Teaching Einsteinian Energy in secondary school: Why do we need it?

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Abstract. Modernising the teaching of energy is both essential and challenging, as it requires bridging deeply rooted classical conceptions with abstract quantum and relativistic frameworks that stretch students' mathematical and epistemological understanding. This presentation explores the design and classroom implementation of an Einsteinian Energy module integrating the equations $E = mc^2$ and $E = hf$ into the secondary school curriculum. The module connects modern physics concepts to existing energy topics through hands-on activities, historical narratives, embodied analogies, and proportional reasoning tasks. The session examines how students engage with energy–mass equivalence, photon quantization, and the meaning of physical constants, highlighting instructional strategies that scaffold conceptual and mathematical understanding while bridging classical and modern scientific frameworks.

Introduction

Energy is a foundational concept in secondary science education, yet it is often presented through a predominantly classical framework that omits the central insights of modern physics. This presentation will explore the feasibility and pedagogical value of introducing Einsteinian energy concepts: specifically, activities relating $E = mc^2$ and $E = hf$ into the secondary curriculum. The learning progression positioned Einsteinian energy as a unifying framework capable of connecting traditional energy forms (heat, kinetic, electrical, nuclear, and light) under a contemporary scientific perspective (Boublil et al., 2023; Boublil et Blair, 2023).

Methods and Results

The curriculum was developed within the frameworks of Design-Based Research and the Model of Educational Reconstruction (MER). Core physics concepts were first epistemologically analyzed and reconstructed to align with students' developmental levels. The resulting sequence integrated hands-on experiments, embodied analogies, historical role-play, mathematical scaffolding using powers of ten, and real-world applications such as solar radiation and stellar energy production.

Analysis of student responses revealed important insights into pre-instructional conceptions. Prior to instruction, energy was commonly understood as observable motion, heat, or electricity, transferable but disconnected from matter. The equation $E = mc^2$ was often treated as symbolic rather than ontological.

Following instruction, three major conceptual shifts were observed:

1. **Ontological Expansion of Energy:** Students increasingly recognized energy as intrinsically related to mass and matter, accepting, even if abstractly, the idea that heating an object increases its mass.

2. **Quantization Understanding:** Students developed clearer conceptions of light as discrete photons with energy proportional to frequency, connecting ultraviolet radiation to biological effects and solar technologies.
3. **Mathematical Meaning-Making:** Students moved from memorizing equations to interpreting them as proportional relationships, demonstrating improved reasoning with powers of ten.

Conclusion

The findings open new pathways for research and curriculum development. Future directions include, structured comparisons between Newtonian and Einsteinian ontologies, strengthened mathematical scaffolding for proportional reasoning, and expanded teacher professional development. Longitudinal studies are needed to assess conceptual retention and transfer across disciplines. Emerging AI-based diagnostic tools may further support real-time identification of student misconceptions.

Overall, this study suggests that introducing Einsteinian energy in secondary school is not only feasible but epistemologically productive. When reconstructed through carefully scaffolded, activity-based pedagogy, modern physics can serve as a coherent conceptual bridge between classical curriculum and contemporary scientific understanding, reframing energy education for the 21st century.

References

Boublil, S. et Blair, D. (2023). Model experiments and analogies for teaching Einsteinian energy. *Physics Education*, *53*. https://doi.org/10.1088/1361-6552/ac96c0

Boublil, S., Blair, D. et Treagust, D. F. (2023). Teaching Einsteinian gravity in grade 7: Design, implementation and analysis of an 8-lesson module [Manuscript submitted for publication]. *International journal of mathematics and science education*.