Bringing Cognitive Tutors to the Internet:
A Website that Helps Middle-School Students Learn Math

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math**tutor**

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We are creating an open-access website for middle-school mathematics (grades 6-8) where students can work on problem-solving activities while being guided by artificially-intelligent software tutors.

http://webmathtutor.org

Motivation

Students who want to spend time outside of school solidifying and extending the mathematics that was learned in school may have difficulty finding effective learning activities. After-school tutoring services are available only on a limited basis and are often not as good as would be ideal. Professional tutoring services are costly. Of the many web sites available for math instruction, few are free *and* offer rich problems with *guided* learning by doing.
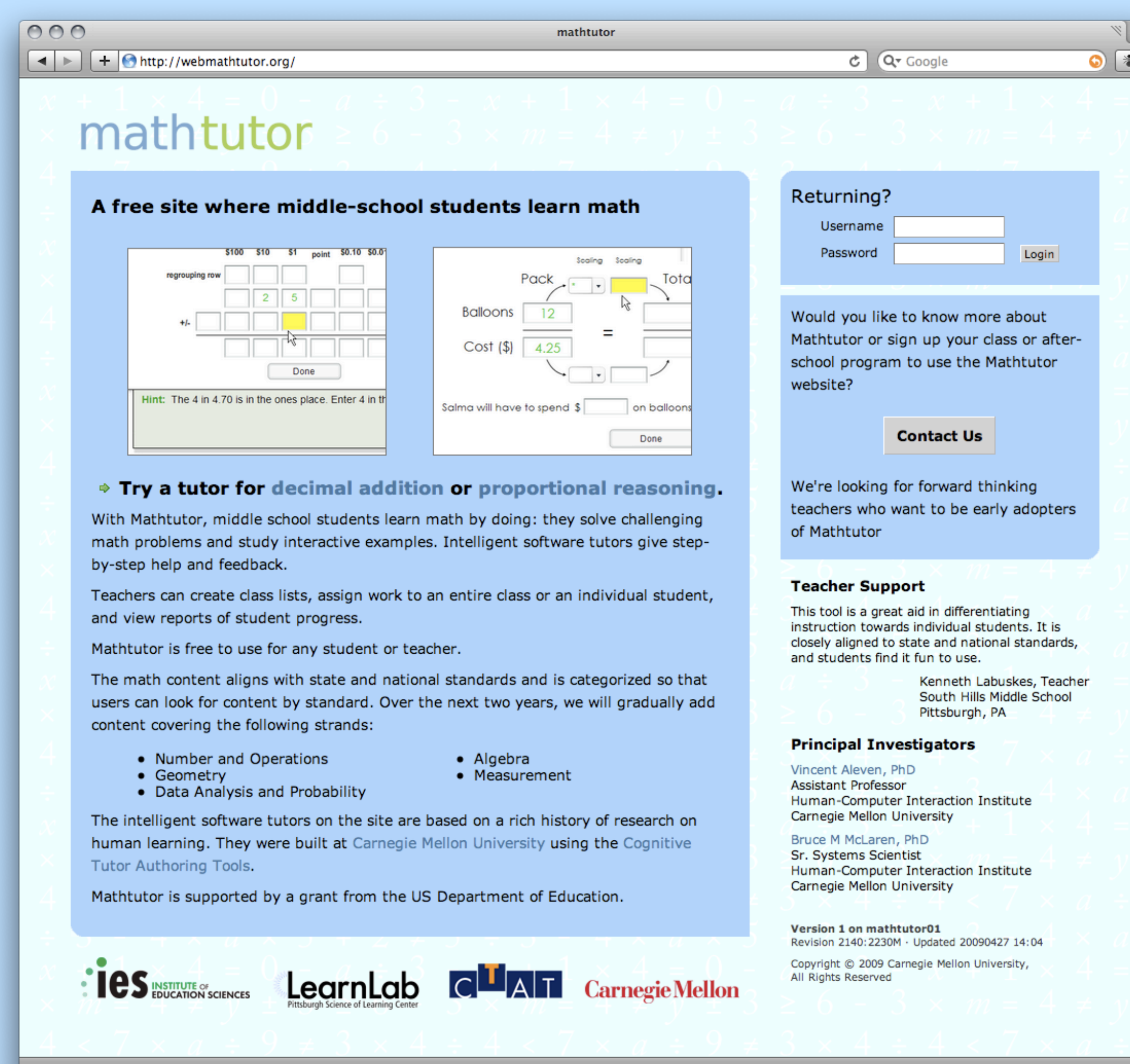
Objective

We are addressing this problem by developing a web site for middle-school mathematics (grades 6-8) where students can work with artificially-intelligent software called 'Cognitive Tutors.' These types of tutors have been shown to improve the math achievement levels of high-school students over more typical mathematics courses. The web site will be freely available for students and teachers. We foresee that it will be useful in after-school programs, homework, classroom exercises, libraries, etc.

Implementation

As we develop the site with the help of experienced teachers and math coaches, we draw heavily from a set of existing Cognitive Tutor middle-school math courses for the 6th, 7th, and 8th grade. We also leverage recent advances in tutoring technology developed in our research group, a suite of authoring tools (CTAT) that make it possible to develop computer-based tutors without requiring advanced programming skills. To make the site maximally effective, we follow a recommendation of many educational researchers, as well as the NCTM standards, namely, that students learn best when they are exposed to multiple strategies for solving math problems.

Success Criteria

We will develop and improve the web site in an iterative manner, improving it each academic year, based on the experience in the previous year. At the end of the grant period, all content will have been piloted in after-school programs, demonstrating the web site's feasibility. The main measures of accomplishment will be successful use of the site by students, as measured by time spent on the site, problems completed, and declining error rates while solving problems on the site, and teachers, as measured by the amount of use of the teacher tools on the site.

Teachers can view reports detailing progress of a class of students through the assigned problem sets.*

An example tutor for proportional reasoning. All tutors on the **Mathtutor** site provide step-by-step hints and feedback.

Teachers can also view reports detailing the progress of each student individually.*

An example tutor for decimal addition and subtraction.

Initial Use of Site

The first version of the site, with all key functionality, is live and has been used in a research study, reaching
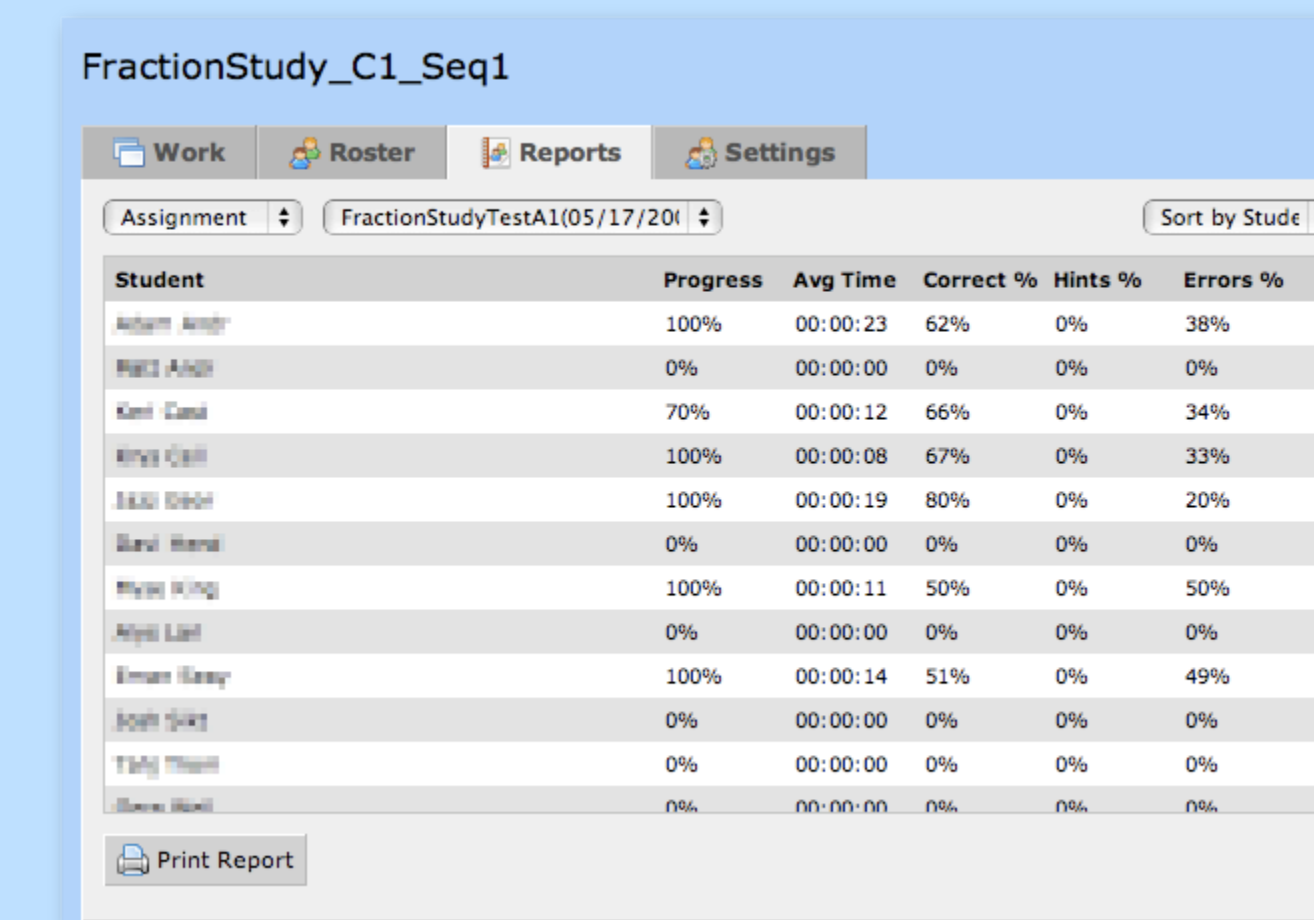
- 390 students—280 fifth grade, 110 sixth grade—in
- 16 classes—11 fifth grade, 5 sixth grade—at
- 3 schools.

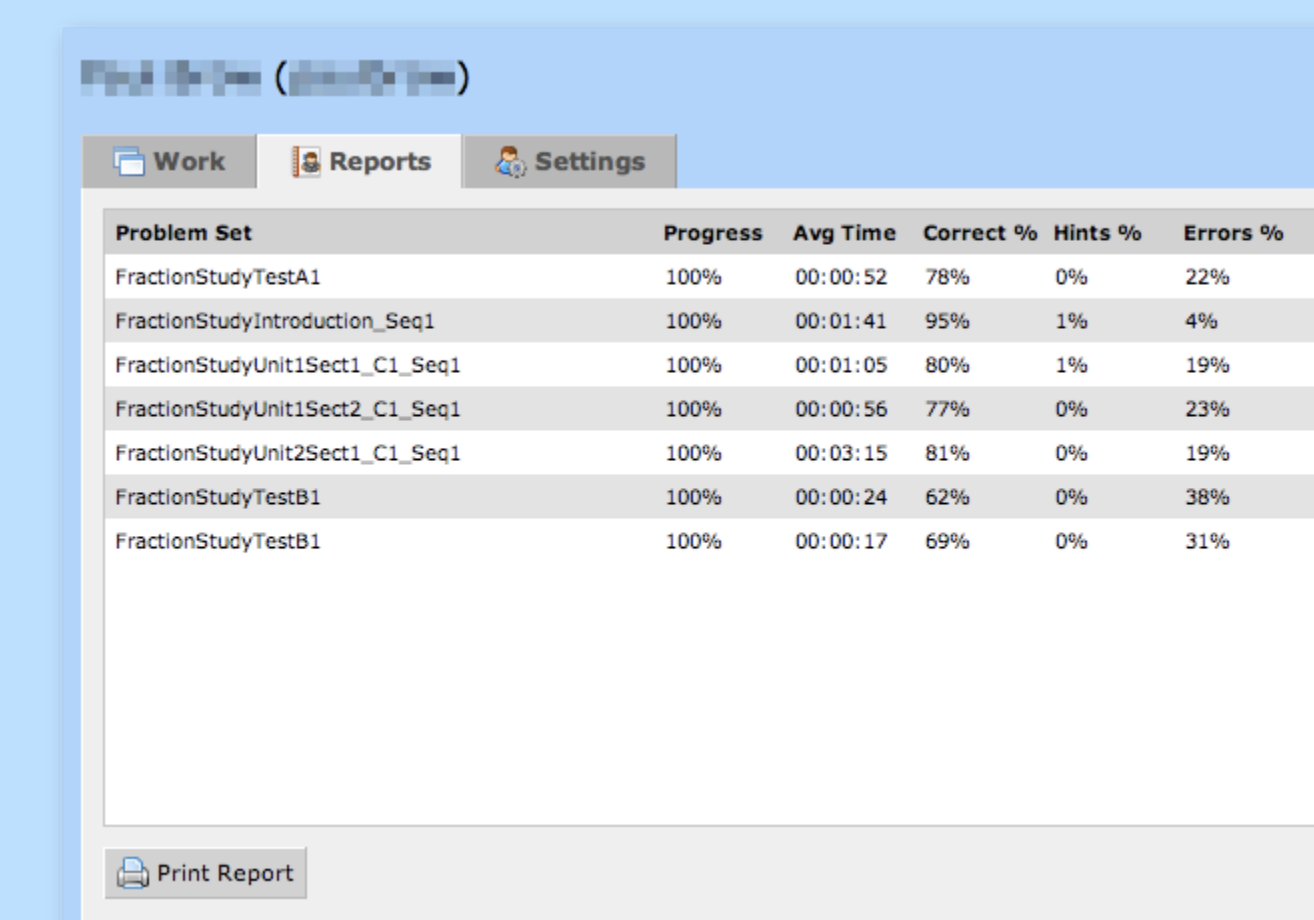Each student, on average, spent 7 hours on the site and completed 70.5 problems.

We are currently recruiting schools to be pilot sites in the fall of 2009. About 12 schools have expressed interest in becoming pilot sites.

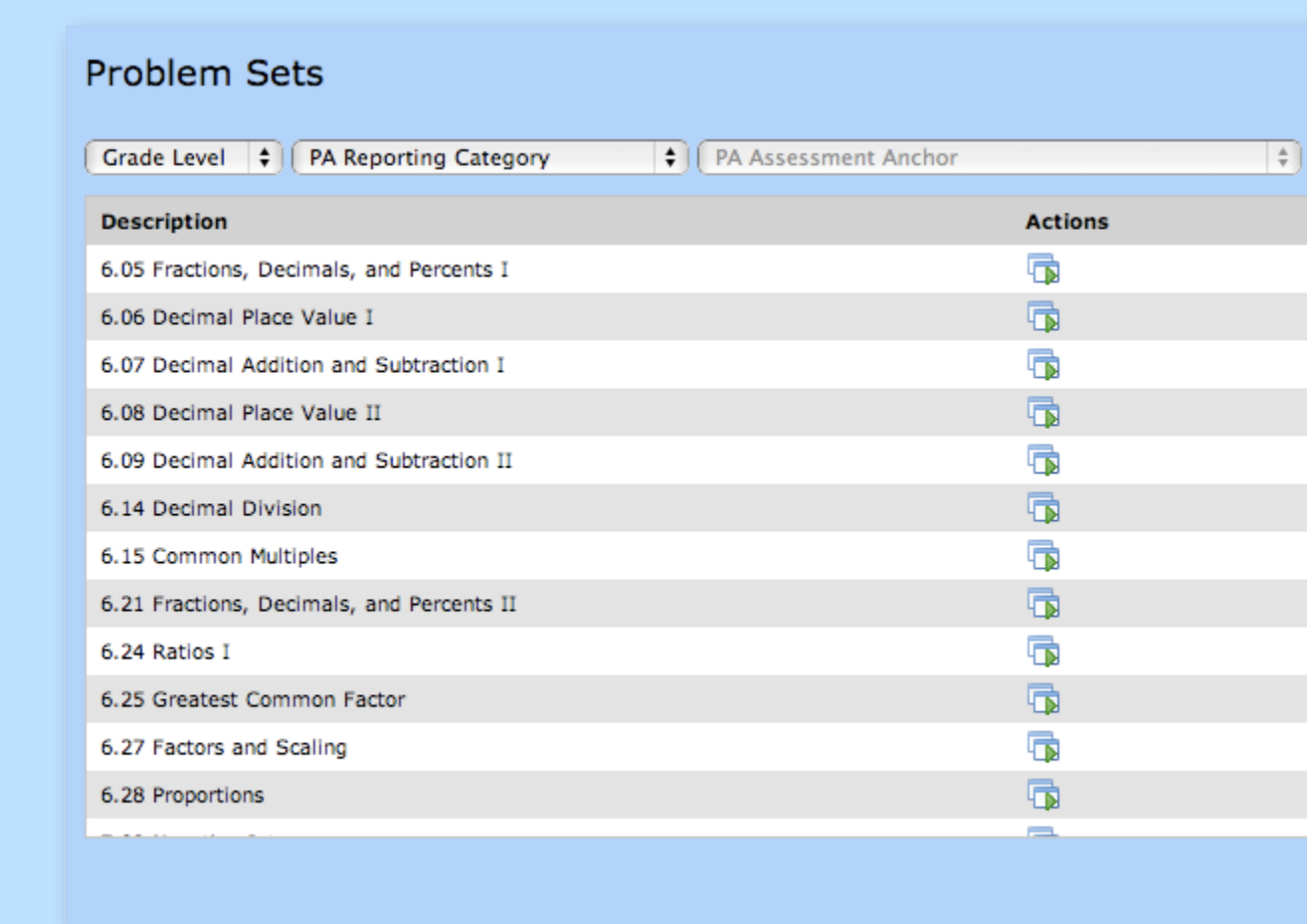## Cognitive Tutor Authoring Tools (CTAT)

The tutors on the **Mathtutor** site are example tracing tutors implemented with the Cognitive Tutor Authoring Tools. These tutors share many of the essential behaviors of Cognitive Tutors, but are easier to build. They utilize specific examples of problem solving behaviors to provide tutoring, rather than a rule-based cognitive model of problem solving. CTAT has been used extensively and the accumulated experience indicates that building example tracing tutors with CTAT is significantly less costly and time-consuming than building regular Cognitive Tutors. For more information, see **http://ctat.pact.cs.cmu.edu**

The problem sets available on the site will comprehensively cover mathematics for grades 6 through 8.

Content developers index problem sets under applicable state standards (e.g., the Pennsylvania Assessment Anchors).

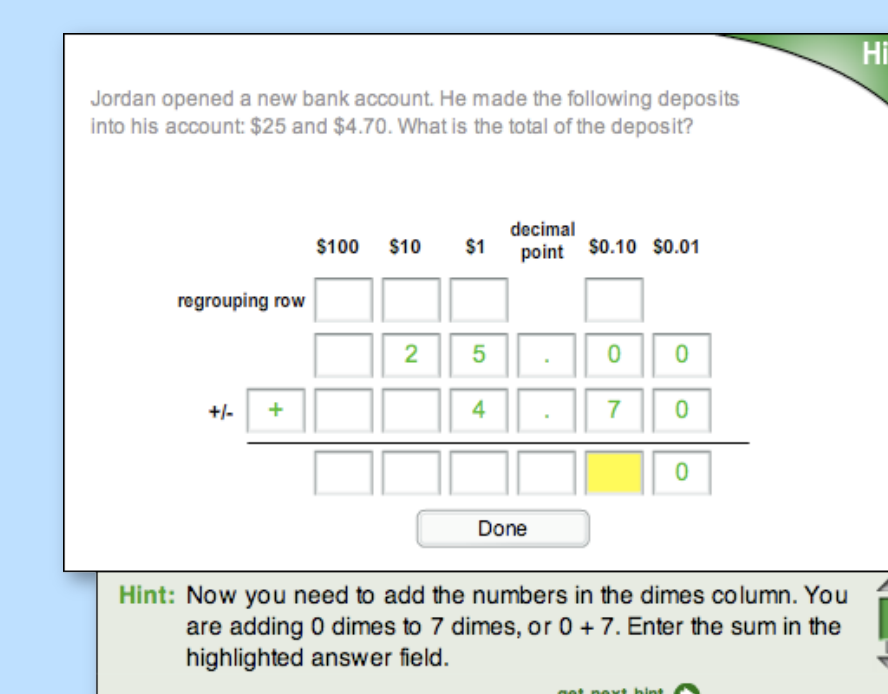* Pseudonyms obscured to protect subjects' anonymity.

Publications

Aleven, V., McLaren, B.M., Sewall, J. (in press). "Scaling up programming by demonstration for intelligent tutoring systems development: An open-access website for middle school mathematics learning." *IEEE Transactions on Learning Technologies.*
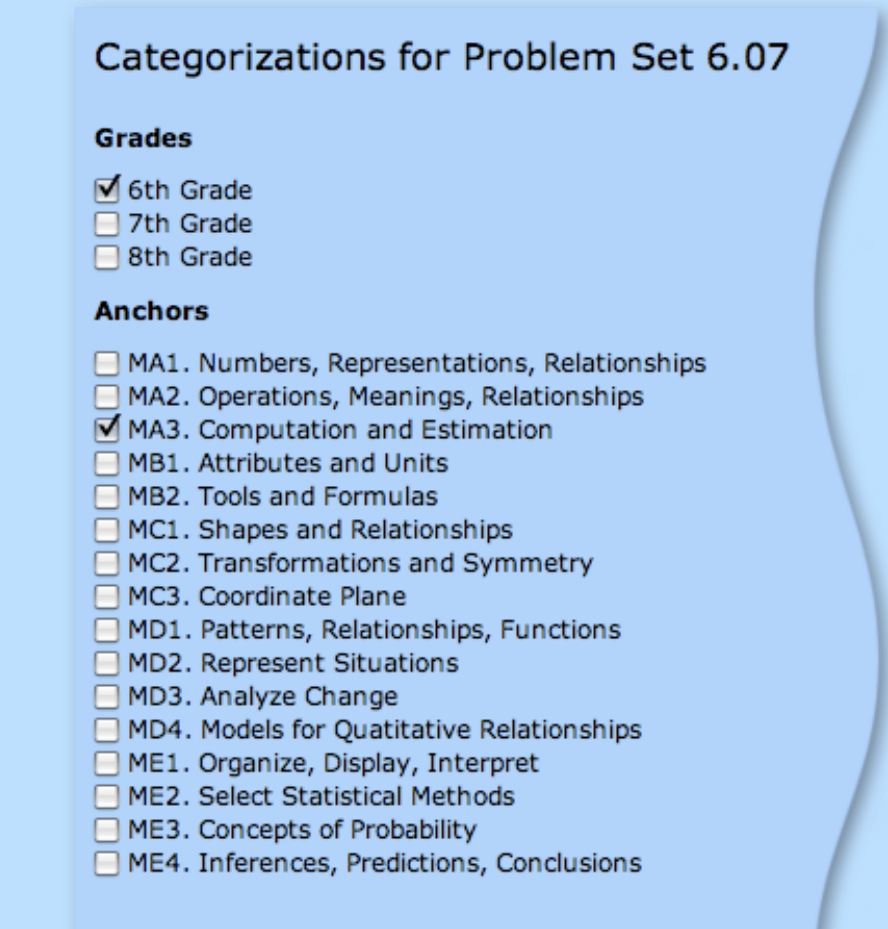
Aleven, V., McLaren, B.M., Sewall, J., Koedinger, K.R. (in press). "Example-Tracing tutors: A new paradigm for intelligent tutoring systems." *International Journal of Artificial Intelligence in Education.* Special Issue on Authoring Systems for Intelligent Tutoring Systems.

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