AI-Powered Tutoring for Conceptual Clarity in Energy and Momentum

An Action Research Project at Sarawak Matriculation College

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Overview

- Persistent conceptual issues in energy and momentum.
- Action research using AI tutoring tools: ChatGPT, Gemini, DeepSeek.
- Implemented with 30 matriculation physics students.
- Based on Socratic questioning and ICAP framework.

Reflection on Past Teaching Practice

- Traditional lectures didn't fix core misconceptions.
- Students confused momentum with mass, energy with fuel consumption.
- Diagnostics: ¡50% understanding in energy/momentum pre-tests.
- Students feared giving wrong answers in class.

Research Focus

- Topics: Energy and Momentum.
- Selected for importance, syllabus alignment, and AI tool feasibility.
- Pre-assessments confirmed persistent misconceptions.
- Goal: Address conceptual gaps with AI-mediated dialogue.

Objectives

1. Improve conceptual understanding through AI dialogue tutoring.
2. Measure learning gains using the ECMS.
3. Evaluate student experience via Likert-based survey.

Implementation Design

3-Phase Learning Cycle:

1. **Pre-class:** AI-based conceptual prompts.
2. **In-class:** Peer discussion + teacher feedback.
3. **Post-class:** Reflection + refinement.

- Students trained in Socratic questioning and ICAP response analysis.
- Used only mobile devices.

Learning Gains

- Pre-test average: **46.67%**, Post-test average: **70.76%**.
- Normalized gain: **42.94%**, Effect size (Cohen's d): **1.77**.

Topic	**Pre (%)**	**Post (%)**
Energy Concepts	41.39	70.00
Momentum Concepts	33.33	67.78
Inelastic Collisions	45.56	73.89
Impulse-Momentum	53.33	77.78

Student Feedback

- Misconception correction: **4.77 / 5**
- Explanation clarity: **4.70**
- Comfort with AI vs teacher: **4.57**
- Recommendation for AI in other topics: **4.73**
- Slightly lower in stimulating critical thinking: **4.50**

Reflections

- AI tutors offer:
  - Immediate feedback
  - Personalization
  - Reduced anxiety
- Effective even for hard concepts like energy transfer and momentum conservation.
- Need better prompts to boost critical thinking.

Conclusion and Future Work

- AI tutoring significantly improved conceptual clarity.
- Strongly endorsed by students.
- Future directions:
  - Long-term retention
  - Control group comparison
  - Improved AI-human teaching balance