Intervention Case Study: Frequency–Amplitude SHM Intuition via PhET and Scaffolding

By Shafiq R

Frequency–Amplitude SHM

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Executive Summary

This report presents an instructional intervention titled Frequency–Amplitude SHM Intuition via PhET and Scaffolding, aimed at correcting the common misconception that amplitude affects the frequency or period of a simple pendulum. Conducted with six Semester 1 Malaysian Matriculation physics students over three face-to-face lessons, the intervention combined PhET simulations, peer discussion, and scaffolded problem-solving to promote conceptual understanding. Students first explored the PhET Pendulum Lab simulation, made predictions, and tested them through guided inquiry. Think–Pair–Share discussions helped them articulate and revise their misconceptions, followed by structured practice to reinforce accurate models. Results showed significant improvement, with average test scores rising from 16.67% (pre-test) to 81.26% (post-test), and an average normalized gain of 0.76. A 10-item self-reflection questionnaire also indicated strong student engagement and conceptual clarity, with most items scoring above 5.3 on a 6-point Likert scale. Overall, the intervention proved effective and practical, offering a replicable model for addressing conceptual misunderstandings in physics through low-cost, inquiry-based methods.

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1 Introduction

Background and Rationale

Misconceptions in physics often stem from intuitive but incorrect reasoning. One such misconception, frequently observed among pre-university students, is the belief that amplitude affects the frequency or period of a simple pendulum. Despite formal instruction, students tend to associate larger swings (amplitude) with slower or faster motion, indicating a poor grasp of the mathematical model of simple harmonic motion (SHM).

This intervention was developed to explicitly address and correct this misunderstanding by engaging students with interactive simulations, peer discussion, and structured problem-solving tasks that make the independence of amplitude and frequency more visible and testable.

Target Group

- **Participants:** 6 students
- **Level:** Semester 1, Malaysian Matriculation Programme
- **Subject:** Physics (Simple Harmonic Motion)
- **Delivery Mode:** In-person

Learning Objectives

By the end of the intervention, students should be able to:

- Explain how the period of a simple pendulum depends on length and gravity, not amplitude.

  Interpret data from simulations to verify the theoretical model of SHM.
- Apply correct conceptual understanding when solving related physics problems.
- Recognize and reflect on prior misconceptions regarding amplitude and frequency.

2 Intervention Design

Instructional Strategies

- **Conceptual Conflict**
  Students are first prompted to make predictions based on their intuition before testing those predictions in the simulation.
- **Guided Inquiry**
  Students explore the **PhET Pendulum Lab** simulation to collect data and verify patterns.
- **Think–Pair–Share**
  Structured peer discussions are used to verbalize and challenge prior beliefs.
- **Scaffolded Practice**
  Targeted problem sets progressively reinforce conceptual clarity and application of correct models.

Planned Activities

Lesson	Activities	Purpose
1	Pre-test + Simulation exploration	Activate prior knowledge, surface misconceptions
2	Think–Pair–Share + Data analysis	Conceptual clarification through discussion and observation
3	Scaffolded problem-solving + Post-test	Reinforce correct understanding, assess conceptual change

Materials and Resources

- **Digital Tools**
  PhET Interactive Simulations – *Pendulum Lab*
- **Worksheets**
  Data collection table, scaffolded problems
- **Assessment Tools**
  Pre/post conceptual test, 10-item self-reflection questionnaire
- **Teaching Aids**
  Whiteboard, projector, timers

Planned Adaptations

- Language of instruction adapted to students' proficiency level where necessary.
- Questions and worksheets were modified based on real-time responses to better match student misconceptions.
- Simulation parameters were adjusted to focus only on relevant variables (e.g., keeping length constant while varying amplitude).

3 Implementation

Delivery Method

Mode	Face-to-face instruction
Location	Physics Lab
Tools	Laptops for simulation use, printed worksheets, whiteboard for synthesis discussion

Schedule and Session Flow

- **Duration**: 3 sessions × 1 hour = **3 hours total**
- **Timeline**:

Lesson 1	Pre-test (10 mins), Prediction and Exploration with PhET (40 mins), Reflection (10 mins)
Lesson 2	Group Discussion (Think–Pair–Share) (20 mins), Group-wide synthesis (20 mins), Data explanation (20 mins)
Lesson 3	Scaffolded Problems (40 mins), Post-test (10 mins), Self-Reflection Questionnaire (10 mins)

People Involved

- **Lead Instructor**: Shafiq Rasulan
- **Students**: 6 Semester 1 Matriculation students

Fidelity and Modifications

- **Planned vs. Actual**: All sessions were conducted as planned with minor timing adjustments to accommodate discussion depth.
- **Adaptations During Delivery**:
  - Some students struggled with simulation controls; instructor provided hands-on guidance.
  - Additional clarification questions were added spontaneously based on student responses.
- **Student Engagement**: All students completed the tasks and participated actively, particularly in peer discussions.

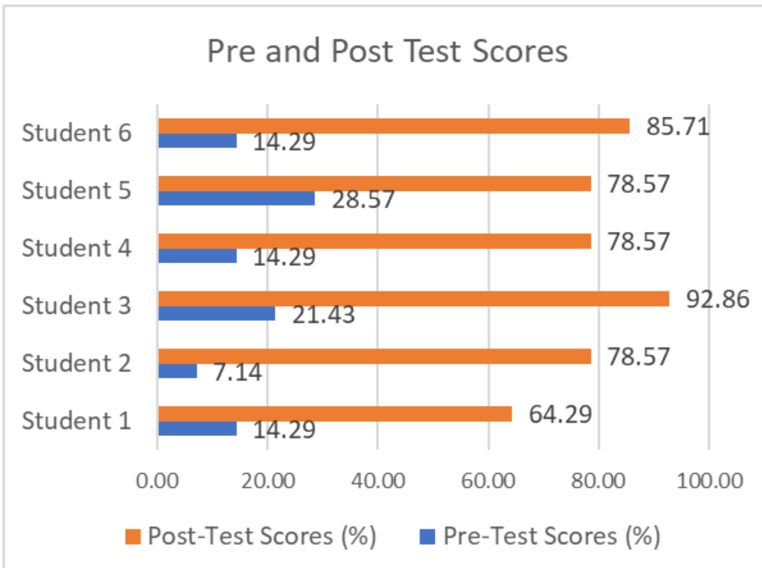
4 Evaluation & Results

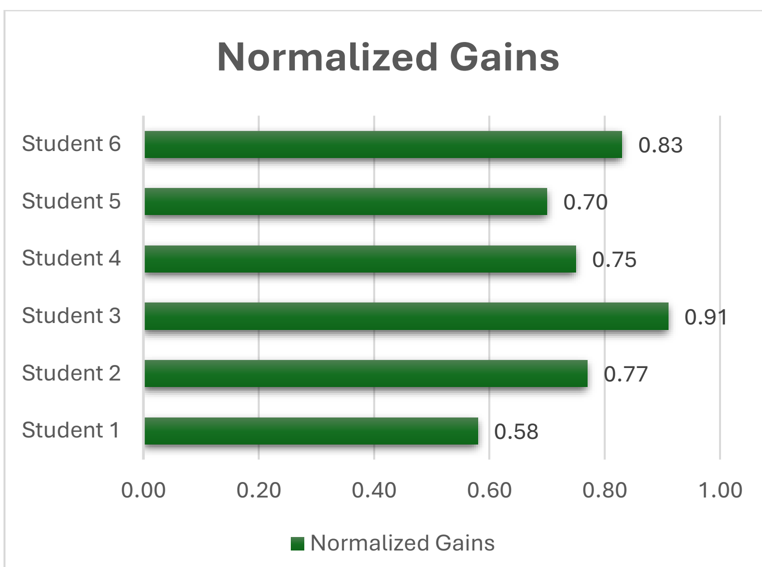
To evaluate the effectiveness of the intervention, both **quantitative and qualitative measures** were employed. These included a **pre- and post-conceptual test** consisting of items focused on the relationship between amplitude, frequency, and period in simple harmonic motion (SHM), as well as a **10-item self-reflection questionnaire** administered after the intervention.

Pre- and Post-Test Outcomes

Students demonstrated significant improvement in conceptual understanding, as reflected in their test scores. The **mean pre-test score** was **approximately 16.67%**, while the **mean post-test score** increased substantially to **approximately 81.26%**. Individual normalized gains ranged from **0.58 to 0.91**, with an average normalized gain of **0.76**, which indicates a **high level of conceptual gain** based on Hake’s (1998) classification for interactive engagement methods (where $\langle g \rangle > 0.7$ is considered high).

Student	Pre-Test Scores (%)	Post-Test Scores (%)	Normalized Gains
Student 1	14.29	64.29	0.58
Student 2	7.14	78.57	0.77
Student 3	21.43	92.86	0.91
Student 4	14.29	78.57	0.75
Student 5	28.57	78.57	0.70
Student 6	14.29	85.71	0.83





This improvement suggests that the combination of simulation-based inquiry, peer discussion, and scaffolded problem-solving was effective in addressing students' misconceptions, particularly the belief that amplitude affects frequency or period in a simple pendulum.

Student Self-Reflections

The self-reflection questionnaire, rated on a **6-point Likert scale**, further supports the success of the intervention. The majority of items scored **above 5.3**, indicating strong student agreement with positive statements about their learning experience.

No	Items	Mean Score*
1	I am more aware of how my intuition can be misleading in physics.	5.17
2	I now feel confident explaining why amplitude does not affect frequency.	5.33
3	I understand what factors affect the period of a simple pendulum.	5.50
4	I used to believe that amplitude affects frequency or period.	5.33
5	I was actively engaged during the sessions.	5.83
6	I would recommend this activity to other students struggling with this topic.	5.33
7	The activities were relevant and meaningful to my learning.	5.50
8	The problems we practiced helped clarify my thinking.	5.50
9	The simulation helped me test and revise my previous understanding.	5.67
10	Working with a partner helped me see the problem from a different perspective.	5.50

*(1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Slightly Agree, 5 = Agree, 6 = Strongly Agree)

Students reported high levels of engagement (Item 5: M = 5.83) and found the activities meaningful (Item 7: M = 5.5). They also recognized the value of the simulation in helping them revise their understanding (Item 9: M = 5.67) and appreciated the scaffolding provided in problem-solving tasks (Item 8: M = 5.5). Importantly, many students acknowledged that their initial intuitions had been misleading (Item 1: M = 5.17), and expressed confidence in their corrected understanding (Item 2: M = 5.33).

The overall reflections suggest that the structured exploration of the PhET simulation, combined with collaborative learning and targeted practice, not only corrected misconceptions but also empowered students to reflect critically on their thought processes and build conceptual resilience.

5 Reflection & Recommendations

Reflections on Effectiveness

This intervention demonstrated that combining interactive simulations, peer discussion, and scaffolded problem-solving can significantly improve students' conceptual understanding of oscillatory motion. The high normalized gains and consistently strong self-reflection scores suggest that the activities successfully addressed misconceptions about the relationship between amplitude and frequency. Notably, students moved from intuitive but incorrect reasoning toward more scientific, model-based explanations.

Lessons Learned

- Misconceptions are resilient, but can be effectively addressed when students are given opportunities to test their ideas through inquiry.
- PhET simulations, when used purposefully, provide an accessible platform for students to confront and revise their understanding.
- Peer interaction adds value, especially when misconceptions are shared and explored collectively.

Recommendations for Future Implementation

- Integrate short pre-discussion prompts to better surface student misconceptions before simulation work.
- Consider using formative assessment tools (e.g., mini whiteboards or exit tickets) throughout the sessions to monitor understanding in real time.
- Extend the approach to other common physics misconceptions, such as those involving force and motion, to build conceptual consistency.

This concise, research-informed model of intervention shows promise for wider application across physics topics where intuition often conflicts with scientific reasoning.

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