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Study of Sound Materials of Water Hyacinth (Eichhornia Crassipes) as Alternative STEAM Integrated Project-Based Learning Model (PjBL)

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Abstract

This study aims to find an alternative sound-absorbing material from nature that is cheap and environmentally friendly, namely the water hyacinth plant (Eichhornia crassipes). The experimental soundproofing tool from a glass box with a placemat skat was developed by integrating science, technology, engineering, arts, and mathematics (STEAM) elements as an alternative project-based learning model (PjBL) for students. The research method used is experimental. Water hyacinth was sun-dried, woven in the form of a placemat with two variations of the test samples at several frequencies of 250 Hz, 500 Hz, 750 Hz, 1000 Hz, and 1500 Hz. Six stages of PjBL are used, and elements of STEAM are integrated. The results of the study obtained the value of Noise Reduction (NR) of sound for test samples 1, test sample 2, or a combination of test samples 1 and 2. Each test sample is effective at 1500 Hz high frequency; namely, test NR 1 = 8.7 dB, test NR 2 = 8.3 dB, and NR Gab=9.3 dB. The combined test sample was also effective at frequencies of 500 Hz and 750 Hz, with NR Gab=4.3 dB and NR Gab=4.7 dB. Following the theory that changes in sound between 3 to 12 dB have effects that humans can feel. This study concludes that natural water hyacinth fiber has fairly good quality as an alternative sound-dampening material. This experimental tool can also be an alternative to the STEAM-integrated PjBL learning model.

Keywords: water hyacinth, PjBL-STEAM, sound-dampening material, noise reduction

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is one of the many diversities of flora in aquatic areas, living floating in water that can develop roots in the mud in shallow water. Water hyacinth was first imported by the Dutch from Brazil to Indonesia at the Bogor Botanical Gardens in 1894. It was initially an ornamental plant loved because its purple flowers were beautiful to decorate ponds, such as the lotus (Hartanto 2020). Water hyacinth is a plant that floats on the water's surface and has thick leaves and bubbles that make it float (Wijaya 2015). Water hyacinth reproduces very quickly, so it is considered a plant that can damage the aquatic environment and is known as the most dangerous weed (Ting et al. 2018; Hartanto 2020). Another negative assumption about water hyacinth is that this plant can be one of the causes of shallow swamps (Samsudin & Husnussalam 2017). Water hyacinth is now considered a serious threat to biodiversity, as it can reduce light and oxygen, alter water chemistry, affect flora and fauna, and cause significant increases in water loss due to evapotranspiration, problematic for lake transportation, fisheries, hydropower, and irrigation schemes (Akbar 2020).

Besides having a negative impact, it turns out that water hyacinth has many benefits. The utilization of water hyacinth can produce handicrafts that have economic value, are reasonable, feasible, and meet life's needs (Hidayatullah 2011). Water hyacinth can be used as raw material for making multiplex, bags, paper, compost, biogas, household furniture, and various handicraft products (Akbar 2020). Water hyacinth is an organic material that can be used to manufacture biogas as renewable energy (Astuti 2013). Utilization of water hyacinth plants can also be used to reduce cod (chemical oxygen demand) content in wastewater (Duarte et al. 2018), for phytoremediation of ammonium nitrogen content in water (Ting et al. 2018), ethanol production (Mishra & Maiti 2017), as compost (Marjefri 2019; Ismail et al. 2020), and biogas (Renilaili 2015; Mishra & Maiti 2017) or biomass (Feng et al. 2017).

Another use of water hyacinth is in acoustics, namely reducing noise used as an acoustic or sound dampening material (Febrita & Elvaswer 2015). Noise is unwanted sound or sound that can cause health problems and environmental comfort. Making a material that can reduce or even absorb sound intensity is necessary, known as proper absorption material or sound absorber (Bahri et al. 2016). Noise can come from the human voice, where the frequency ranges between 600-4000 Hz (Satwiko 2008). Efforts that can be made to control noise are by making acoustic materials. These materials can absorb sound so that unwanted noise or noise can be muffled by using these materials (Kurniawan and Syamsiyah 2020). Acoustic materials that can be sound absorbers are usually characterized by the presence of pores (Putra and Nazhar 2020). Sound-absorbing materials that reduce high frequencies are porous and fibrous absorbers (Satwiko 2008) and those available in nature, namely water hyacinth absorbent fibers. Fiber is a material in the form of pieces that form a complete network. The fiber used in this study is natural water hyacinth fiber. It is known that water hyacinth fiber contains cellulose 18-31%, lignin 7-26%, hemicellulose 18-43%, and ash 15-26% with a water content of 85-95% (Nata et al. (2013).

Students in the 21st century have real-life problems (Rahmawati 2020). Students cannot solve these real-life problems quickly with traditional education. Traditional education focuses on developing student knowledge, but in the 21st century, students need skills-based education to deal with these real-life problems. Social and technological changes have grown in recent decades and have raised fundamental questions about what types of skills will be needed by future generations (Kim et al. 2019; Jatmiko et al. 2020). Likewise, in education, the development of science and technology has provided many innovations in delivering knowledge in teaching (Widyanti 2021). The very rapid development of science and technology requires the world of education to improve learning (Marta 2018). Entering the 21st century and the era of the Industrial Revolution 4.0, students must have several abilities or skills. The 21st century is a century of knowledge marked by technological advances and application in all fields, requiring qualified human resources, skilled in learning and innovation. In human resources in the 21st century, in this case, students must have critical thinking skills and problem-solving, communication, collaboration, creativity and innovation, and master information technology (Keane et al. 2016).

The benefits of water hyacinth allow it to be used as an alternative learning model that supports 21st Century Education, namely the project-based learning model (PjBL) integrated with STEAM (science, technology, engineering, arts, and mathematics). Afriana (2016) said PjBL is a learner-centered learning model that provides students with a meaningful learning experience. Students' learning experiences and concepts are built based on the products produced in the project-based learning process. The PjBL approach creates a "constructivist" learning environment where students develop their knowledge and educators become facilitators. According to Whatley (2012), PjBL is constructivist and collaborative learning that allows students to work together in solving a problem from knowledge. PjBL is a project-based learning process centered on students solving problems, designing, and creating work (Serevina & Muliyati 2015). At the same time, STEAM offers activities that involve students in design and engineering tasks to explore students' science and math skills through creativity, expression, and visual aspects that also support logical thinking (Ismayani 2016; Spiko et al. 2017). The PjBL-STEAM model is a learning process that combines a project-based learning model using the STEAM approach. The PjBL-STEAM model encourages students to gain more profound knowledge by actively exploring real-world challenges and problems by integrating each STEAM component (Annisa et al. 2019).

The STEAM approach is an approach that integrates five disciplines that teachers can apply in various learning environments (Suganda et al. 2021). As technology develops, the STEAM approach is increasingly popular and is used to measure creative thinking skills (Wandari et al. 2018; Anindya 2020) and problem-solving (Sun & Jeong 2015; Ozkan & Umdu 2020), concept understanding, and critical thinking (Fatimah 2017). It can make science learning more interesting (Conradty & Bogner 2019). The teacher can integrate STEAM with environmental concepts (Suganda et al. 2021). In the learning process, the STEAM approach can collaborate with project-based learning. Project-based learning can target one or more content. Still, STEAM can be an excellent opportunity to create projects that meet science, mathematics, technology, and even elements of the arts (Miller 2017). Fatimah's (2017) research proves that applying the STEAM approach to learning using PjBL can develop 21st-century skills, namely critical thinking and problem solving, creativity and innovation, communication and collaboration, information literacy, media literacy, technological literacy, flexibility, and adaptability. The advantages of STEAM integrated PjBL is also stated by Santi (2020) that the PjBL model can be used to improve 21st Century skills (4C: Critical thinking, Collaboration, Creative, Communication) by being integrated with the STEAM approach. According to Reza (2017), the STEAM approach using PjBL can develop students' soft skills: collaboration, empathy, communication, critical thinking, environmental care, hard work, adaptability, responsibility, creative thought, leadership, and curiosity, and honesty.

From the literature review results above, the researcher will conduct further research on sound absorbers made of water hyacinth. Previous research on silencers made of water hyacinth fiber has been carried out by Febrita and Elvaswer (2015) using the 2-microphone impedance tube method. The data displayed is the absorption coefficient of the material at several different frequencies. Meanwhile, this study will be presented with another technique, namely, the data displayed is Noise Reduction (NR) versus frequency. In addition, it will also explain the usefulness of this research as an alternative to the STEAM-integrated project-based learning model (PjBL) for students. Thus, this research aims to find an alternative sound-absorbing material from nature that is cheap and environmentally friendly, namely the water hyacinth plant. The experimental soundproofing tool from the glass box was developed by integrating STEAM elements as an alternative project-based learning model (PjBL) for students.

METHODS

Research procedure

This research procedure begins with a study of research conducted by Noviandri and Harjani (2016), which divides two rooms with room one as the source room and room 2 for the receiver. The first room has active speakers and Sound Pressure Level (SPL), while the second room only has SPL. What is used as space is cardboard media and soundproofing material made of patchwork. This research began by designing an experimental soundproofing device by making modifications, namely a room made of glass of a specific size and in a tightly closed position. On the top side, it is designed to be opened and closed to insert the sound damper test sample and SPL application, as shown in FIGURE 1, which is the schematic of the proper suppression experiment.

FIGURE 1. (a) Sound Damping Experiment Equipment, (b) Experimental Device Setting

The glass is shaped into a box with 30 x 30 cm. The box glass was partitioned into two rooms; the first room for sources of sound and the second room for receivers. An active speaker is connected to a frequency generator in the first room, while the second room is empty. SPL is used to measure the sound intensity of each room. The SPL used is the SPL application on a smartphone, as shown in FIGURE 2, downloaded using the Google Play application. While the generator also operates an online application, the Online Tone Generator, as shown in FIGURE 3.

FIGURE 2. SPL smartphone application

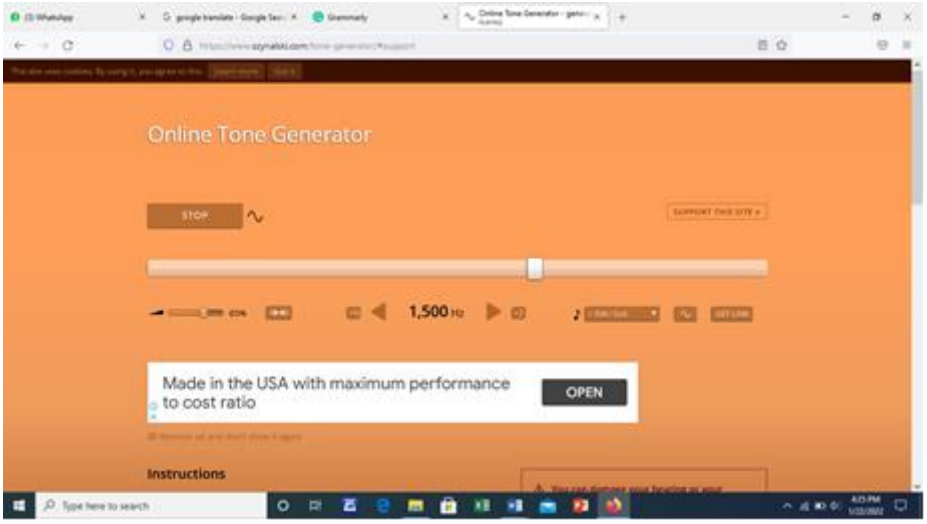

FIGURE 3. Online tone generator application

The acoustic or sound-absorbing material is made of water hyacinth fiber formed into round weaved or round placemats, as shown in FIGURE 4. Two round placemats are made, respectively, as test sample 1 and test sample 2.

The experimental tool mentioned above is a project designed to be integrated with STEAM, which contains science, technology, engineering, art, and mathematics elements. Students can explain science from the material about sound waves and their properties. Technology is explained with experimental tools that utilize IT technology. The technique is presented through how to take experimental data. Art is presented through round Placemat weaved art on acoustic materials. While mathematics through practical data analysis techniques that use mathematical operations.

FIGURE 4. Round Water Hyacinth Placemat

Data Collection Technique

Data retrieval varies the frequency and on the online tone generator application. The frequency of the online tone generator is varied on a scale of 250 Hz, 500 Hz, 750 Hz, 1000 Hz, and 1500 Hz. Before taking measurements, it is necessary to set the sound intensity for each frequency ranging from 60-70 dB by turning down the volume on either the online tone generator or the active speaker. This is done to not interfere with hearing (Kustaman 2017). The first step is to measure the sound intensity with the SPL application with a smartphone in the sound source and receiving rooms. Because the SPL application uses the same smartphone, the data is first collected in the sound source room for the variations of the five frequencies above and recorded as SPL 1 data. Then the smartphone is moved to the receiving room and recorded as SPL data 2. The next step is SPL data collection. 1 and SPL 2 with a glass slide without a silencer test sample, then the researcher took data for test sample 1, test sample 2, and a combination of test samples 1 and 2. The researcher took each sample 3 times with data in different positions by rotating the placemat. The data is then recorded in a table and displayed in a graph. The data collection process is as shown in FIGURE 5.

(a) (b)

FIGURE 5. (a) Setting for data collection using a glass slide, (b) Setting data collection using a glass slide plus a water hyacinth placemat sample

RESULTS AND DISCUSSION

The other studies have developed tools for student experiments to help observe sound intensity. But the tools developed in this study did not use natural materials as sound absorbers (Athiyyah et al. 2020). The research conducted was to find sound-absorbing materials derived from natural water hyacinth fibers (Febrita & Elvaswer 2015). The researcher chose water hyacinth because it is an abundant plant commonly found in swamps or lakes, even identical to the most dangerous weed plants (Ting et al. 2018; Hartanto 2020). Water hyacinth is also a porous fiber and contains cellulose 18-31%, lignin 7-26%, hemicellulose 18-43%, and ash 15-26%, with a water content of 85-95% (Nata et al. (2013). Analysis of sound absorbers is done in this study by analyzing Noise Reduction (NR). Noise Reduction (NR) is the difference in the level of sound intensity between the room that is the sound source and the sound receiving room, which is separated by a medium, such as a partition wall (Noviandri & Harjani

2016). Different things were done by Febrita & Elvaswer (2015), namely by looking for the absorption coefficient using an impedance tube. This was done because analyzing NR is easier to apply in science learning and is carried out by students. The experimental tools used are as shown in FIGURE 1. it is also easy to make and inexpensive. Whereas impedance tubes are more complicated and the equipment is more expensive. As for other devices such as smartphones, large laptops, and active speakers, almost all students now have these tools and do not need to buy new ones. The sample uses round wicker or a round placemat because it is easy to do and can be used as a first step in making art and soundproofing material. Furthermore, this research can also be used as an alternative to the STEAM integrated project-based learning (PjBL) model of the experiments and tools used. This means that experiments using sound suppression devices such as FIGURE 1 will provide information about integrating various disciplines consisting of science, technology, engineering, arts, and mathematics.

Noise Reduction (NR)

Sound is a mechanical wave in air or solid objects that can still be caught by the average human ear, with a 20 – 20000 Hz frequency range. Sounds at specific frequencies can cause noise, such as human voices, engine noise, or traffic noise. Noise from the human voice is 600 – 4000 Hz (Satwiko, 2008). In this study, an acoustic material made from natural fibrous and porous materials, namely water hyacinth, is woven in the form of a round placemat, as shown in FIGURE 4. Noise Reduction (NR) acoustic material analysis was carried out to see the effectiveness of the material as a sound absorber. The magnitude of the NR value describes how much the object reduces the sound intensity and can be calculated using EQUATION 1.

$$NR = SPL_1\text{-}SPL_2 \quad (1)$$

where,
NR = Noise Reduction (dB)
SPL_1 = average sound pressure level in the source room (dB)
SPL_2 = average sound pressure level in the receiving room (dB)
(Noviandri & Harjani 2016)

The observations using the experimental tool above (FIGURE 1) were carried out in several stages on the test sample at five different frequency variations, namely 250 Hz, 500 Hz, 750 Hz, 1000 Hz, and 1500 Hz. First, observations using an experimental device **(**FIGURE 1) without a test sample or just a glass slide, the results obtained are NR which are given the symbol NR K sequentially at a frequency of 250 Hz, 500 Hz, 750 Hz, 1000 Hz, and 1500 Hz of 10 dB, 22 dB, 18 dB, 17 dB, and 23 dB. The next stage is observing by adding a test sample, as shown in FIGURE 5**.** Variations made are by adding test sample 1, test sample 2, and a combination of test sample 1 and test sample 2. In observations using this test sample, each is carried out three times. At five different frequency variations as in the first stage of the experiment. The NR value is obtained, which gives the symbol NR S. To get the NR value referred to in this study, the NR S value results from 3 observations at each frequency minus the NR value. K at the same frequency with the formula as in EQUATION 2.

$$NR = (NR\ S - RN\ K) \quad (2)$$

where,
NR = Noise Reduction (dB)
NR S = noise Reduction after being given a test sample (dB)
RN K = Noise Reduction before being given a test sample (dB)

The NR value obtained from the 3 observations is then determined by the average NR at each frequency, as shown in TABLE 1.

TABLE 1. The results of the calculation of the average Noise Reduction (NR)

NO	Test Sample	250 Hz (dB)	500 Hz (dB)	750 Hz (dB)	1000 Hz (dB)	1500Hz (dB)
1	Test Sample 1	0.3	2.0	1.7	1.7	8.7
2	Test Sample 2	1.0	3.0	0.3	1.7	8.3

NO	Test Sample	250 Hz (dB)	500 Hz (dB)	750 Hz (dB)	1000 Hz (dB)	1500Hz (dB)
3	Test Sample 1 + Test Sample 2	0.7	4.3	4.7	2.7	9.3

According to Satwiko (2008), sound changes between 3 to 20 dB have effects that humans can feel. The observed NR value shown in TABLE 1 shows that the test sample is effective at a high frequency of 1500 Hz, both test sample 1 with NR = 8.7 dB, test sample 2 (NR = 8.3 dB), or a combination of test sample 1 and test sample 2 (NR = 9.3 dB). This is also following what was said by Satwiko (2008) that porous and fibrous materials function well to reduce high frequencies. Still, according to Satwiko (2008), the thickness of the test sample must be increased to reduce sound at low frequencies. As shown in TABLE 1, test sample 1 is only effective at a frequency of 1500 Hz, test sample 2 is effective at 500 Hz and 1500 Hz, and the combined test sample is effective at 500 Hz, 750 Hz, and 1500 Hz. There is a difference in the frequency of 500 Hz between test sample 1 and test sample 2 because test sample 2 is thicker than test sample 1. The calculation results of the average NR of each test sample are plotted in a graph. The NR value of each test sample will look like FIGURE 6. The graph shows that each test sample is very effective at a frequency of 1500 Hz and ineffective at a low frequency of 250 Hz.

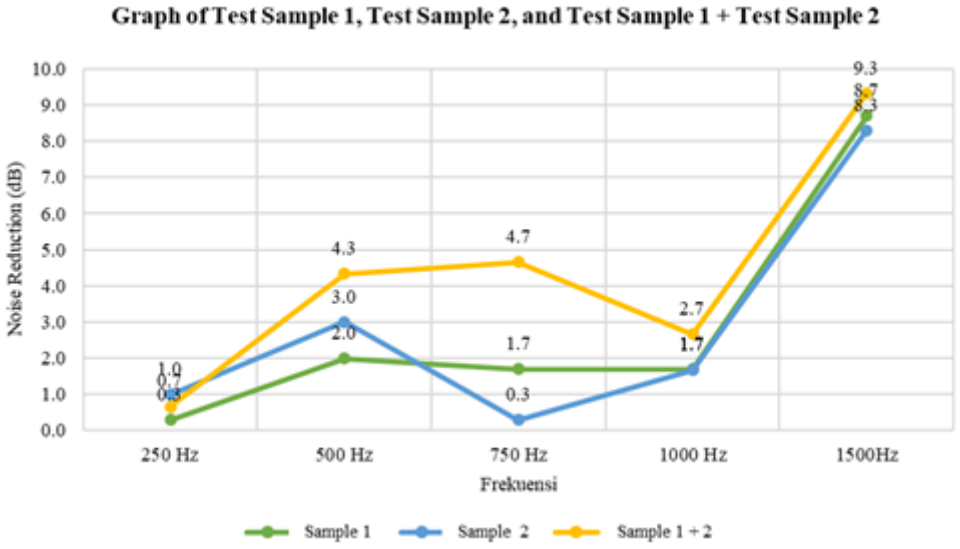

FIGURE 6. Graph of the NR Value of each test sample and the combined test sample

The experiment results above show that the test sample woven from water hyacinth can be used as an alternative to silencers, especially in rooms where the noise comes from the human voice. The woven shape of the water hyacinth is not only in a round placemat, but this experiment can adjust it to what place the woven will give it. Woven can be presented in the form of decoration on furniture, for example, for tablecloths, chair wrappers, or hinges made of woven water hyacinth

Project-Based Learning (PjBL) Integrated with STEAM

PjBL is a project-based learning process centered on students solving problems, designing, and creating work. At the same time, STEAM offers activities that involve students in design and engineering tasks to explore students' science and math skills through creativity, expression, and visual aspects that also support logical thinking (Ismayani 2016; Spiko et al. 2017). The PjBL-STEAM model is a learning process that combines a project-based learning model using the STEAM approach. The PjBL-STEAM model encourages students to gain more profound knowledge by actively exploring real-world challenges and problems by integrating each STEAM component (Annisa et al. 2019). This research aims to find an alternative soundproofing material from nature that is cheap and environmentally friendly as a project, then integrate STEAM elements as an alternative learning model for students. Therefore, explaining the PjBL model with the STEAM approach in the silencer developed in this study is essential.

Project-based learning (PjBL)

Goodman et al. (2010) define PjBL as a teaching approach built on learning activities and actual tasks that provide challenges for students related to everyday life to be solved in groups. In the experiment above, it can be categorized in the PjBL learning model. The reason is that this sound suppression experiment is an actual task that can provide challenges for students, noise due to sound is a daily life problem that students can solve in groups.

Science

The scientific content contained in this experimental soundproofing device includes sound waves. Sound is a mechanical wave in air or solid objects that can still be captured by the average human ear, with a 20 - 20000 Hz frequency range. Then about the properties of sound waves, which can be reflected, transmitted, or absorbed. In addition, the magnitudes of sound waves are also studied, including sound frequency, sound intensity, and noise reduction (NR). You can learn science from the materials about the water hyacinth plant, which has the scientific name Eichhornia crassipes. This experimental tool investigates materials that can absorb sound from water hyacinth by exploring NR at several frequency variations.

Technology

This experiment utilizes several technologies, including computer technology, speakers, smartphones, and software application programs. The applications used in this experimental tool include the Sound Pressure Level (SPL) application and the online tone generator frequency generator. Students can also use information technology in searching for libraries to prepare projects and solve problems about silencers.

Engineering

Techniques are needed during data collection, namely how to arrange for the experimental tool to function as a research data collection tool. Practical tools are set by connecting all components to obtain experimental data. The speakers are placed in the sound source room, connected to a laptop/computer with an online tone generator application. The SPL application on a smartphone is used to measure the sound intensity in each room.

Art

In addition to functioning to collect data, it requires a touch of art for the experimental tool to look attractive. So that students in compiling the device are not random. Students can also present art in manufacturing acoustic material test samples in woven water hyacinth (round placemat). Students are taught the art of making the placemat.

Mathematics

Mathematics is used in this experiment from the time of making the tool, which follows the shape of a specific size. Then mathematics is also used for data analysis by using mathematical operations. The explanation of the integration of STEAM in the silencer above shows that the silencer in this study can be applied as an alternative learning model. The most appropriate model is to use a project-based model to follow the purpose of this study, namely to make a water hyacinth silencer as an alternative to the STEAM-integrated project-based learning model (PjBL). Next, we will explain using a silencer that integrates STEAM using a project-based learning flow. According to Desta (2017), STEAM can develop students' creative thinking skills by following six stages of PjBL, namely; (1) Start with an essential question, (2) Design Project, (3) Create a schedule, (4) Monitoring the students and progress of projects, (5) Assess the outcomes and (6) Evaluation the experience. The stages of PjBL integrated STEAM, if implemented in learning, areas in TABLE 2.

TABLE 2. Stages of PjBL-STEAM Implementation in Learning

PjBL Stages	STEAM Integration	PjBL-STEAM Stages
Start with the essential question	Learning about the use of water hyacinth plants for soundproofing in Acoustic materials is confirmed to contain STEAM, namely Science, Technology, Engineering, Art, and Mathematics.	Start with the essential question: at this stage, students are given problems related to scientific content about sound material, the properties of sound, and the problems it causes
Design Project		Design Project: at this stage, students design a soundproofing project which contains elements of STEAM
Create a schedule		Create a schedule: at this stage, the students and the lecturers make an agreement on the schedule for doing the project until the completion of the project
Monitoring the students and the progress of projects		Monitoring the students and the progress of projects: at this stage, the lecturer monitors project creation activities by paying attention to STEAM elements
Assess the outcomes		Assess the outcomes: The final activity is carried out with a project presentation and assessment. Lecturers assess projects made by students by looking at the elements of STEAM
Evaluation of the experience		Evaluation of the experience: Lecturers and students reflect on the activities and results of the water hyacinth fiber silencer project. Students are asked to express their feelings and experiences while completing the project

CONCLUSION

Acoustic materials can reduce noise from unwanted noise with a porous and fibrous nature. One alternative material is the water hyacinth plant, namely by drying it first and then woven in the form of a placemat. The water hyacinth mat is an alternative soundproofing material from noise originating from the human voice (600-4000 Hz). The test was carried out by making a water hyacinth mat a bulkhead between rooms 1 and 2. The experimental instrument was made of a glass box designed into two rooms: room 1 as a sound source and room 2 for sound receivers. Technology is also utilized as part of integrating elements of science, technology, engineering, art, and math (STEAM), including active speakers, Sound Pressure Level (SPL) applications on smartphones, and Online Tone Generator applications.

Furthermore, this tool is used as a project for students in learning. So that the alternative learning model developed in this study can be called the STEAM integrated PjBL learning model. Six stages of PjBL are carried out, and STEAM elements are described. The experimental results show that the test sample is effective as a sound absorber at a high frequency of 1500 Hz, with the NR value of the test sample 1 = 8.7 dB, the NR of the test sample 2 = 8.3 dB, and NR Gab = 9.3 dB. The test sample is also adequate at low frequencies. Namely, test sample 2 is sufficient at a frequency of 500 Hz with NR of the test sample 2 = 3.0 dB.

The combined test sample also effectively reduces sound at a frequency of 500 Hz with NR Gab = 4.3 dB and a frequency of 750 Hz with NR Gab = 4.7 dB. The result of this experiment found the results of the sound attenuation to be similar to the theory that sound changes between 3 to 12 dB have an effect that humans can feel. Thus, the result of this experiment can say that natural fiber from water hyacinth has reasonably good quality as an alternative sound-dampening material.

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