Eliciting Intelligent Novice Behaviors with Grounded Feedback in a Fraction Addition Tutor

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Abstract. Standard intelligent tutoring systems give immediate feedback on whether students' answers are correct. This prevents unproductive floundering, but may also prevent students from engaging deeply with their misconceptions. This paper presents a prototype intelligent tutoring system with grounded feedback that supports students in evaluating and correcting their own errors. In a think-aloud study with five fifth-graders, students used the grounded feedback to self-correct, and solved more fraction addition problems with the tutor than with paper and pencil. These preliminary results are encouraging and motivate experimental work in this area.

Keywords: Intelligent Novice, Grounded Feedback, Visual Feedback, Situational Feedback, Fraction Addition

1 Grounded Feedback and the Intelligent Novice

Intelligent tutoring systems often give immediate *explicit feedback* telling students whether a step is correct, for example by coloring wrong answers red. However, given some scaffolding, students may be able to determine that they have made an error without explicit feedback. If students' actions have consequences that the students recognize as being desirable or undesirable, they can use these consequences to recognize and often learn from their errors [5]. When students correctly interpret the consequences of an action in light of their prior knowledge, we refer to those consequences as *grounded feedback* [2]. Grounded feedback in an Excel formula tutor and an equation-writing tutor has been shown to lead to better learning than explicit feedback [3, 4].

This paper presents a grounded feedback tutor for fraction addition, and a discussion of how students interact with the tutor. For each symbolic fraction n/d, the feedback shows a rectangle divided into d parts, with n colored in. The rectangles allow for easy comparison between the given fractions in the problem and the student-inputted converted and sum fractions. The tutor updates the feedback to reflect the fractions students enter. This tutor contains the key elements of grounded feedback: the feedback by itself does not indicate correctness, and it gives clues about the nature of students' errors (for example it shows if the students' fractions are too big or too small). We found that students connected the grounded feedback to their prior knowledge and used the feedback to correct errors. Students also displayed *intelligent*

novice behaviors: they made errors, found them without explicit feedback, corrected them, and appeared to learn from them.

1.1 The Grounded Feedback Tutor

The tutor (see Fig. 1) displays two symbolic fractions and a question mark representing their sum. Below the symbolic forms, fraction bars represent the given fractions and the answer fraction. Below the first set of fraction bars, a second set displays the fractions the students input at the bottom of the interface. The goal is to

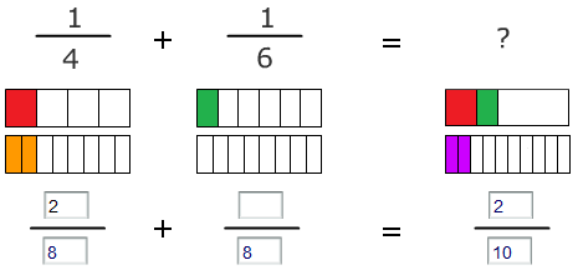

Fig. 1. The tutor interface with a composite of typical student errors (converting to eighths works for the first fraction but not the second; adding the given numerators and denominators to find the sum). The first row of fraction bars are given and the second row updates based on the student entries in the text boxes below. Entering a denominator produces dividing lines.

allow students to see if the original (1/4) and converted (2/8) fractions are equivalent, and whether their answer fraction is equivalent to the sum of the two given fractions (in this case the answer 2/10 is too small). The tutor does not give explicit feedback on the correctness of intermediate steps during problem solving.

In a think aloud study, participants are asked to perform a task while verbalizing their thoughts [1]. We conducted our think aloud sessions with paper-and-pencil problems followed by tutor problems to determine 1) whether the students correctly interpret the grounded feedback, 2) how students use the feedback, and 3) what intelligent novice behaviors students display.

1.2 The Fraction Addition Think Aloud

Five fifth graders from an all-girls school in Pittsburgh volunteered to participate in the think aloud (all of them had participated in a similar think-aloud with an earlier version of the tutor). According to their math teacher, the girls had learned about fractions but not fraction addition. Each student participated individually in a 20-25 minute think aloud with the experimenters. Students solved three categories of problems: same denominator, one denominator is a multiple of the other, and unrelated denominators. Students solved one problem from each category on paper and one new problem from each category with the tutor. In addition to the grounded feedback, the tutor included a 3-level succession of on-demand hints that first told students to find a common denominator, then gave a general, then problem-specific

suggestion for how. The hints did not give students the answer to the specific next step.

With grounded feedback alone, the five students correctly solved more problems with the tutor (12/14) than on paper (8/15). One student did not start the last tutor problem. Students' first attempts with the tutor reflect their problem solving without grounded feedback. Out of eight incorrect first attempts, students self-corrected and ultimately solved six problems (75%) with the grounded feedback alone. Students solved the remaining two tutor problems using on-demand hints (for example, to find a common denominator). After finishing the tutor problems, two students returned to their unrelated-denominator paper problems and corrected their earlier mistakes, suggesting that they learned from the tutor.

Students' comments show how they ground the tutor's feedback in their prior knowledge. For example, one student converted 1/4 to 1/8, but changed it to 2/8 after seeing the fraction bar. The student explained, "a) I looked at the picture and realized they weren't matched up and b) I realized that I'd doubled the bottom but not the top." The interface already displayed the given fraction 1/4, and the student saw the fraction she had entered, 1/8, was much smaller than 1/4. The difference between her expectation (the pictures would match) and the consequences of her action (they did not) alerted her to her error, which she then corrected. The student seemed to already understand how to convert fractions and the images reinforced why that procedure works.

This study suggests grounded feedback can effectively elicit intelligent novice behaviors for fraction addition. Students connected the grounded feedback to their prior knowledge, and used it to evaluate and correct their errors. Although this formative research does not conclude that grounded feedback is better than the alternatives, the results are encouraging, especially in conjunction with existing studies on tutors with grounded feedback.

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