Conceptual understanding and calculation accuracy in Physics

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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Rationale

Much of the research on physics learning in universities focuses on the concern that traditionally taught courses can leave students able to calculate correct answers to calculus-based questions without actually having gained much conceptual understanding of physics (Crouch and Mazur, 2001). This has led to a significant focus on active learning type methods (use of Peer Instruction, etc.) in science teaching (Freeman *et al.*, 2014).

It is interesting therefore to explore whether students who succeed in first year physics in the EPFL context have done so without gaining conceptual understanding.

Method

Concept inventory questions test students on their understanding of how physics applies to real-life situations, rather than testing their ability to calculate. The Force Concept Inventory is widely used in English-language research on student learning in university physics.

A French-language version of the Force Concept Inventory (FCI) (originally developed by Hestenes, Wells and Swackhamer) was administered to 236 first-year physics students in Spring 2014.

Data on their attainment in General Physics I was also obtained through a questionnaire given to the students.

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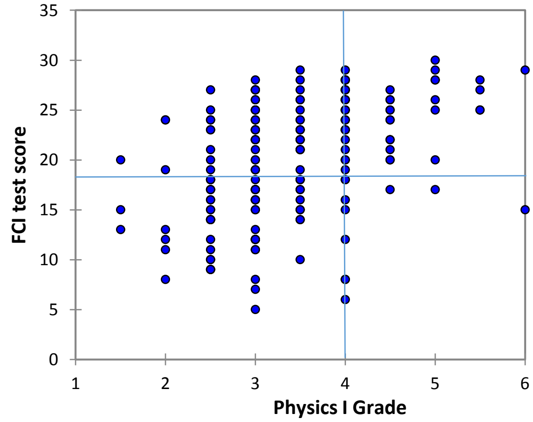
Is this true in the EPFL context?

What is a concept inventory-type question?

Question: Two children have been pushed on a sled and are now moving at a constant velocity across a (frictionless) frozen lake. The front child pushes the second child, who then falls off the back of the sled. What happens to the speed of the sled?

(a) Decreases
(b) Stays constant
(c) Increases
(d) Impossible to tell without knowing their weights

Numerous studies have found that many students who pass calculus-based physics exams still struggle to answer questions like this (see Crouch and Mazur, 2001). This sample concept question is based on one used by Michael Dubson at the University of Colorado.



Students' General Physics I grade compared to their score on the FCI

Results

Do students pass General Physics without conceptual understanding? No. Almost all students who passed the exam (scored 4 or higher) had gained a reasonable level of conceptual understanding (score of 18 or higher on the FCI). Unlike international contexts, few students with low FCI scores had passed the exam (lower right quadrant).

Is conceptual understanding enough? No. Conceptual understanding is necessary but not sufficient for passing the exam. Many students with high levels of conceptual knowledge fail the exam (top left quadrant) presumably because they lack calculation precision.

Implications

Other studies have found that many students pass physics exams without strong conceptual understanding. In this study, conceptual understanding appears necessary, but not sufficient, for passing these physics courses.

We found many students have gained conceptual understanding but still do not pass the exam. This suggests that increased success rates may be attainable if the conceptually strong students are challenged to improve their calculation ability and accuracy.

References:
Crouch, C.H. & E. Mazur (2001) Peer instruction: ten years of experience and results *American Journal of Physics 69 (9)* 970-977.
Freeman *et al.* (2014) Active learning increases student performance in science, engineering, and mathematics *Proceedings of the National Academy of Sciences* *http://www.pnas.org/content/early/2014/05/08/1319030111*
Hestenes, D., M. Wells, & G. Swackhamer (1992) Force Concept Inventory *The Physics Teacher*, 141-158.

More about this study

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