Identification of common errors in learning classical mechanics

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Rationale

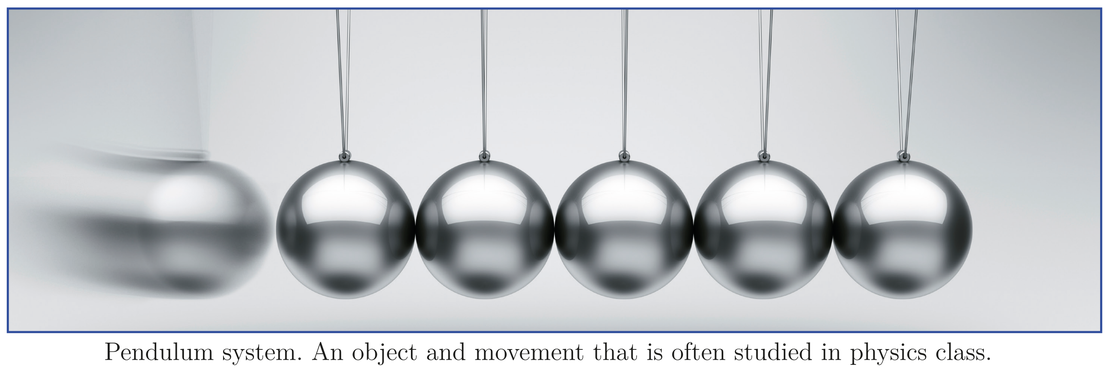
This work seeks to identify errors of classical mechanics in a 1st year physics exam at EPFL.

Classical mechanics, as the core subject of any engineering syllabus, has been the object of various studies regarding common misconceptions amongst students. Common errors can be found in the literature and range from confusion between scalar and vector (Flores & Kanim, 2004) and conceptual misunderstanding of mass, momentum and force (Clement, 1982) and energy (Lindsey, 2012). This kind of study was not yet performed in a European university and thus it is interesting to identify typical misconceptions proper to students with European education.

The research proposed aims to identify such typical errors and misconceptions that 1st year EPFL students make while learning classical mechanics. Subsequent studies may then seek to describe conceptual structure and develop and evaluate instructional strategies

Methodology

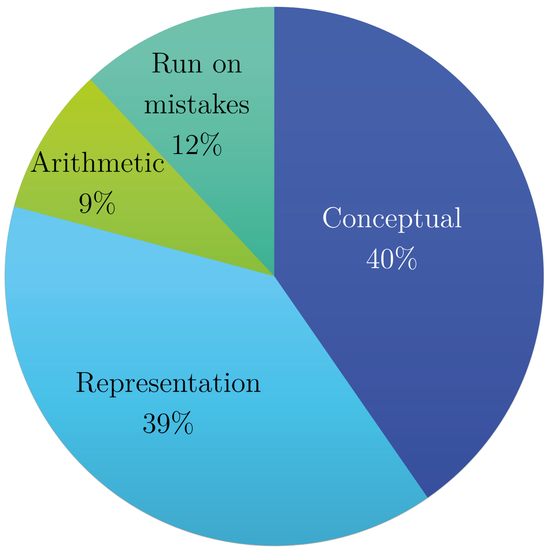
- 136 exams of 1st year students in civil engineering collected and anonymized.
- Creation of a list of possible mistakes based on the exam and the literature.
- Quantification of mistakes and extension of list of mistakes (Each group member analyzed 34 exams).
- Creation and classification of a common and more generic list of mistakes based on what was observed while analyzing every exam.



Pendulum system. An object and movement that is often studied in physics class.

Results

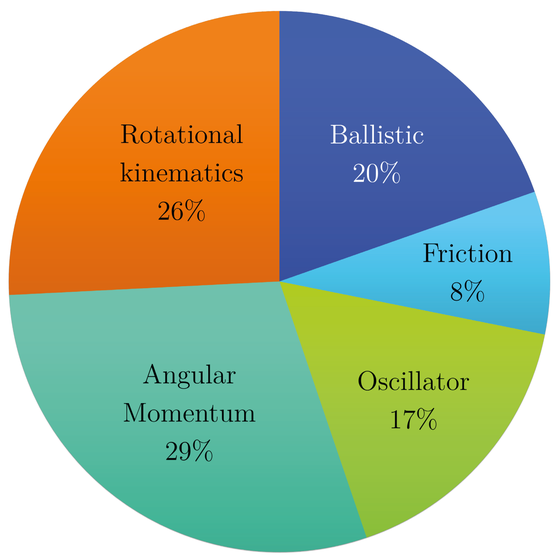
On average, the students attempted to solve 67% of the entire exam. Errors were classed in four main categories:



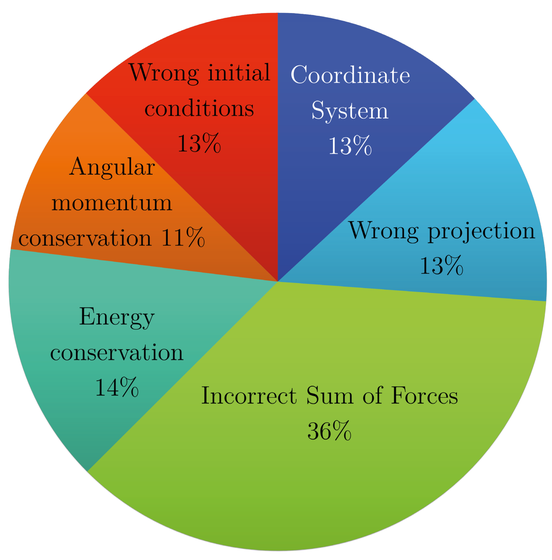
- Arithmetic (9%): incorrect mathematical calculations.
- Conceptual mistakes (40%): lack of understanding of the underlying physical concepts governing classical mechanics.
- Representation errors (39%): mistakes in representing the problem in space and manipulating physical entities within this representation.
- Run on mistakes (12%): an error committed early on and carried throughout the development of an answer, which ultimately led to a wrong final answer.

Conceptual and representation errors were separated into categories and the following incidence of mistakes was found

Conceptual errors



Representation errors



Key findings and implications

- 79% of errors are of representation or conceptual mistakes, i.e. dependent on learning and teaching in class in contrast to arithmetic and run on mistakes.
- In the given class, significant conceptual errors were found in both rotational kinematics and angular momentum.
- Misconceptions of representation were the most prominent in the sum of forces compared to all other types of representation errors.
- Following identification of errors, subsequent steps are analysis of the origins of these misconceptions which shall allow the development and analysis of teaching methods

More about this study

This study was completed by EPFL Master Students as part of a Social and Human Science course called How People Learn II. We would like to thank Professor Furbringer from the physics department for providing all exams of his class, for anonymizing them and for the interest he had towards our research.

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References
Clement, J., 1982. Students' Preconceptions in introductory mechanics. American Journal of Physics, 50(1), pp.66–71.
Flores, S., Kanim, S.E. & Kautz, C.H., 2004. Student use of vectors in introductory mechanics. American Journal of Physics, 72(4), p.460.
Lindsey, B. a., Heron, P.R.L. & Shaffer, P.S., 2012. Student understanding of energy: Difficulties related to systems. American Journal of Physics, 80(2), p.154.