* A and *saron* B ten blades, *saron* A and *saron* B five blades, *saron* A and *saron* B seven blades, and so on.

2. Physical dimensions of *saron* Sasak

The most striking feature of the *saron* is its blade, which can vary in length, width, thickness, mass, and frequency of the tone produced. The length of the blade ranges from 25-40 cm, the width of the blade is approximately 5-7 cm, and the thickness of the blade is approximately 0.5-1 cm. The mass of the blade varies depending on the material it is made of (bronze or iron), which ranges from 100 g to 1 kg. The frequency of the tone is tuned according to the gamelan scale (usually pelog or selendro) with a higher frequency range than that of the Javanese gamelan.

Rancakan (frame or body of *saron*) can vary in length, width, height, and mass depending on the type and function of the *saron* used. The length was approximately 60 cm, the width approximately 20 cm, the height approximately 50 cm, and the mass approximately 20 kg. *Pemantok/tabuh* (beat) also varies in length, diameter, and mass according to the type of *saron* used. The length of the *pemantok* is approximately 20 cm, the diameter of the head of the beater is approximately 2 cm, and the mass of the beater is approximately 200 g.

The resonator is a cylindrical column in the form of an organ pipe, made of bamboo and closed at only one end. This column functions as a resonance amplifier for the tone produced by the blades. The dimensions of the column also vary in depth, diameter, and volume of the space, depending on and adjusting to the tone frequency of each *saron* blade. The dimensions of the resonance space depend on the size of the blades and *rancakan*, usually with a depth of 5–24 cm. The lower the fundamental tone frequency produced by the *saron* blade, the greater the depth of the resonator pipe, and vice versa. The diameter of the resonator pipe for all blades by the Sasak people is usually made identical to make it easier to adjust the harmonic resonance, focusing only on adjusting the pipe depth. The depth of the resonator pipe is adjusted using the principle of constructive superposition produced by each *saron* blade and the resonator pipe, which is closed at one end. The binding rope also varies in length and tensile strength depending on the size and number of *saron* blades or the size of the *saron* chain that occupies it. The length of the rope was approximately 2 m, and its tensile strength was adjusted to ensure it was strong enough to hold the blades stable during vibration and not shift when played.

The frequency of tones and harmonics is the most important physical measurement of saron musical instruments. The frequency is directly related to the sound wavelength. The fundamental frequency of the sound produced by each *saron* Sasak blade is in the range of 400–1200 Hz, depending on the dimensions of the blade. The wavelength varies with the frequency and the medium (air) through which the sound waves propagate. Determining the fundamental frequency of each blade's sound on the *saron*, a musical instrument of the Sasak, requires measurements with specialized tools such as tuners or frequency meters. However, in traditional gamelan music, including that played by the Sasak tribe, the blades on the *saron* are usually tuned in pelog or slendro scales, which have different tones than the Western diatonic scale system. Pelog scale: has seven tones in one octave with uneven intervals. Slendro scale: has five tones in one octave with more even pitch spacing. The specific frequency of each blade on the *saron* varies depending on the tuning (musical scale) used and the instrument's manufacturing process, which is often manually tuned and varies between regions or makers. In general, the estimated fundamental frequency for a gamelan with slendro tuning is as follows: the first bar is approximately 200-250 Hz, the second bar is approximately 250-300 Hz, the third bar is approximately 300-350 Hz, the fourth bar is approximately 350-400 Hz, and the fifth bar is approximately 400-450 Hz. However, for the *saron*, the frequency range for all its blades is approximately.

3. Study of teaching materials for vibrations and sound-waves in the *saron*

The basic concepts of vibrations and waves that can be learned through the *saron* Sasak musical instrument are shown in Table 1. The potential of local resources as learning resources in vibration-wave physics is rarely applied to students (middle level) and universities (students who are prospective physics teachers).

Table 1. Basic concept of vibrations on the *saron* Sasak musical instrument.

No	Indicator
1.	Definition of waves through
2.	Definition of physical wave quantities through waveform exploration.
3.	Superposition of waves.
4.	Speed
5.	The quality of the tone/color of the sound (timbre).
6.	Fourier analysis of the *saron* stone wave based on the frequency spectrum
7.	Fourier synthesis of *saron* tone waves
8.	Natural vibrations and plate system resonance.
9.	Musical mathematics (tonal structure and scales).
10.	Damping.
11.	Sound intensity.

However, this problem can be addressed using the results of this research, which are incorporated into the design of the main material and learning indicators through the traditional musical instrument Saron Sasak and ICT in learning activities, as shown in Table 2.

Table 2. The main material for studying vibrations and waves is the *saron* Sasak musical instrument.

Topic	Main material	Indicator
I.	Characteristics of vibration and waves. a. Definition of vibration and waves. b. Physical quantities of vibration-waves and their meanings. c. Mathematical models/equations or functions of vibration-wave deviations.	1. Observing vibration and wave phenomena in the *saron* musical instrument plate system. 2. Explaining the meaning/definition of vibrations and waves. 3. Observing blade vibrations, waveforms, and sound, as well as wave propagation, and connecting them to define Amplitude (A) and the strength and weakness of sound, as well as the differences between vibrations and waves. 4. Analyze the relationship pattern of period (T) and frequency (f) of waves and define period (T) and its relationship to frequency (f). 5. Relating the number of waveforms (n) formed to the duration (Δt) to define the frequency (f) and the pitch of the sound, and its relationship to the period (T). 6. Describes the definition of wavelength (λ) and wave number (k) by relating the number of waves (n) formed to (λ) in the spatial dimension ($n \times 2\pi$). 7. Explains the definition of angular frequency (ω) and its relationship to frequency. 8. Analyze the general relationship between wave propagation speed (v) and λ and f, and explain its physical meaning. 9. Building a mathematical model/function of vibration/wave deviation of a Saron tone.

		10. Identifying the physical components of vibrations/waves (Amplitude A, angular frequency ω, wave frequency f, wave phase angle θ, and initial wave phase angle θo).
II.	Superposition of vibrations/waves.	1. Explains the meaning of the superposition of various conditions, and the phenomenon of wave levitation/beat.
III.	Wave propagation and speed.	1. Investigating the relationship between frequency, wavelength, resonator column length, and wave propagation speed in air at a certain temperature. 2. Investigating the relationship between wave propagation speed in the air medium and variations in distance or length of the wave propagation medium. 3. Investigating the relationship between wave propagation speed in a medium under conditions of various wave frequency variations. 4. Investigating the relationship between wave propagation speed in the air medium and variations in sound amplitude or volume. 5. Investigating the speed of wave propagation in the air medium under conditions of temperature variation.
IV.	Timbre and harmonic content. (Fourier Analysis and Synthesis).	1. The frequency spectrum of the Saron tone. 2. Distinguish the characteristics of two or more sound waves based on the following criteria: - The same sound source but played in different ways (struck and rubbed). - Different types of sound sources (*saron* and *reong*) produce the same/identical tone or frequency. 3. Comparing the harmonic spectrum state (such as the number of harmonic contents) of two identical and/or different sound waves. 4. Explains the causes of differences in the sound quality of a note produced by a musical instrument. 5. Describes the concept of sound color (timbre) as a manifestation of tone quality based on waveform and harmonic spectrum. 6. Synthesize the waveform of a Sharon tone and investigate the relationship of the sum of the Fourier series to reconstruct the original waveform.
V.	Natural resonance and vibration.	1. Identifying the natural frequency spectrum and/or harmonics of the Saron tone sound. 2. Investigating the natural resonance and harmonics of the Saron blade plate system. 3. Investigating the natural resonance and harmonics of the Saron Resonator air column system, which is closed at one end. 4. Showing the relationship pattern of the natural fundamental frequency (f_o) of the Saron blade vibration with the dimensions (length, width, thickness) of the Saron blade. 5. Determining the damping formula and damping factor of the Saron tone wave and its relationship to the vibration or sound energy through waveform and spectrum analysis.

VI.	Stationary waves along the air column (*saron* resonator).	1. Shows a mathematical model of the relationship between the fundamental frequency (f_1), the fundamental wavelength (λ_1), the measured air column length (L), and the wave speed (v), and explains its physical meaning in a closed air column system at one end. 2. Shows the functional relationship between the air column diameter (D) and the fundamental frequency (f_1) and determines the ratio/comparison of the pipe end correction (C_i) to the pipe diameter (D). 3. Shows the graph and mathematical pattern of the relationship between the length of the air column (l_h) and the fundamental frequency (f_1) of the Saron blade.
VII.	Sound and intensity of the *saron* tone.	1. Determining the intensity level (*TI*) of the *saro*n tones. 2. Calculating the average intensity level (*TI*) of the *saron* tones. 3. Comparing the intensity level (*TI*) of one tone to many tones. 4. Showing whether or not there is an effect of distance (r) on the intensity level (*TI*) of a tone produced by the *saron*.
VIII	Saron scale note structure	1. Investigation of the structure and system of musical scales produced by the *saron*. 2. Describes the relationship between traditional and modern Saron scale structures.
IX	Creativity projects	1. Create unique/creative/different musical instrument products from existing ones by paying attention to producing the right notes according to the reference notes.

Several teaching material designs in Table 2 are also supported by the research results of Cytasari and Mitrayana (2015), namely, analyzing the relationship between the fundamental resonance frequency values ($f_{o,\,i}$) of each *saron* region, which increases with the region width (L_i) by assuming the same thickness (d). Kuswanto (2011) also stated that the sound signal pattern of each *saron* region (seven regions) is identical, but not identical for each waveform, and that it exhibits a damped pattern. This study presents the basic frequencies of each *saron* instrument in the Nagawilaga and Gunturmadu gamelan. Research on the resonator-hole factor of the Slenthem musical instrument, located under each region, was conducted by Ardiansyah et al. (2014). Explains that examples of musical instruments and computers can be applied as an introduction to understanding Fourier series in explaining complex wave equations, and can provide a basic view of the mathematical and physical concepts in musical instruments.

4. Study of ICT devices for the saron Sasak

The sound wave phenomena of musical instruments are very difficult to observe using only human senses (Yusuf et al., 2021) because the sound waves produced by musical instruments are complex; therefore, tools are needed to acquire data. These tools are software-based ICT devices that run on computers or smartphones (Anwar et al., 2020). The ICTs that can be used to acquire data on the vibrations and waves of the *saron* Sasak musical instrument are listed in Table 3.

Table 3. Software and applications for data acquisition of vibration-wave events for the *saron* Sasak musical instrument

No	Software/ applications	Description
1.	Adobe Audition	Software with a multitrack system and audio editing. In the "menu bar" or "toolbars" of Adobe AuditionTm-1.5, there are various tools for editing and analyzing recorded signals, such as cutting files, zooming in/out, adding sound effects, mixing files, analyzing the frequency spectrum, checking statistical data, changing amplitude, and checking signal duration.
2.	MacScope II	The type of computer-based digital oscilloscope software is free to access, practical, relatively easy to operate, and provides a fairly good level of accuracy and precision, making it an efficient tool for science learning.
3.	LoggerPro	Software that functions as a curve fitting based on selecting a fitting function that suits the data pattern (sine, cosine, regression, power, logarithmic, etc.).
4.	*Advanced Spectrum*^{pro}	An Android-based application of a signal spectrum analyzer with an official website www.vuche.com. For the purpose of learning about Saron sound waves, this application has the following features: (play) ►, (pause)❚❚ : to start and end data observation; Screenshot: to capture the results of the data display, Enable peak hold: to display the spectrum graph on the main page.
5.	DaTuner/Lite Chromatic	It is an application for measuring frequency and tuning musical instrument tones. However, this application can be used to determine the pitch, namely the sound frequency of a musical instrument, at small deviations from the standard value.
6.	Intensity meter	An Android application that measures the noise level of a sound source.

The signal of the Saron musical instrument is difficult to observe directly with a Cathode Ray Oscilloscope (CRO), especially for very short sounds, due to the limitations of human hearing. Adobe Audition software was developed for industrial music production and offers comprehensive audio editing features. However, for the purposes of learning science, this software can help visualize the sound signal of the Saron musical instrument through recordings (Virgin, 2018). The MacScope II was used in this study to analyze and synthesize the waveform and harmonic frequency spectrum of the recorded sound signal from the *saron*. This software can display the shape of a signal (waveform), record its constituent numerical data in discrete form, determine the components that form the signal, and synthesize the signal. LoggerPro software can be used to determine the mathematical formula of the relationship between two variables. For example, in the case of the *saron* musical instrument, a functional relationship between the length of the *saron* blade and the frequency of the *saron's* basic tone can be obtained precisely. Advanced SpectrumPro can be used to display the spectrum of the signals generated by *saron*.

Furthermore, it can show the harmonic frequency value data contained in Saron. The use of the DaTuner/Lite Chromatic application in this example is to find out the pitch for the note $A_{4(+21)}$, then the actual note frequency that we get is $f_{A4(0)}\times$=440×= 440×1,0122 = 445,369 Hz, and or if our tuning is minus at -21 cents, then the frequency value obtained will be $f_{A4(0)}\times$ = 440×= 440×0,9879 = 434.679 Hz. The Intensity meter application can serve as a tool to measure the noise level of each struck *saron* blade at various distances.

Integrating ICT into inquiry activities can promote students' digital literacy, which is useful in their lives (Oppong et al., 2023). The quality of smartphone applications and computer software can serve as a supporting medium for learning about vibrations and waves (Momox & Ortega De Maio, 2020). The use of technological devices can help students understand the theories and concepts taught easily and quickly (Fadhya et al., 2023). The application of ICT for learning about vibration-wave phenomena can represent these events as observables, such as oscilloscope software or applications, the Phys Clips simulation website created by Wolf et al. (2013), and PhET *(*Physics Education Technology*)* created by the PhET Colorado Department of Physics, University of Colorado. Meanwhile, to analyze sound signals, one can use the frequency analyzer and spectrogram analyzer applications (Florea, 2019) because they have an FFT/Fast Fourier Transform feature to determine the basic frequency of tuning fork and piano sound waves with high precision in the frequency range between 100 Hz and 11 kHz. Hawley and McClain (2018) visualize sound direction with smartphone sensors, where data collection via the smartphone audio port is very effective, whereas Fadhya et al. (2023) stated that smartphones and their applications could be a cheap alternative to a signal generator for physics laboratory activities. Jaafar et al. (2019) developed a KIT to demonstrate the harmonic series of an organ pipe system using a smartphone and its application. In addition, Audacity and similar software can be used to explore various signals (electromagnetic and acoustic) and characterize their information content through frequency spectra or amplitude analysis. The concept of wave propagation speed in an air medium under temperature variation was also investigated by Staacks et al. (2019), who used only smartphones as their devices.

5. Eligibility of teaching materials

The suitability of teaching materials is based on eight components, each of which contains indicators (content/material suitability aspect, presentation/objective aspect, language aspect, method aspect, evaluation aspect, systematic aspect, graphic/interesting aspect, and detailed aspect), each of which consists of several statements/questions. The evaluators' assessment of the suitability of the developed teaching materials is shown in Table 4.

Table 4. Results of the assessment of teaching materials by the evaluator

Component	**Evaluator**				**Average**
	Material expert	Media expert	Artist	User	
Material	90	84	86	87	86.7
Objective	89	83	83	86	85.2
Linguistics	75	66	65	76	70.5
Method	88	88	87	78	85.2
Evaluation	82	75	85	75	79.2
Systematic	*82*	75	86	75	79.5
Interesting	90	78	85	82	83.7
Detailed	80	86	87	80	83.2
Average	86	80	79	80	81.7
Category	Very good	Good	Good	Good	Good

The material component is indicated by the alignment of learning outcomes and objectives, alignment with concepts, principles, laws, and facts, up-to-date/contextual material, clarity, relative ease of independent understanding, conciseness, and material written in a multi-representational manner. The objective component is indicated by clarity and measurability, in accordance with basic competencies. It reflects understanding of concepts and principles, the application of concepts, and skills in activities based on data acquisition. The linguistic component concerns simple sentence structures and ease of understanding, suitability with scientific writing rules, and the use of effective, efficient, and communicative sentences. The method component emphasizes the scientific approach, is suitable for students with varying abilities, provides instructions, is oriented towards improving skills, tools, and materials contained in available and easily accessible textbooks, is oriented towards the use of ICT, and identifies laboratory activities in the text.

Furthermore, the evaluation component is constructed with questions that require readers to review what they have learned, can be used independently, and motivate students to explore it further. The systematic component focuses on the presentation of sequential, well-structured, interrelated, and flexibly organized material. The attractiveness component is evident in the reader's attention, proportional print dimensions, up-to-date illustrations, and the clear presentation of images and graphics. Meanwhile, the detailed component is indicated by a concept that is explained in detail, in accordance with students' abilities and based on the needs of prospective physics teachers in the 21st century. The data in Table 4 show that validation by experts on content, objectives, methods, and presentation yielded an average score above 80%, indicating that the developed teaching materials are categorized as good to very good. This finding indicates that the integration of the *saron* Sasak instrument with ICT tools is both pedagogically sound and scientifically valid.

In general, the teaching materials developed through the phenomenon of the *saron* sasak musical instrument received a good eligibility statement. However, some general notes recommended by the evaluator include correcting the sequence numbers of tables, diagrams, and images, errors in writing words and sentences, consistency in writing symbols, and words or sentences that are to be emphasized do not need to be added with double signs (such as quotation marks + italics + bold), but only use one sign. Other inputs include suggestions to position formulas consistently in the center margin, write tables, and number them sequentially. Tables that are split across pages need to be re-identified in each column (repeated header row). References must be consistent and sufficient, including the name and year. Images, graphs, and their components must be clear and easy to read. Affirmation of the designation of tables, images, or equations is sufficient with their sequence numbers. It does not need to be added with positional adverbs (such as above, below, and so on). It is recommended that the material on the use of ICT be divided into several chapters because it is too dense.

6. Students' perception of teaching material products

In general, user responses to teaching materials designed through the phenomenon of the *saron* Sasak musical instrument were very positive, with an average score for all aspects of 399.91 (max. 500). The aspects observed in student perceptions of the practicum program consisted of aspects of motivation, benefits and uses, effectiveness and efficiency, interest, attitude, ease, knowledge development, development of science process skills, novelty, and ICT literacy, as shown in Figure 3.

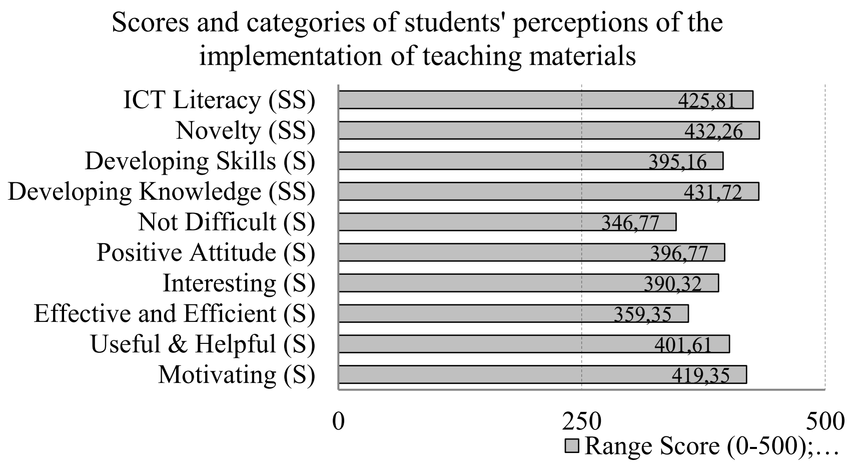

Figure 3. Students' perceptions of vibration-wave teaching materials based on the *saron* musical instrument

The majority of students responded positively to the teaching materials on the phenomenon of the traditional musical instrument, *saron* Sasak, integrated with ICT. The teaching materials on vibration waves associated with the traditional musical instrument Saron can motivate and interest students in learning. In addition, students can recognize the various types and characteristics of the acoustics of traditional musical instruments through learning with visual representations of waveforms, directly and in real time, involving and activating all students' senses.

Furthermore, user perception data (Figure 3) showed a very positive response with an average score of 399.91 out of 500, reflecting students' high motivation, engagement, and recognition of the benefits of contextual and technology-based learning. Taken together, these quantitative results provide strong empirical support for the argument that ethnoscience-based learning materials, when combined with modern technology tools, can significantly improve students' science process skills, creativity, and digital literacy, thus aligning with the theoretical framework of contextual learning and TPACK.

The findings of this study strongly align with the theoretical foundation of contextual learning, which emphasizes that students learn more effectively when abstract scientific concepts are connected to familiar cultural experiences. The use of the *saron, a* Sasak traditional instrument, as a learning medium demonstrated how local wisdom can serve as an entry point for exploring complex concepts in physics, such as resonance, frequency spectrum, and sound intensity. This is consistent with the TPACK theory, which holds that integrating technology, pedagogy, and content creates a meaningful learning environment by combining ICT tools with traditional media. The students' positive responses indicate that contextual and technology-supported approaches foster not only conceptual understanding but also creativity and scientific process skills. Moreover, expert validation, with high feasibility scores, confirmed that the developed materials met both pedagogical and technological standards. Such integration bridges the gap between theory and practice, highlighting that physics learning rooted in cultural contexts can also cultivate 21st-century competencies.

These findings imply that teaching physics through traditional musical instruments such as the *saron* Sasak provides a concrete and engaging way to practice scientific process skills. When students observe vibrations, measure frequencies with ICT devices, and analyze resonance patterns, they learn theoretical content and engage in authentic scientific inquiry. This process trains students to formulate hypotheses, design simple experiments, collect and interpret data, and draw evidence-based conclusions. These activities embody core science process skills, including observing, classifying, measuring, inferring, and predicting. Consequently, contextual learning with cultural instruments, supported by digital technology, equips students to bridge theory and practice while fostering creativity, critical thinking, and problem-solving skills essential to 21st-century scientific literacy.

The integration of ICT devices in this study significantly impacted students' understanding of wave and vibration phenomena. Applications such as Adobe Audition, LoggerPro, and DaTuner enabled students to visualize sound waves as spectra, waveforms, and frequency data, which are often difficult to perceive directly. This technological support provides more precise and reliable measurements, allowing students to analyze variables such as amplitude, frequency, resonance, and intensity with greater accuracy. As a result, abstract concepts became tangible and accessible, fostering a deeper conceptual understanding. Furthermore, the use of smartphones and computer-based applications encourages active exploration and experimentation, which aligns with the principles of inquiry-based learning. These findings highlight that ICT integration not only improves students' scientific literacy but also equips them with digital skills highly relevant to 21st-century learning.

Compared with previous studies integrating traditional musical instruments into physics learning, this study offers broader and more in-depth contributions. For example, Anggraeni et al. (2019) used gamelan and smartphones to teach about sound waves, while Anwar et al. (2020) used bamboo flutes during the Covid-19 pandemic to explore acoustics. These studies confirmed the feasibility of using traditional instruments to visualize basic sound concepts, but their scope was still limited to specific wave phenomena. In contrast, this study used *the Saron* Sasak instrument to examine fundamental aspects such as frequency, resonance, and waveform. It developed comprehensive teaching materials that were validated by experts and tested with users. Furthermore, this study integrated ICT-based data acquisition tools, such as Adobe Audition, LoggerPro, and DaTuner, thereby enabling more precise exploration of wave phenomena and greater technological enrichment. Therefore, while previous research has highlighted the cultural and pedagogical potential of ethnoscience, the current findings extend this line of research by demonstrating a comprehensive approach that aligns with TPACK principles and supports the development of 21st-century skills.

IV. CONCLUSION AND SUGGESTION

This study developed and validated vibration- and sound-wave-based teaching materials using the traditional Sasak saron musical instrument, integrated with low-cost ICT devices, to support the development of science process skills, technological literacy, and creativity among prospective physics teachers. The results demonstrate that the developed materials are pedagogically feasible and scientifically sound, as indicated by high expert validation scores and very positive user responses. The integration of the *saron* Sasak as a contextual learning medium enabled students to explore core wave concepts, such as vibration, frequency, resonance, waveform characteristics, and sound intensity, through direct observation and data-driven analysis. Supported by ICT-based tools, students were able to bridge abstract theoretical concepts with real-world phenomena, fostering meaningful inquiry, deeper conceptual understanding, and greater engagement in physics learning.

Although the findings indicate positive outcomes, this study is subject to several constraints. The intervention was implemented with a relatively small group of prospective teachers, which may limit the extent to which the results can be generalized to broader educational contexts. Future research is therefore recommended to involve larger and more diverse participant groups. Further research could explore integrating other traditional instruments from diverse cultural backgrounds or using advanced ICT applications, such as virtual laboratories and augmented reality, to enhance students' inquiry-based learning and collaborative skills. Nevertheless, this study contributes to the field of physics education by providing validated teaching materials that integrate cultural resources with modern ICT. The integration of the *saron* Sasak musical instrument as a contextual medium demonstrates how local wisdom can be transformed into a powerful tool to bridge abstract theory with practical experience, in line with the demands of 21st-century education.

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