Using prompted self-explanations in first-year calculus

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Background

A **worked example** is an example that involves a step-by-step solution to a problem. It can be presented in textual, graphical, video or face-to-face format (latter is sometimes called "expert modelling").

A **self-explanation** or a **self-generated explanation** is an explanation of presented instruction that integrates the presented information with background knowledge and fills in tacit inferences.

A **prompted self-explanation** is a process by which, when given a piece of material to study, students are given external cues eliciting self-explaining.

Many studies show the effectiveness of both worked examples (Renal et al.), self-explanations (Chi at al.). However, there is a large amount of variance in the amount and quality of individually produced self-explanations. Prompting self-explanations is a more reliable technique and has been shown to work with:

- verbal prompts (Chi et al., 1994),
- computer-generated prompts (McNamara, 2004; Aleven and Koedinger, 2002; Hausmann and Chi, 2002),
- prompts embedded in the learning materials (Hausmann and VanLehn, 2007).

So far, none of the studies were applied to a service first-year calculus course.

Course

MATH 110 is a two-term, six-credit course in differential calculus that covers the same calculus content as the one-term courses, but with additional material designed to strengthen understanding of essential pre-calculus topics.

This course is meant for students who do not satisfy the prerequisites for one-term calculus courses and normally students with Pre-Calculus 12 grades higher than 85% are not permitted to take MATH 110.

Implementation

Why? Pilot study to test out materials and figure out controls for next year's implementation.

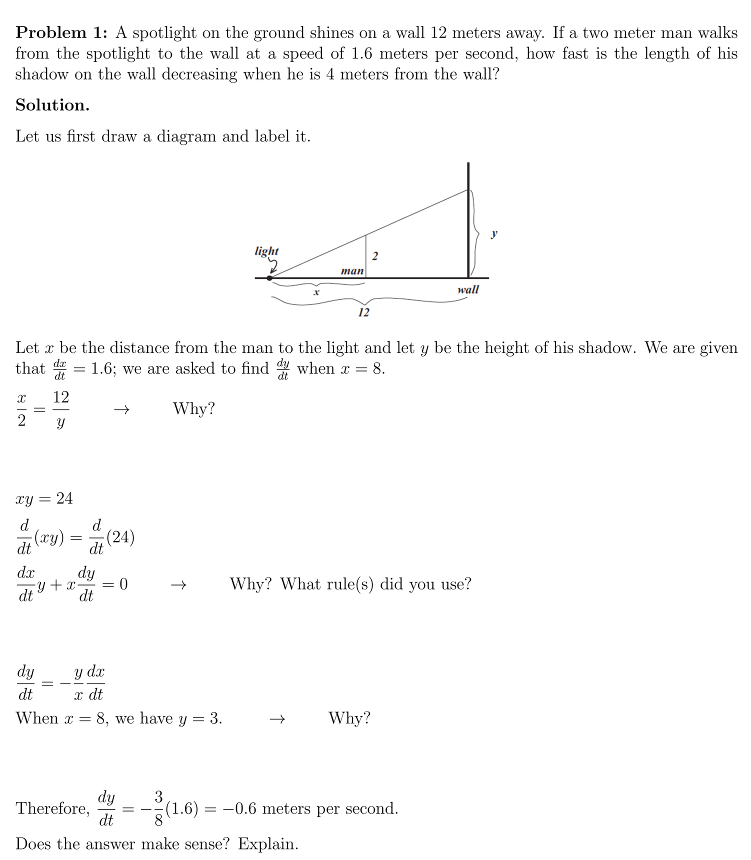
Who? One section of MATH 110 with ∼50 students.

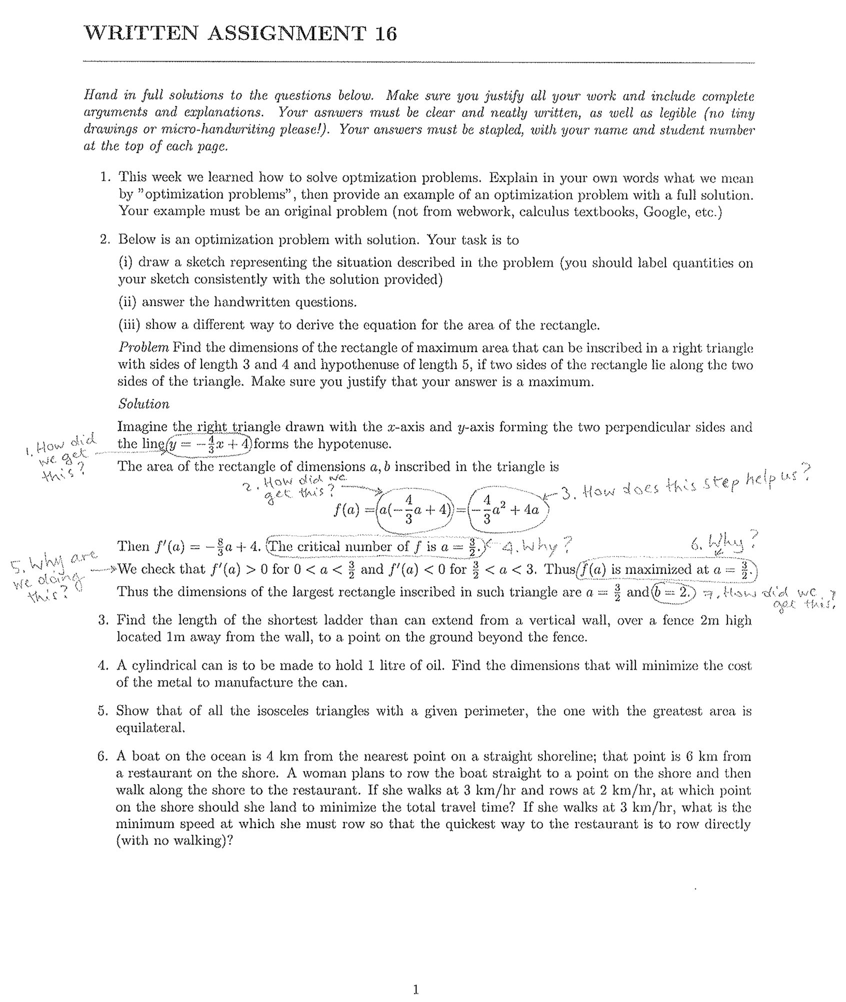
What? Introduce prompted self-explanations as an active learning technique.

How? Provide worked examples and ask students to explain particular steps.

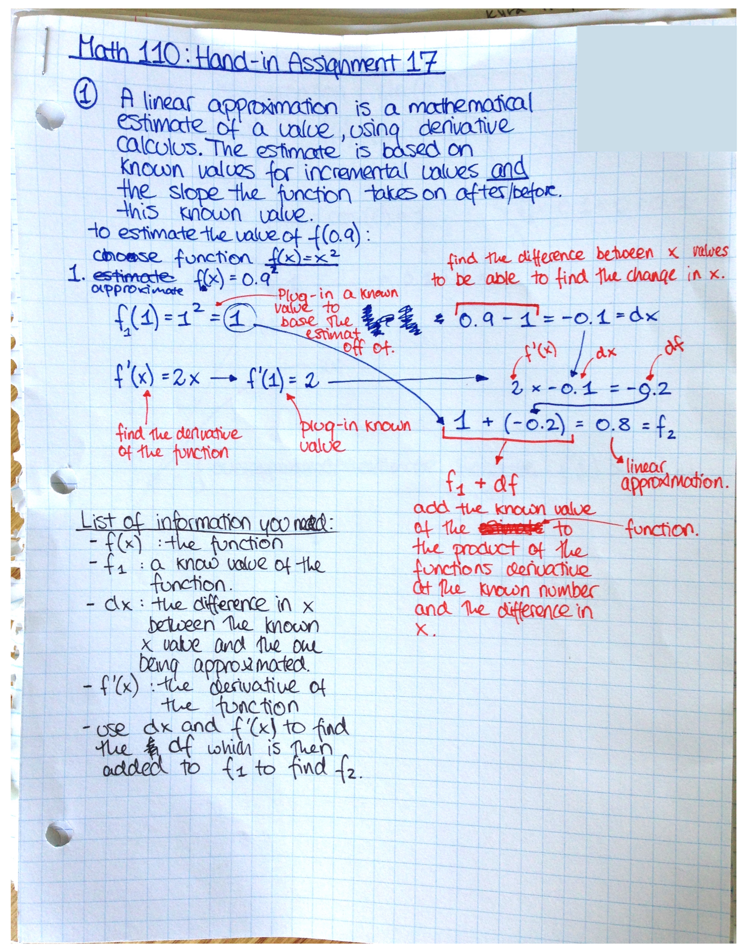
How often? One hour a week in class (worksheets) plus one question on every assignment.

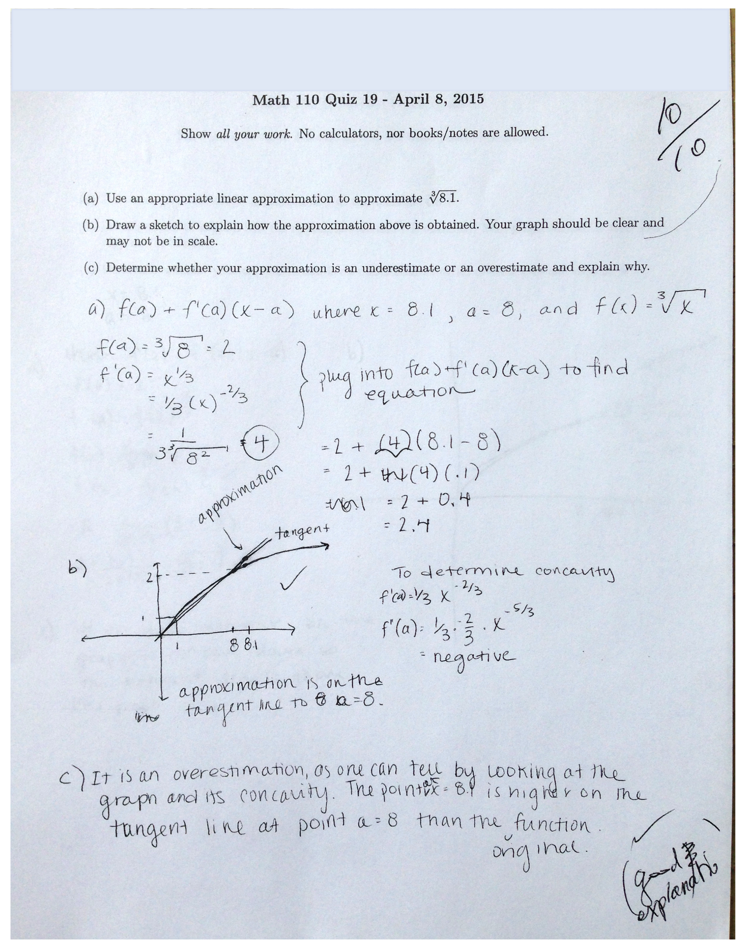
Sample materials





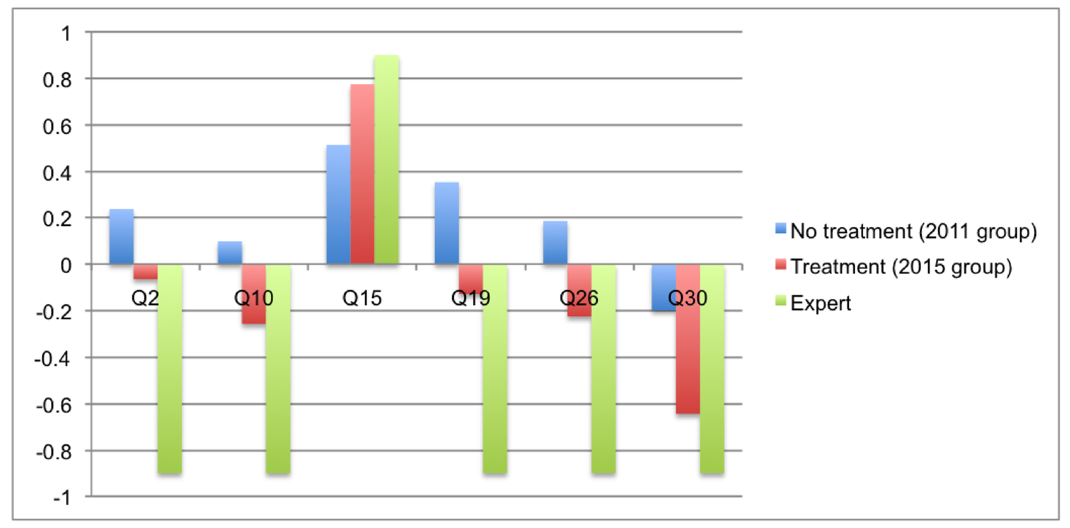
Sample student work





Encouraging preliminary results

We used Mathematics Attitudes and Perceptions Survey (MAPS) to study the results. The basis for comparison was MAPS data collected in MATH 110 in April 2012. Assuming the population of Math 110 students does not significantly change through the years, we see some non-trivial improvements. Below we present the data for questions with the most significant improvement:



Q2: After I study a topic in math and feel that I understand it, I have difficulty solving problems on the same topic.
Q10: Understanding math means being able to recall something you've read or been shown.
Q15: In math, it is important for me to make sense out of formulas and procedures before I use them.
Q19: I often have difficulty organizing my thoughts during a math test.
Q26: School mathematics has little to do with what I experience in the real world.
Q30: If I get stuck on a math problem, there is no chance that I will figure it out on my own.

Overall MAPS average agreement with the experts:
27% for the 2015 group versus 11% for the 2012 group.

Student comments

"Explaining worked solutions was very useful in my understanding how to solve the problem as well as learning where I was going wrong. Having to explain solutions made sure that I had to be confident I knew why I did each step which was helpful."

"I was doubtful on the usefulness at the start but going through the problems step-by-step with teacher and students helps."

"Showing how problems/questions or approached step-by-step help. Being asked to explain how certain values are obtained, helped me understand how each step is related to another."

Drawbacks

As with any technique, there are some drawbacks in its implementation.

- Time-consuming.
- Need a good instructor/TA to student ratio.
- Paper heavy.