Indonesian Journal of Physics
Vol. 35. No.1, 23 August 2024
Journal homepage: http://ijphysics.com

A REVIEW ON EXPLORING THE RESONANT VIBRATION OF THIN PLATES: RECONSTRUCTION OF CHLADNI PATTERNS AND DETERMINATION OF RESONANT WAVE NUMBERS USING RESEARCH BASED LEARNING

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(Received: 19 August 2024, Revised: 19 September 2024, Accepted: 30 September 2024)

Abstract

Learning is a process of acquiring knowledge or skills through study or experience. One of the learning methods used to improve students' understanding is Research-based Learning (RBL), which aims to instill critical thinking, creativity and problem-solving skills. In this research, the RBL method is used to increase understanding in the Chladni experiment by observing the resonance phenomenon when the plate is vibrated with a certain frequency, as well as to determine the frequency that produces said Chladni patterns. With this method, students work in groups of 3 people. There are five steps carried out in this RBL: (i) formulating problems and objectives, making hypotheses, (ii) conducting experiments, collecting data from experimental results, (iii) searching for information on the experiments, processing data, (iii) analyzing data, answering formulations problems, (iv) drawing conclusions, (v) and presenting the results to the lecturer/examiner. At the end of this experiment, students would be able to prove Chladni's law.

Keywords: Chladni, Experiment, Frequency, RBL, Resonance

INTRODUCTION

Learning is the process of acquiring knowledge or skills through study or experience. The modern era has witnessed a variety of learning methods, the most common of which is the educator-centered learning process, where knowledge is transferred from an educator to his students. The teacher-centered learning process is a passive type of learning, because students are only expected to accept, listen and memorize. Encouraging students to learn by conducting research, finding their own methods for solving problems, and being actively involved in the learning process are the keys to building better knowledge [1]. One such method that encourages students to learn actively is the Research-based Learning (RBL).

There are several reasons why the RBL method is used to instill knowledge in students. First, this method can increase students' learning motivation, such that they will have a greater understanding by learning more about the material. Second, students will gain experience in a variety of intellectual and social abilities. Third, RBL can improve a number of students' skills, such as analytical skills, literacy skills, research skills, problem solving skills, critical thinking, etc. [5-9].

The application of RBL in the physics department, where testimonials are obtained from students, can increase learning motivation and have a greater understanding of the material in depth. RBL also trains independence in investigating problems and improves skills in research, because throughout the process many discussions are carried out with assistants or group friends [5-9]. The RBL method

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allows students to gain more information about a topic and a better understanding of it.

In this paper, the RBL method is used to improve understanding in the Chladni experiment by exploring the resonant vibrations of a thin plate and determining the number of resonant waves.

EXPERIMENTAL METHOD

In the process, students will first be grouped into 3 people, each of whom is accompanied by an assistant. Each group can choose a topic they are interested in, which has been prepared by the assistant and approved by the relevant course lecturer. The topic that will be discussed in this paper is related to the Chladni experiment and a review will be carried out on one of the groups that carried out the Chladni experiment. In general, the RBL method consists of the following steps [10]:

- Stimulation : During this step, the lecturer or assistant will provide a brief introduction to the topics available for students to choose from. The assistant will also provide modules related to the topic. Each group will be formed by the students themselves.
- Objective : In this process, each group is expected to discuss their choice of topic and the problems they want to solve regarding that topic. The result of this discussion is identification of problems, objectives and hypotheses for the selected topic.
- Basic Theory and Data Acquisition : To solve the problems that have been identified, each group would conduct experiments, collect data, and search for as many sources as possible.
- Data Processing : All data that has been obtained will be processed, formulated, interpreted by each group so that it can be used later to facilitate the data analysis.
- Discussion and Analysis : From the results obtained in data processing, these results will then be compared with the hypothesis created at the beginning of the RBL process.
- Conclusion : From the results of the discussion and analysis carried out, each group can form conclusions from the completed research,

RESULTS AND DISCUSSION

Resonance is the tendency of a system to vibrate with a greater amplitude at a certain frequency in response to an external driving force. Resonance basically occurs when the natural frequency of the system is the same as the frequency of the vibrator. Natural frequency is the vibration frequency of a system as a consequence of the collective vibration of its constituent particles when there is no external vibration source. In the 18th century, a German physicist, Ernst Chladni, studied and popularized the phenomenon of resonance in two-dimensional objects using thin plates made of metal. Chladni's experiments have been used as an initial stage of various research fields such as seisomology, musical instruments, quantum, nano-mechanics, etc.

If a thin plate is subjected to vibrations equal to one of its natural frequencies, the plate will form a standing wave with fixed vertices. These nodes form lines on the plate. In Chladni's experiment, a certain amount of sand is sprinkled on a plate, which would then be vibrated using a violin bow. At certain frequencies of the vibration, the sand on the plate forms resonance patterns that correspond to the friction frequency. These patterns would come to be known as Chladni patterns.

In the Department of Physics, Bandung Institute of Technology, Experimental Physics is a course which employs the RBL method in the process of knowledge transfer to students. This method was chosen to provide a better understanding of how to conduct experiments and aims to teach students how to create a scientific work.

In this RBL, each group must meet a standard to be considered to have passed the Experimental Physics course, specifically for the Chladni experiment, the minimum achievements that must be met by groups taking this topic are as follows:

- Practitioner understands the principle of resonance in the Chladni experiment.
- Practitioner is able to understand the frequencies that can produce vibration patterns in the Chladni experiment.
- Practitioner is able to analyze the influence of plate geometry and grain size on the resulting Chladni pattern.
- Other questions or issues they would like to analyze further can be added to the report.

In this Chladni experiment, practitioners, namely members of the group who took the topic of the

Chladni Experiment, prepared tools. The set of tools consists of an audio generator, vibration generator, oscilloscope, connecting cable between the audio generator and the vibration generator (crocodile clip cable), connecting cable between the oscilloscope and the vibration generator (oscilloscope cable), Chladni plates with various shapes (square measuring (20, 2 x 20) cm2 which is assumed to be a square shape, as well as a square measuring (25.1 x 25.1) cm2, a circle with a diameter of 19 cm, and an equilateral triangle measuring 30.3 cm long), as well as various granules (salt, tea, yeast, and rice). In this case, an audio generator is used as a frequency input medium, a vibration generator is used as a medium for vibrating and placing the Chladni plate, an oscilloscope is used as a medium for displaying signal amplitude, as well as frequency readings received by the plate. There are two types of connecting cables used, namely to connect the audio generator to the vibration generator and to connect the oscilloscope to the vibration generator. Practitioners collect data with variations in frequency, plate geometry, and granularity.

From the experiments, practitioners obtained Chladni patterns with frequency and amplitude values for each plate with various types of grains (salt, yeast, tea and rice). Data is separated for each plate shape and grain type for easy comparison. After the Chladni patterns are obtained, amplitude and frequency data are tabulated when the patterns appear. The pattern obtained is then matched with the one in the pictures below to get the values of m and n, to finally obtain the value of $(m + 2n)2$.

After collecting and processing the data obtained from the experiment, practitioners began to analyze the results of the data obtained: the first analysis consisted of the plate size, grain size, and type of grain used. Practitioners discovered that the resonance event caused the structure of the plate system to experience large oscillations, giving rise to a pattern of vibration modes in the plate. This resulted in standing waves on the surface of the plate indicated by the movement of grains that form specific patterns. With stationary waves, all particles on the surface of the plate vibrated with the same frequency. The amplitude at the minimum point is called nodes, indicated by places where grains had gathered, while the maximum amplitude is called antinodes (stomach), indicated by places where grains did not exist.

Practitioners also discussed the patterns obtained and their correlation with frequency and amplitude. According to practitioners, based on the results of their experiments, the larger the grain dimensions, the more difficult it is for the Chladni pattern to form clearly. This is caused, among other things, by the influence of granule mass and space for movement. With the same amplitude, grains with a large mass will be more difficult to vibrate, so there will be little movement, even just movement in place, which will cause the Chladni pattern to not form or be faint/indistinct. Meanwhile, if the grains are too small, even very fine and very light, the Chladni pattern will also be difficult to form clearly because the grains will often stick to the plate and pile up. This is caused by the static force that attracts the fine grains so that they stick to the plates so that they overlap, and their small/fine size makes it difficult to move when they are stacked and takes a long time to form a pattern. There are certain sizes and shapes of grains used to obtain a clear Chladni pattern.

After analyzing the data obtained, practitioners could observe that for different plate geometries, the Chladni patterns and the resonant frequencies that gave rise to the Chladni patterns are also different. This is because different geometries produce different wave equation solutions, different boundary conditions for each plate, so that the stationary/standing waves formed on the plates are also different. Square plates use Cartesian coordinates, while circular plates use polar coordinates. But every plate, whether square, circular, or triangular in the experiment, shared one thing in common, namely that the boundary conditions at the edges of each plate were antinodes.

In their report, practitioners also listed the obstacles they experienced when setting the frequency. Even though the frequency on the audio generator had been confirmed to be in a constant state (stable position and the knob is not rotated), it turned out that the frequency value read on the oscilloscope varied with values proximate to each other. Therefore, we were able to find out the reason as to why the vibrations that appeared on the plate were fluctuating (sometimes increasing or decreasing) along with small changes in the frequency values on the oscilloscope screen, thus the resonant frequency value data collection was selected when the frequency shows the right vibration.

CONCLUSION

It can be concluded that the RBL method used to increase understanding in the Chladni experiment among students is successful, since students are able to meet the minimum achievements and can properly prove the Chladni law in their reports.

ACKNOWLEDGMENT

I would like to express my deepest gratitude to Dr. rer. nat. Sparisoma Viridi, for his invaluable guidance, support, and encouragement throughout this journey. His expertise and insights have been instrumental in shaping my research and professional development. Thank you for your unwavering mentorship and for always inspiring me to strive for excellence.

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