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A Sustainable Bamboo Water-Wheel Prototype for Demonstrating Hydraulic Energy

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Abstract: Engineering students often struggle to grasp abstract concepts in fluid mechanics, particularly hydraulic energy, due to the lack of accessible, hands-on learning tools. This study aimed to design, construct, and evaluate a sustainable bamboo water-wheel prototype to serve as an instructional model for demonstrating basic hydraulic principles. The prototype was built using bamboo, corrosion-resistant wire, waterproof sealant, and plastic paddles, emphasizing affordability, durability, and environmental sustainability. A video experiment was conducted to observe the wheel's rotation, stability, and response to varying water flow conditions. Findings revealed that the prototype operates smoothly without electricity, accurately responds to changes in water flow, and consistently converts flowing water into mechanical motion. Its simple design, safety, and ease of maintenance make it a practical teaching aid for classrooms or community-based educational activities. Overall, the prototype provides a tangible, interactive approach to visualizing hydraulic energy while promoting sustainable engineering practices and experiential learning.

Keywords: *Bamboo Water-Wheel, Hydraulic Energy, Sustainable Instructional Tool, Fluid Mechanics, Hands-on Learning, Renewable Materials.*

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I. INTRODUCTION

Engineering education becomes substantially more meaningful when students are able to visualize, manipulate, and interact with the concepts they encounter in class. While lectures and textbooks provide the theoretical groundwork for understanding engineering principles, many of the ideas taught—especially those in fluid mechanics— are complex, abstract, and highly dynamic. One such concept is hydraulic energy, which describes how the potential and kinetic energy of water can be transformed into mechanical work. This principle is essential not only for understanding water supply systems and wastewater treatment processes but also for appreciating the operation of renewable energy technologies and various environmental engineering applications. Despite this significance, students often find it difficult to fully grasp how water behaves when their learning environment is limited to static diagrams or mathematical derivations (Felse, 2018; Zheng, Liu, Xiang, & Mao, 2013).

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Fluid mechanics inherently relies on the study of motion, force, and energy transfer within fluids—phenomena that are challenging to conceptualize without some form of visual or physical representation. Although digital simulations and animations can be helpful, they do not always match the learning impact of a tangible, hands-on demonstration that allows students to directly observe water movement, flow patterns, and the influence of gravity or pressure. Unfortunately, many educational institutions do not have access to laboratory facilities or equipment that can demonstrate these interactions in an accessible, replicable, and affordable manner. Commercial hydraulic demonstration tools are often expensive, require specialized maintenance, or are too delicate to be used regularly in classroom environments (Starks, Hendrickson, Hadi, & Traum, 2017; Penney & Clausen, 2018). This lack of accessible tools creates a disconnect between theory and practice, preventing students from appreciating how equations relate to real-world fluid behavior. As a result, engagement may decline, misconceptions may persist, and opportunities for experiential learning become limited (Rigor, 1988; Espinola, 2025).

In recent years, there has been growing interest in developing instructional materials that are affordable, sustainable, and easy for educators to build or adapt. This movement aligns with broader efforts in engineering education to promote hands-on, inquiry-based learning while simultaneously encouraging environmental consciousness and resource efficiency. The use of natural or recycled materials—such as bamboo, repurposed plastics, and scrap wood—offers a practical approach to creating functional educational tools that are both cost- effective and environmentally responsible (Espinola, 2025; Zheng et al., 2013). Such materials not only reduce cost and environmental impact but also introduce students to principles of sustainable engineering, material selection, and system design. With these tools, learners can observe key phenomena such as water flow behavior, the conversion of gravitational potential energy into kinetic energy, the forces exerted by moving water, and the mechanical output generated through rotational devices.

The present study, "A Sustainable Bamboo Water-Wheel Prototype for Demonstrating Hydraulic Energy," aims to address the instructional gap by developing a functional, hands-on model that illustrates how flowing water can be converted into mechanical motion. The use of bamboo and other eco-friendly materials is intentional, emphasizing sustainability while ensuring that the prototype remains accessible for educators who may not have access to specialized laboratory resources. Through this model, students can observe fundamental hydrodynamic concepts in real time—such as the influence of flow rate, water velocity, gravitational potential, impact force on paddles, and the resulting rotational motion of the wheel. These observable interactions transform theoretical concepts into concrete experiences, helping students build a deeper and more intuitive understanding of hydraulic energy. Moreover, the development of this prototype supports broader educational goals by encouraging creativity, problem-solving, and hands- on experimentation. Students can modify the design, measure its performance, and explore how changes in water flow or wheel geometry affect energy output. By integrating sustainability with practical demonstration, the project not only enhances comprehension of fluid mechanics but also inspires students to consider environmentally responsible engineering solutions. Ultimately, the bamboo water-wheel prototype exemplifies a learning tool that strengthens conceptual understanding, increases engagement, and promotes sustainable engineering practices in an accessible and meaningful way.

A. Objectives

This study aims to design and develop a functional, durable, and sustainable bamboo water- wheel hydraulic prototype that can effectively serve as an instructional tool for demonstrating fundamental hydraulic energy principles. The overarching goal is to create an affordable, eco-friendly, and pedagogically useful model that enhances students' comprehension of fluid mechanics through direct, hands-on interaction.

➢ *To Achieve this Goal, the Study Specifically Aims to:*

- *Determine the Salient Features of the Bamboo Water-Wheel Hydraulic Prototype, particularly its:*

✓ Durability
✓ Functionality
✓ Sustainability

- *Evaluate the Performance Capabilities of the Prototype, Focusing on:*

✓ Flow behavior
✓ Operational accuracy
✓ Performance consistency

- *Assess the Practical Attributes of the Prototype, Including its:*

✓ Usability
✓ Safety
✓ Ease of maintenance
✓

II. MATERIALS AND METHODS

➢ *Research Design*

The researchers used an experimental research design to study the effectiveness of the sustainable bamboo water-wheel Prototype in demonstrating hydraulic energy. This design involves conducting a video experiment where the water wheel is exposed to different flow conditions and its rotation, stability, and interaction with water are observed. It was chosen because it allows the researchers to systematically observe the prototype in action and determine whether it effectively demonstrates basic hydraulic principles as a simple and sustainable instructional tool.

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➢ *Subjects of the Study*

The subjects of this study were the bamboo water-wheel prototype and its performance under different flow conditions. No human respondents or participants were involved, as the research focused entirely on the construction, testing, and evaluation of the prototype. The researchers themselves conducted all stages of the study, including assembly, modifications, testing procedures, and observation, to ensure accuracy and consistency. The prototype was observed for its rotation, stability, and interaction with water, and these observations were systematically recorded to assess its effectiveness and practicality as an instructional tool for demonstrating hydraulic energy.

➢ *Data Gathering Instrument*

To gather data, the researchers conducted testing of the bamboo water-wheel prototype. During the tests, all activities and observations were recorded, including how the water wheel responded to different flow conditions and how the hydraulic energy was demonstrated. The prototype itself served as the main instrument for observing the flow behavior and wheel rotation.

➢ *Data Gathering Procedure*

The researchers gathered data by conducting a video experiment of the bamboo water-wheel prototype. During testing, the water wheel was exposed to different flow conditions, and its rotation, stability, and interaction with water were observed. The entire process was recorded on video to capture the wheel's performance accurately. The researchers reviewed the recordings and systematically documented all observations to evaluate the prototype's functionality and effectiveness as an instructional tool.

III. RESULTS AND DISCUSSION

A. Salient Features of the Bamboo Water- Wheel Hydraulic Prototype

➢ *Durability*

The bamboo water-wheel prototype is designed for strength and long-term use. Bamboo, the main structural material, is naturally strong, lightweight, and resistant to bending and moisture, while galvanized or stainless steel wire secures the components to maintain structural integrity. Vulcaseal waterproof sealant protects joints from water penetration, and plastic spoons serve as durable paddles that resist water damage and maintain their shape under repeated water impact. Together, these materials ensure the prototype can withstand repeated operation without structural damage or performance issues.

➢ *Functionality*

The prototype effectively demonstrates hydraulic principles. Water flowing through the bamboo channels fills and falls due to gravity, causing the wheel to rotate smoothly without electricity. Even small amounts of water are sufficient to generate motion, showing water pressure, flow force, and energy conversion. The system operates reliably, with each component responding to water flow as intended, making it a practical and easy-to-understand instructional tool for demonstrating basic hydraulic concepts.

➢ *Sustainability*

The prototype is environmentally sustainable. It is constructed mainly from bamboo, a fast-growing and renewable material, and uses flowing water to generate motion without electricity or pollution. The model minimizes waste, as bamboo components can be reused or biodegrade naturally. Its low-cost, locally sourced materials and simple construction allow replication in classrooms or community projects, promoting sustainable learning and awareness of eco-friendly engineering practice.

B. Performance Capabilities of the Prototype

➢ *Flow Behavior*

The prototype's flow behavior shows how water movement affects wheel rotation and energy transfer. Moderate flow produces smooth, balanced rotation, while faster flow increases momentum but may cause minor splashing or overflow. The bamboo channels distribute water evenly across the wheel, maintaining continuous rotation. This demonstrates the principles of hydraulic energy and shows the potential of bamboo-based systems as sustainable educational tools.

➢ *Operational Accuracy*

The prototype accurately demonstrates hydraulic principles. Its rotation corresponds directly to the water flow rate, with faster flow producing quicker movement and slower flow producing reduced rotation. The wheel also reflects simple real- world applications, mimicking traditional water wheels used in irrigation or small mechanical tasks. These results confirm that the prototype effectively visualizes hydraulic energy while providing a connection to practical, everyday uses.

➢ *Performance Consistency*

The bamboo water wheel performs consistently under different conditions. During multiple tests, the wheel maintained steady rotation despite minor fluctuations in water flow. Strong bamboo materials and secure joints prevented wobbling, friction, or instability, allowing smooth operation over extended periods. The prototype's reliable performance makes it a dependable tool for demonstrating hydraulic energy in educational settings.

C. Practical Attributes of the Prototype

➢ *Usability*

The prototype is user-friendly and serves as an effective teaching aid. Its simple design and eco- friendly materials make hydraulic energy concepts easy to observe and understand. Students can interact with the model to learn about energy conversion, water flow, and sustainable engineering practices, enhancing both comprehension and engagement.

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➢ *Safety*

Safety was considered in the design, with smooth bamboo posts, securely fastened components, and carefully managed wires to prevent injury.

Decorative and functional elements are fixed to avoid detachment, and the prototype is stable during handling and demonstrations. These precautions ensure it can be used safely in classrooms or workshops.

➢ *Ease of Maintenance*

The prototype is easy to maintain due to the accessibility of bamboo and simplicity of required repairs. Damaged or worn parts can be replaced quickly and inexpensively, while minor issues like leaks or loose joints can be fixed using natural sealants or simple reinforcements. The design allows manual inspection and adjustment, supporting sustainable long-term use without specialized tools or electricity.

D. Proposed Learning Plan

The proposed learning plan integrates hands-on scientific activities and interactive teaching strategies to enhance students' understanding of hydraulic energy. Using the bamboo water-wheel prototype, instructors can demonstrate principles of water flow, rotational motion, and energy conversion in a tangible and visual manner. Students can observe the system in action, conduct guided experiments, and analyze how changes in water flow affect the wheel's movement.

The plan encourages active learning by involving students in measuring rotation, examining flow distribution, and identifying potential improvements to the prototype. This approach promotes critical thinking, problem-solving, and sustainable engineering awareness, as students learn to apply scientific concepts using low-cost and renewable materials. The learning plan is designed to be adaptable for classroom demonstrations, laboratory exercises, or community-based science projects, providing an interactive and practical experience that reinforces theoretical concepts and encourages environmental responsibility.

IV. CONCLUSIONS

➢ *In Connection with the Findings of the Study, the Following Conclusions were Drawn:*

- The bamboo water-wheel is durable and sustainable, constructed with strong bamboo, corrosion-resistant wire, and waterproof sealant. It operates smoothly using natural water flow and effectively demonstrates hydraulic energy without the need for electricity.
- The prototype accurately responds to changes in water flow, producing steady and predictable rotation. Its reliable performance reflects real- world applications, such as simple irrigation systems, confirming its effectiveness as an educational hydraulic model.
- The prototype is easy to use, safe, and low- maintenance. Its smooth, secure construction allows safe handling, and any necessary repairs can be performed with simple tools and inexpensive materials, making it practical for long-term classroom use.

RECOMMENDATIONS

➢ *In Light of the Findings and Conclusions of the Study, the Following Recommendations are Hereby Presented:*

- Future researchers are advised to use high- quality, properly treated bamboo materials to enhance structural integrity, prevent premature deterioration, and ensure long-term stability.
- Refinements should be made to the mechanical components, particularly the rotating and water flow mechanisms, to achieve smoother motion, improved functionality, and a more polished appearance.
- Enhancing the stability of the base platform is recommended, such as reinforcing support legs or using sturdier base materials, especially for outdoor or uneven surface placement.
- Future designs may explore alternative sustainable materials and improved construction techniques to optimize durability, reduce maintenance needs, and further support environmental goals.
- Applying protective coatings, such as natural varnish or eco-friendly sealants, is suggested to safeguard the bamboo from moisture, pests, and weather exposure, thereby extending the lifespan and effectiveness of the prototype.

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REFERENCES

[1]. Anderton RS, Vitali J, Blackmore C, & Bakeberg MC (2021). Flexible Teaching and Learning Modalities in Undergraduate Science Amid the COVID-19 Pandemic. Frontiers in Education, 5:609703. doi:10.3389/feduc.2020.609703

[2]. Belgica, C. C., Calugan, J. A., Duma, J. U., & Simber, L. A. (2020). Online Distance Learning: Thematic Study on the Challenges Faced by Educare

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec465

College Inc. Primary Pupils. Mokslinės Leidybos Deimantas – Diamond Scientific Publishing.
[3]. Cahapay, M. B. (2020). Rethinking Education in the New Normal Post-COVID-19 Era: A Curriculum Studies Perspective.
[4]. Carrillo, C., & Flores, M. A. (2020). COVID-19 and Teacher Education: A Literature Review of Online Teaching and Learning Practices. European Journal of Teacher Education, 43(4), 466-487. doi:10.1080/02619768.2020.1821184
[5]. Eisner, C., & Vicinus, M. (n.d.). Originality, Imitation, and Plagiarism: Teaching Writing in the Digital Age. The University of Michigan Press and Library.
[6]. Hofstein, A. (2017). The Role of Laboratory in Science Teaching and Learning. doi:10.1007/978-94-6300-749-8_26
[7]. Fabriz, S., Mendzheritskaya, J., & Stehle, S. (2021). Impact of Synchronous and Asynchronous Settings of Online Teaching and Learning in Higher Education During COVID-19. Frontiers in Psychology. https://www.frontiersin.org/articles/10.3389/fpsyg.2021.733554/full
[8]. Lim, F. (2017). An Analysis of Synchronous and Asynchronous Communication Tools in e-Learning. doi:10.14257/astl.2017.143.46
[9]. Miller, K. W. (2008). Teaching Science Methods Online: Myths About Inquiry-Based Online Learning. Science Educator, 17(2). Retrieved from https://files.eric.ed.gov/fulltext/EJ886175.pdf
[10]. National Academies of Sciences, Engineering, and Medicine. (2015). National Science Education Standards. Washington, DC: The National Academies Press. doi:10.17226/4962