

## The Eyes are the Window into the Soul-Mind

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Part of what makes our Cognitive Tutors so successful is that they include a Cognitive Model that is able to understand what students are thinking about when they solve a problem. But how does it know what a student is thinking?

The easy answer to that question is that the Cognitive Model encodes information about mathematical problem solving gathered by careful observation of students. There are several methods that we use to study students' thinking. This article focuses on one of the newest.

Kevin Gluck's doctoral research at Carnegie Mellon University involved having students solve problems in a variant of the Algebra I Cognitive Tutor. Students in the study wore a headset which tracked their eye movements. In this way, Dr. Gluck was able to study what information students used when solving problems.

<p>You have been saving money and now have \$20 for video games. During your time at the arcade, you spend \$4 per hour.</p> <p>1. How much money will you have after two hours?</p> <p>2. How many hours can you play before you run out of money?</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td></td> <td style="text-align: center;">Time</td> <td style="text-align: center;">Money</td> </tr> <tr> <td style="text-align: right;">Unit</td> <td style="text-align: center;">Hours</td> <td style="text-align: center;">Dollars</td> </tr> <tr> <td style="text-align: right;">Expression</td> <td style="text-align: center;">X</td> <td style="text-align: center;">20-4x</td> </tr> <tr> <td style="text-align: right;">1</td> <td style="text-align: center;">2</td> <td></td> </tr> <tr> <td style="text-align: right;">2</td> <td></td> <td></td> </tr> </table>		Time	Money	Unit	Hours	Dollars	Expression	X	20-4x	1	2		2		
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**Figure 1: Partially-completed word problem**

Consider Figure 1. Earlier research had shown that students might answer the first question in one of two ways. First, they might reason from the problem scenario (perhaps imagining having \$20 and then using repeated subtraction to calculate the money left after spending \$4 two times). The second method would be to derive the algebraic expression  $(20-4x)$  and then substitute 2 for X and calculate the result.

Other research has shown that our tutors help students transition from the first method (which works well with simple problems) to the more sophisticated algebraic method. That's why the expression row appears at the bottom of the worksheet in early lessons (supporting the first method) and at the top in later lessons (supporting the second method).

But the eye tracking data showed that students don't always make this transition in the way we expected. Some students don't use the algebraic expression, even when it is available. In About 13% of the time, when students were answering a question like question 1, they looked at the problem scenario but not the expression. 54% of the time, students looked at the expression (sometimes along with the scenario). Almost 34% of the time, they looked in neither place.

Someday, students might wear eye-tracking devices while using Cognitive Tutors in their classrooms. Until then, better knowledge of what students do when solving problems of this type guides us in structuring the curriculum and in constructing the hints that students receive from the system. In this case, Gluck's research shows that some students who are able to identify the algebraic representation of a problem may not understand how to use that expression to calculate a value. As a result, we are investigating ways to make the system more effective at promoting this understanding.