Research in Learning, Assessing, and Tutoring Effectively

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Overview
The major thrust of our group this last year has been developing and demonstrating a new pedagogy that helps students become more expert problem solvers.

1. Modeling Applied to Problem Solving

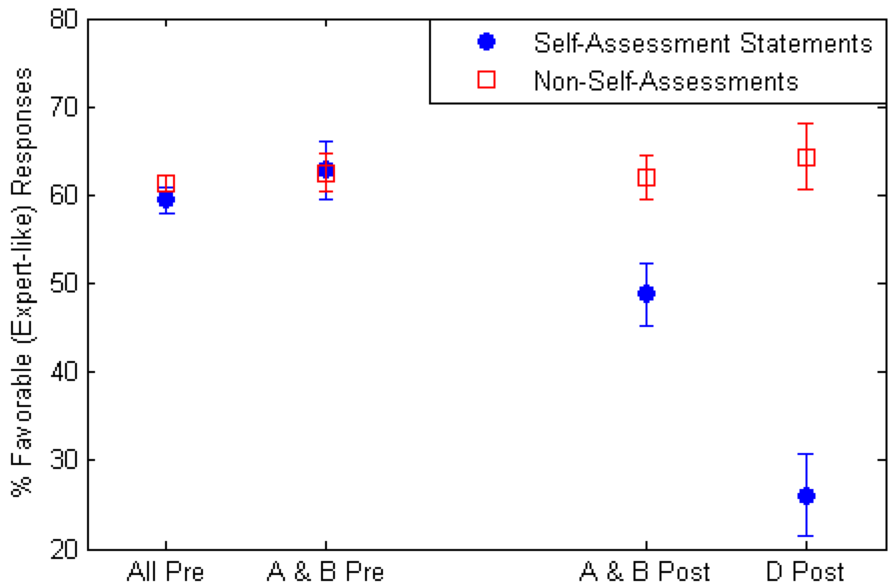
Freshman physics courses are failing to make students more expert problem solvers. Experts possess the insight to sort problems into categories based upon fundamental physics principles. This requires a good understanding of the nature of interactions, for example that if no external forces are applied to a system, its momentum will be conserved. If, on the other hand, non-conservative forces are absent or do no work, mechanical energy is conserved, and so on. Our students cannot do this and are therefore classified as novices [1]. Intermediate novice students like ours also look for conserved quantities, but do so by using superficial similarity to previously done problems and equation hunting rather than attempting to qualitatively understand the nature of the interactions [1,2,3]. For this reason, when novices are presented with a problem that they do not recognize based on pattern matching to previous problems or equations, they are helpless to proceed.

Students recognize this helplessness, and it has a dramatic impact on their self-confidence in their own problem solving ability. The Colorado Learning Attitudes about Science Survey (CLASS) [4] is a standardized instrument for assessing student attitudes about physics and learning physics. Students are asked to respond to statements on a scale from 1 (strongly disagree) to 5 (strongly agree). The survey contains several statements assessing students' attitudes about problem solving. Four of these statements unambiguously assess students' self-confidence in their own problem solving:

After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
I enjoy solving physics problems.
I can usually figure out a way to solve physics problems.
If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

The other statements about problem solving involve students' perception of problem solving procedures, for example: *I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.*

Examining the trend among MIT students' responses to the self-assessment statements and to the non-self-assessments related to problem solving on the CLASS shows that even A and B students at MIT exit their freshman physics course with substantially decreased problem solving confidence.



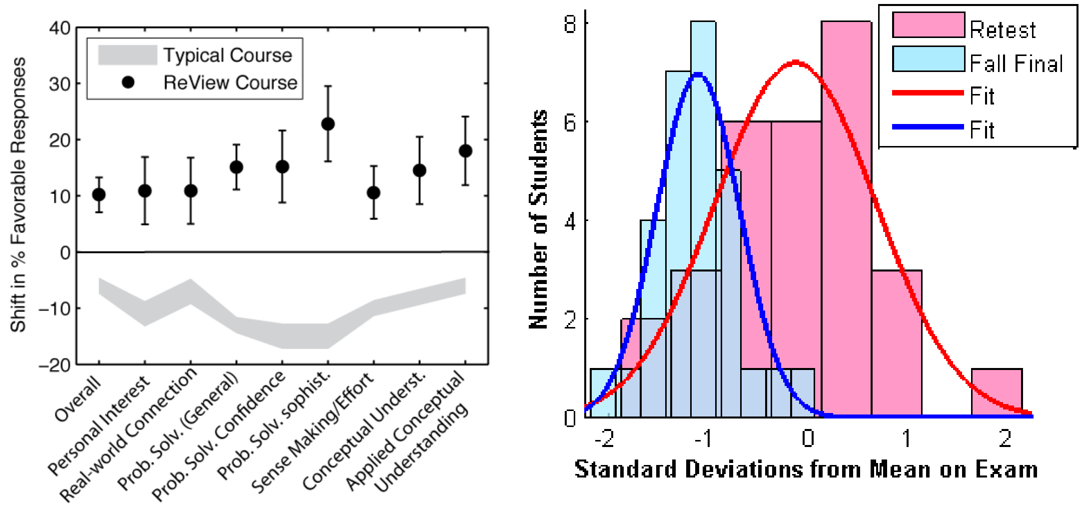
Responses of specified groups of MIT students to problem solving self-assessments and other problem solving related statements on the CLASS before (Pre) and after (Post) taking the freshman mechanics course.

We have developed a new pedagogy to help students become more expert problem solvers. We call it Modeling Applied to Problem Solving (MAPS). Models are used to present and hierarchically organize the core syllabus content and apply it to problem solving, but the students are not asked to construct and validate their own Models through guided discovery which is typically central to modeling pedagogies. Instead, the students are asked to classify problems under the appropriate core Model or Models by selecting a system to consider and describing the interactions that are relevant to that system. This explicit System, Interactions and Model (S.I.M.) problem modeling rubric represents a key simplification and clarification of the widely disseminated modeling approach originated by D. Hestenes and collaborators [5,6]. Our narrower focus allows modeling physics to be integrated into (as opposed to replacing) a typical introductory college mechanics course, while preserving the emphasis on understanding systems and interactions that is the essence of modeling.

2. ReView Course – from D to B in three weeks

We have employed the MAPS pedagogy described above in a three-week ReView course for MIT freshmen who received a D in the fall mechanics course, with extremely encouraging results.

In stark contrast with traditional and reform introductory physics courses (including the MIT freshman mechanics course) which generally leave students with a *more novice* conception of both problem solving and the discipline of physics than they had when they entered, our ReView course using the MAPS pedagogy generated positive shifts in student attitudes in every category measured with the CLASS. These shifts were statistically significant in all five categories dealing with problem solving and conceptual understanding and included positive shifts in the self-assessment statements.



(left) Shifts in the nine commonly reported categories of the CLASS survey for a typical one-semester college course [4] and for our three-week ReView course.
(right) Performance of the ReView course students on their fall term final exam and on the retest administered after the ReView.

Improved student attitudes were accompanied by improved student performance. Students exiting the three-week ReView course achieved a mean score on an MIT freshman mechanics final exam that was one standard deviation higher than their mean performance on an equivalent exam before the ReView.

References

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