Students' epistemic difficulties in analysing Energy Transfer Problems in Mechanics

Abstract. The teaching of the concept of energy, along with the processes of energy transformation and transfer in Newtonian mechanics, is a complex issue that continues to present significant pedagogical challenges. This study examines the epistemic practices of High School students (ages 16-18) in Argentina and Spain when solving problems related to energy transformation, transfer, and the application of the principle of conservation of energy in Newtonian Mechanics. The responses to the problems we administered reveal that many students fail to explicitly define the system and its environment when analyzing energy transfer phenomena, leading to confusion and conceptual errors in their understanding of energy.

Introduction

The understanding of the concept of energy, along with its transformation and transfer, has become a key teaching and learning objective in the science curricula of many countries. On the one hand, it is a central topic in introductory physics courses at both the high school and university levels; on the other, it is crucial for fostering citizen literacy, enabling individuals to make informed decisions about social development. Numerous studies explore students' general understanding of energy and the processes of transformation and transfer (Neumann and Nordine, 2023). These studies reveal that, overall, students in introductory courses often exhibit confusion about key concepts and the role of energy in physical changes. However, there is a gap in research regarding the scientific practices that high school students employ when analyzing problems related to the transfer, transformation, and conservation of energy in Newtonian Mechanics.

Theoretical Framework

In recent years, a teaching approach has emerged that emphasizes the importance of student participation in scientific practices as an essential part of learning science [1]. This approach, in broad terms, advocates for learning science through doing science, integrating cognitive processes, procedural skills, and scientific knowledge. Research into students' epistemic practices when solving energy-related problems can provide valuable insights for educators seeking to adopt a teaching model based on scientific practices. However, there is a lack of research on the scientific practices that high school students use when analyzing problems related to the transfer, transformation, and conservation of energy within the context of Newtonian Mechanics. In this study, when we refer to "epistemic" scientific practices, we are specifically addressing the processes involved in justifying scientific knowledge [2]. This includes the skills typical of the scientific community for justifying the construction of knowledge, such as formulating questions, designing and planning solutions, analyzing and interpreting data, building arguments based on evidence, and developing scientific explanations.

Our research focuses on investigating the epistemic practices employed by high school students, as well as the difficulties they face in understanding energy transformation and transfer phenomena and applying the principle of energy conservation in Newtonian Mechanics. The research question we aim to address is: What comprehension and epistemic challenges do high school students encounter when analyzing problems related to energy transfer and transformation in mechanics?

Methodology and Findings

To address the research questions, we designed a questionnaire consisting of five questions, which was administered to 118 high school students (67 from Argentina and 51 from Spain) under exam conditions, after they had received instruction on the topic. The duration and content of the instruction were similar in the selected schools in both countries, as were the levels of knowledge demonstrated by both groups in the initial pre-test.

For analyzing the written responses, this study adopts a phenomenographic approach to explore how different ways of perceiving and understanding reality (the associated concepts and modes of reasoning) can be organized into categories that describe that reality. These categories represent shared patterns of understanding, visible across many individuals, and thus reflect a form of collective knowledge [3,4].

We show, as an example, one of the questions from the questionnaire that describes an athlete throwing a javelin and asks students to explain the energy transformations and/or transfers involved. The question presents a non-routine challenge, requiring students to identify the system in which they will analyze the energy phenomenon. The responses were classified into explanatory categories, which emerged as interpretive trends: i) A minority of students (about 12%) did not define the system but accurately identified the energy transformations for a "javelin-athlete-earth" system; ii) Half of the responses focused on attributing kinetic and potential energy to the javelin in relation to its motion or height, without defining the system, transformation mechanism, or transfer process. Many students regarded potential energy as a property of the object itself, rather than a property of the object-Earth system, and showed confusion between force and energy.

Conclusion

Although the full results will be presented at the conference, we can anticipate that the findings reveal a tendency among students not to recognize that energy analysis depends on the choice of system. This gap in their analytical approach leads to conceptual errors and an inability to define the mechanisms of energy transfer and transformation. Addressing this epistemic challenge in analysing energy processes could enhance students' understanding and improve their learning.

References

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