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Providing feedback on computer-based algebra homework in middle-school classrooms

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ABSTRACT

Homework is transforming at a rapid rate with continuous advances in educational technology. Computer-based homework, in particular, is gaining popularity across a range of schools, with little empirical evidence on how to optimize student learning. The current aim was to test the effects of different types of feedback on computer-based homework. In the study, middle school students completed a computer-based pretest, homework assignment, and posttest containing challenging algebraic problems. On the homework assignment, students were assigned to different feedback conditions. In Experiment 1 ($N = 103$), students received no feedback or correct-answer feedback after each problem. In Experiment 2 ($N = 143$), students received (1) no feedback, (2) correct-answer feedback, (3) try-again feedback, or (4) explanation feedback after each problem. For students with low prior knowledge, feedback resulted in better posttest performance than no feedback. However, students with high prior knowledge learned just as much whether they received feedback or not. Results suggest the provision of basic feedback on computer-based homework can benefit novice students' mathematics learning.

1. Introduction

Modern advances in educational technology and increasing access to computers gives teachers a wide range of tools for assigning homework and assessing student progress. Intelligent tutor systems and computer-based homework are quickly gaining popularity and prevalence in classrooms across the world. One of the bedrocks of these systems is the availability of individualized, just-in-time feedback (Ma, Adesope, Nesbit, & Liu, 2014). Indeed, many researchers have attributed the effectiveness of computer tutors and computer-based homework, at least in part, to greater frequency and immediacy of feedback (e.g., Azevedo & Bernard, 1995; Martin, Klein, & Sullivan, 2007). The goal of the current research was to experimentally evaluate the effects of feedback on computer-based algebra homework for middle school students with varying prior knowledge.

In general, research supports the use of feedback as meta-analyses continue to show that, on average, feedback has positive effects on learning outcomes relative to no feedback (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Hattie & Timperley, 2007). However, there is considerable variability; feedback helps in some cases, but not others (see Hattie & Gan, 2011). A growing body of evidence suggests that some of the variability in feedback effects is due to students' prior knowledge (e.g., Fyfe & Rittle-Johnson, 2016a, 2016b; Fyfe, Rittle-Johnson, & DeCaro, 2012; Gielen, Peeters, Dochy, Onghena, & Struyven, 2010; Krause, Stark, & Mandl, 2009). Specifically, feedback often has strong, positive effects for students with lower prior knowledge, but neutral or even negative effects for students with higher prior knowledge. For example, in Fyfe et al. (2012), second- and third-grade students solved novel math problems with or without feedback in a one-on-one tutoring context. Students with low prior knowledge on a pretest benefited from feedback. In contrast, students with higher prior knowledge on a pretest learned *less* when immediate, corrective feedback was provided.

There are several potential reasons why feedback may result in lower learning than no feedback. For example, feedback may reduce mindful processing of the task if students become over-reliant on the feedback message (e.g., Schmidt & Bjork, 1992),

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feedback may draw attention to the self rather than the task and elicit affective reactions (e.g., I must not be smart) that interfere with learning (Kluger & DeNisi, 1996), or feedback may overload cognitive resources simply by providing additional information that needs integrated with the student's prior knowledge (Sweller, van Merrienboer, & Paas, 1998). Given these potential consequences, more work is needed to identify the conditions under which feedback is effective.

One learning context in which the provision of feedback is particularly relevant is computer-based homework. As access to computers increases, so too does the prevalence of systems that allow students to complete their homework online. These systems are gaining traction in K-12 schools as more schools in the U.S. are adopting one-to-one computing programs, which supply each student with his/her own laptop for classroom work (Bebell & Kay, 2010). The goal of the current study was to experimentally evaluate the effects of feedback using a particular system, ASSISTments.org (Heffernan & Heffernan, 2014). ASSISTments is a computer system that can provide scaffolds and feedback to assist student learning. The use of computer-based homework offers several advantages for understanding the effects of feedback.

First, computer-based homework provides an ecologically valid context in which to evaluate the role of feedback on student learning. Many prior studies that have experimentally evaluated the effect of feedback have been conducted in laboratory contexts in the presence of a researcher (e.g., Fyfe & Rittle-Johnson, 2016a, 2016b; Krause et al., 2009). Computer-based homework provides a means to experimentally test the effects of feedback in an authentic learning setting on homework assignments given to students by their teachers.

Second, computer-based homework represents a learning setting that may reduce the potential negative effects of feedback (see Fyfe & Rittle-Johnson, 2016b). As mentioned above, one condition under which feedback may hinder learning is when it draws attention to the self and evokes evaluations of one's self or abilities (Kluger & DeNisi, 1996). Computer-generated feedback is often viewed as a less evaluative source of information than person-generated feedback (Karabenick & Knapp, 1988), and may help decrease attention on the self. Computer-based homework may also reduce cognitive overload by giving students control over when and how they process the feedback. For example, students can choose whether and how long to study the feedback message, and they can choose when they are ready to move on.

Third, computer-based homework represents a flexible system for evaluating different feedback types. Dempsey, Driscoll, and Swindell (1993) outlined a hierarchy of feedback types based on the information provided:

1. *No feedback*: provides no information about the student's response.
2. *Verification feedback*: informs the student if the response is correct or incorrect.
3. *Correct-answer feedback*: informs the student what the correct response is.
4. *Elaborated feedback*: provides some explanation for why a response is correct or incorrect or allows the student to review part of the instruction.
5. *Try-again feedback*: informs the student if the response is correct or incorrect and allows one or more additional attempts to try again.

One possibility is that providing feedback with more information will have positive effects for both low- and high-knowledge students. Indeed, one of the advantages of computer-based homework is the ability to provide second attempts, hints, and explanations to guide student learning. There is some consensus that effective feedback should go beyond verification and provide the correct answer (see Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Kluger & DeNisi, 1996 for meta-analyses). But, the benefits of providing additional information are less clear (Mory, 2004).

Finally, ASSISTments in particular provides a unique platform for conducting educational research that maintains rigorous experimental control. In addition to providing a learning a tool for students and teachers, ASSISTments supports researchers in creating randomized controlled experiments (Heffernan & Heffernan, 2014). It includes a building interface that allows researchers and teachers to write content and create assignments that vary on one or more dimensions (e.g., the presence versus absence of feedback). It then allows students within the same classroom to be randomly assigned to different assignments. This type of system is key for conducting experimental research in classroom settings.

The current study tested the effects of feedback for middle school students solving algebraic equations on computer-based homework via the ASSISTments system. In Experiment 1, students were assigned to receive correct-answer feedback or no feedback during their homework assignment. Experiment 2 included two additional feedback conditions: explanation feedback and try-again feedback. Based on previous research, feedback was predicted to interact with prior knowledge such that feedback would have a stronger, positive effect on learning and problem solving for students with low prior knowledge on the pretest.

2. General method

2.1. Participants

In each experiment, the participants were students from public middle school classrooms in the U.S. whose teachers were using the ASSISTments system as part of their regular classroom experience and volunteered to participate.

2.2. Materials

All materials were presented using ASSISTments.org. Problems were presented one at a time on the computer screen and students typed their response to each item. In each experiment, materials included a pretest, a homework assignment, and a posttest, all of which assessed students' abilities to solve algebraic equations. There were four different equation types: $ax + b = c$, $b + ax = c$, $a(x + b) = c$, and $a(x + b) + c = d$. Table 1 displays the items presented on the pretest and posttest. The homework assignment contained two worked examples at the beginning of the assignment to familiarize students with correct problem-solving solutions (see Fig. 1 for an example). The worked examples demonstrated a step-by-step solution to each problem and provided the correct answers. The remaining problems on the homework were equations for the students to solve on their own. The problems were similar to those presented on the pretest and the problem types were presented in a mixed sequence.

2.3. Design and procedure

The experiments had a pretest-homework-posttest design. Students completed the pretest on computers during class or at home. Within three school days, students completed the homework assignment on their own. For the homework assignment, students were randomly assigned to one of several feedback conditions (described below). Finally, students completed the posttest. All teachers assigned the posttest the same day students finished