The effect of research-based instruction in introductory physics on a common cognitive bias

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1. Motivation and context

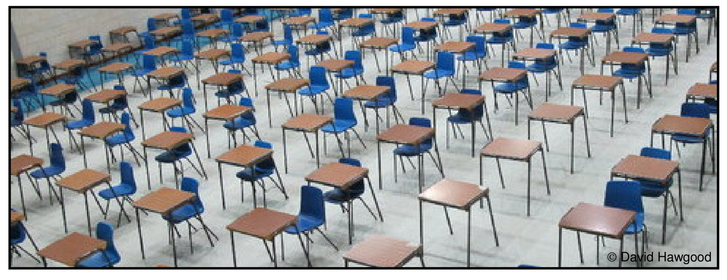
At the 2011 PERC meeting, Rebello [1] presented a study comparing students' individual and cohort mean score estimations with their actual assessment scores. He found that competent students somewhat underestimated their own performance, whereas weaker students greatly overestimated theirs. This is consistent with the well-known 'Dunning-Kruger effect' [2].

Inspired by Rebello's findings, we have conducted a replication study with our first year class at the University of Edinburgh in the UK, *Physics 1A*:

- First semester, calculus-based introductory course in Newtonian mechanics.
- Running for the first time this year in full 'inverted classroom' mode (Peer Instruction lectures supported by small-group problem workshops).
- Around 200 students in the class. Gender balance approximately 75% male to 25% female. Around half of students were physics majors. Remainder were non-majors e.g. engineering or chemistry students.

2. Data collection

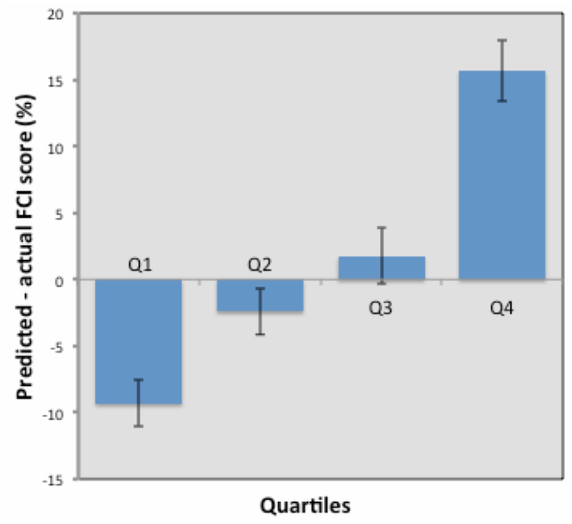
Students were asked to voluntarily predict their score on two assessments. The first was the pre-instruction administration of the FCI. The test was undertaken online prior to the start of formal teaching on the course, with an additional free-text response question appended at the end of the FCI instrument asking students to predict their score.



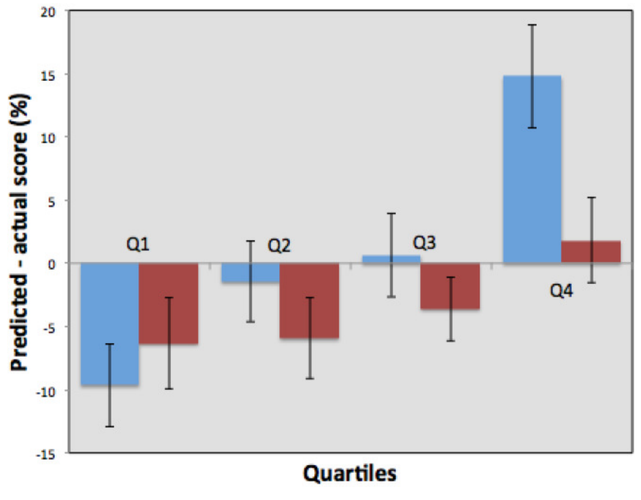
Students were also asked to predict their performance on the end-of-course examination, counting for 70% of the final course grade. The written examination comprises two sections, the first containing compulsory short answer questions across the breadth of the course, followed by a choice of two from four longer questions testing areas in greater depth. Students were asked to state their expected percentage score at the end of their exam scripts.

3. Pre-instruction results

We split the students into quartiles based on their actual FCI scores, and for each quartile determined the mean prediction discrepancy (calculated as predicted – actual score). The figure illustrates these mean prediction discrepancies per quartile (with Q1 showing the highest performing students and Q4 the weakest students). Our findings confirm the previously-reported result that there are significant differences in both the size and sign of discrepancy of prediction for groups of different ability. Students in the upper quartiles tend to underestimate their score. Conversely, students in the lowest FCI score quartile dramatically overestimate their score.



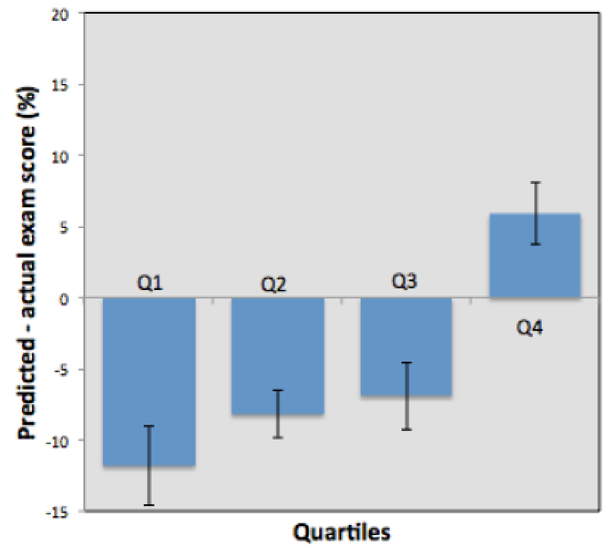
4. Changes after a semester of instruction



Of the 167 students who predicted their score on the FCI, 56 also volunteered a prediction for their final exam scores. The figure shows this matched data set of FCI predictions (blue bars) and estimated exam scores (red bars). Only the lowest ability quartile shows a significant change between FCI and exam prediction discrepancies. Furthermore, the mean exam prediction discrepancy for Q4 students is now not significantly different from those in any of the other three quartiles. The over-estimation of performance by those originally in the lowest quartile according to the pre-instruction FCI score is dramatically reduced, and the global mean discrepancy (across all four quartiles) is slightly negative for the exam score predictions.

5. Post-instruction results reconsidered

It is tempting to suggest that the teaching methods used (or some other factor) had a disproportionately large effect on the weakest Q4 students. However, the picture is not quite this simple. The figure in panel 4 maintains students in their original FCI score quartiles, whereas in fact they may turn out to be in very different quartiles if the split was made on the basis of exam performance. This figure illustrates that split, and shows that although the tendency to over-estimate one's score is diminished, it is still present for those students who now find themselves in the lowest quartile on the basis of exam performance.



6. Conclusions

Our results suggest that there is an improvement in the ability of the weakest students to individually predict their own scores on an assessment after a semester of 'inverted classroom' instruction. However, in the cohort as a whole there persists a pattern whereby the currently weakest students continue to over-estimate their own ability.

Some caution is appropriate: we do not know how much of any improvement in the weaker students' ability to predict their own scores is due simply to them maturing into learning at university. Nonetheless, this study suggests that research-based instructional strategies – already valued for their role in improving conceptual understanding and content knowledge – may also be valuable ingredients to enhancing students' metacognitive abilities.

References

[1] N. S. Rebello, "How accurately can students estimate their performance on an exam and how does this relate to their actual performance on the exam?", PERC Proceedings, AIP, 2012, vol. 1413, pp. 315–318.

[2] J. Kruger and D. Dunning, "Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments.", *J. Pers. Soc. Psychol.* 77(6), 1121–1134 (1999).

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