Towards Fostering Strategic Choices in Using Diagrams in Early Algebra

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Abstract. An important goal of education is to prepare students to be self-regulated learners who can strategically utilize available external representations (e.g., diagrams) to navigate problem solving. However, students do not typically choose to use external representations during problem-solving. My prior work has shown that *diagrammatic self-explanation*, a scaffold embedded in an Intelligent Tutoring System, helps students learn and perform well in the domain of early algebra. My dissertation proposes to evaluate the effectiveness of providing a personalized visualization which shows students' own problem-solving performance on their use of diagrams in a subsequent problem-solving activity. The proposed work will contribute to the understanding of how learners' choices in using diagrams can be effectively supported through the use of personalized educational technology.

Keywords: Self-Regulation, Intelligent Tutoring Systems, Tape Diagrams

1 Introduction

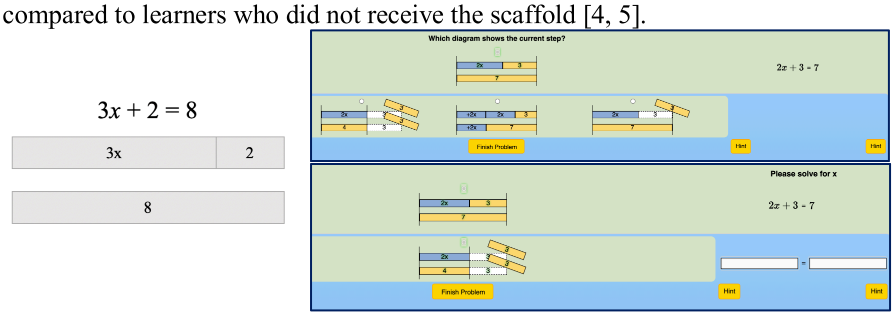
One of the important goals of education is to prepare students to be self-regulated learners who can strategically utilize external representations (e.g., diagrams) to navigate complex problem solving [1]. Despite the importance of acquiring the skill of choosing to use external representations, there are many open questions regarding how learners can be supported to do so [2, 3]. My work aims to address some of these open questions in the domain of early algebra. Specifically, my work investigates how personalized educational technology can be leveraged to help students become self-regulated learners who can strategically choose to use diagrams when solving algebra problems. Prior studies on diagrams have rarely focused on assessing whether learners choose to use diagrams and how such a choice influences their performance and learning [2]. Given the importance of acquiring such a skill, more research is needed to understand what instructional strategies can facilitate learners' choices in using diagrams [2, 3].

My past work has shown that when learners engaged in *diagrammatic self-explanation* (i.e., learners *explain* their problem-solving steps by selecting an appropriate diagram from among multiple choices) while solving problems in an Intelligent Tutoring System (ITS), they performed faster, used hints less frequently, and learned formal algebraic problem-solving strategies [4, 5]. My proposed work will examine and assess the impact of engaging with personalized visualization which show learners' own performance with and without diagrams. Specifically, the proposed research asks: *Will engaging with personalized analytics that shows learners' own problem-solving performance with/without diagrams help them strategically choose to use diagrams, perform well, and learn well?*

2 Completed Work

In a mixed-method study, I explored how a specific type of diagram, called "tape diagrams" (Figure 1, panel a) [6], can be designed to promote student learning of concepts, procedural skills, and performance during a learning activity in the domain of middle-school algebra.

After several design iterations with math teachers, I developed *anticipatory diagrammatic self-explanation*, a scaffolded approach to supporting student learning and problem solving with diagrams, embedded in an Intelligent Tutoring System (ITS) (Figure 1, panel b) [4, 5]. Anticipatory diagrammatic self-explanation provided multiple tape diagrams for each equation-solving step *before* learners worked on the step with math symbols in order to encourage strategic inference generation regarding what step to take next. Classroom studies have shown that this approach supports both learning and performance in algebra; learners given the diagrammatic self-explanation scaffold learned formal algebraic strategies, solved problems faster, and requested fewer hints, compared to learners who did not receive the scaffold [4, 5].



(a) (b)

Fig. 1. (a) An example of tape diagrams. Tape diagrams depict quantitative relationship in an equation and are used widely in practice in many countries. The tapes altogether show the equation, $3x + 2 = 8$. (b) Our anticipatory diagrammatic self-explanation in an equation-solving ITS. Learners engage in an anticipative diagram selection task before solving the step with symbols.

3 Proposed Work

Although the completed work shows that students learn and perform well when they were *required* to use diagrams for every problem-solving step, an important yet under-explored issue is how to help students *learn to use* diagrams [2]. It is critical that learners acquire the skill of choosing to use diagrams to guide their problem solving, rather than processing diagrams that are given for all problems and steps [1, 2]. To support learning of such a self-regulated diagram use, learners need to understand the utility of diagrams [2]. For this purpose, personalized educational technology could potentially be effective as it has been shown to promote behavior changes [7]. I propose to design a personalized visualization that shows information about each learner's problem-solving performance on equations *with* and *without* diagrams. The proposed work involves an experimental study testing the effect of engaging with the personalized analytics on learners' diagram use in a subsequent problem-solving activity where the use of diagrams is optional. At the Graduate Symposium, I will seek feedback on my experimental study plan and measures for evaluating the effectiveness of the proposed work on learners' use of diagrams.

My dissertation will contribute to the literature on diagrams by introducing how to promote strategic choices in using diagrams and how it might influence students' problem-solving performance and learning. In particular, the dissertation will investigate whether and how personalized educational technology can help learners understand the utility of using diagrams in problem solving.

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