article:2314

Optimizing Worked-Example Instruction of Electrical Engineering: The Role of Fading and Feedback during Problem-Solving Practice

Objectives

The goal of this study was to examine the role of different problem-solving practice methods for computer-based electrical engineering instruction. First, we tested the effects of *fading*: asking students to gradually solve an increasing number of solution steps after being presented with a full worked-out problem example. To this end, we asked the participants in our study to practice with a *backward fading* (BF) method, which consisted of completing the last solution step of the first practice problem, then the last two solution steps of the second practice problem, and finally all steps of the third practice problem; a *forward fading* (FF) method, which consisted of completing the first solution step of the first practice problem, then the first two solution steps of the second practice problem, and finally all steps of the third practice problem; or with no-fading, (NF) where students need to solve all steps of the practice problems. Based on the findings of fading studies in the domains of mathematics and physics, we expected that the fading groups would outperform the no-fading group on a near-transfer test. In addition, we tested the effects of three different feedback forms: *step-by-step feedback* (S) for each practice problem solution step, *total feedback* (T) after completion of each practice problem, and *meta-level feedback* (M), which consists of asking students who do not provide a correct response for one of the problem steps to compare their solutions to those of a worked-out problem.

Method

The participants were 232 students who were enrolled in an Introduction to Engineering Design course. Students were randomly assigned to learn about parallel electrical circuit analysis in one of the following conditions: NF-S, NF-T, BF-S, FF-S, and BF-M. Comparisons were made among the groups on measures of near transfer, far transfer, and the perceived difficulty of the lesson. To examine the effects of fading we compared groups NF-S, BF-S, and FF-S. To examine the effects of step-by-step feedback, we compared groups NF-S and NF-T. Lastly, we compared groups BF-S and BF-M to examine whether meta-level feedback would promote the learning from BF methods. Students learned with the help of an instructional computer program that included the following sections: a conceptual overview of electrical circuit analysis; a pretest; a problem-solving practice session including a worked-out example and three practice problems; the near and far transfer tests and the perceived difficulty survey.

Results

Three findings are of interest to engineering education. First, students who practiced with NF and FF produced higher near-transfer scores those who practiced with BF. Second, students who received S feedback outperformed those who received T feedback on near transfer. Finally, adding meta-level feedback to the BF treatment increased both near- and far-transfer.

Conclusions

Consistent with prior research, both fading methods failed to promote far transfer. This suggests that the cognitive capacity that is presumably freed up by gradually incrementing the number of steps to-be-solved is not necessarily used by learners in a productive way. Additionally, the findings support the hypothesis suggested by chaining research that that the effectiveness of BF or FF methods depends on the level of difficulty of the materials: For low difficulty materials (such as the ones used in this study), FF and NF are more effective practice methods than BF. We believe that the delay in prompting students to engage in problem solving in BF may have limited their cognitive engagement during problem-solving practice. This interpretation is supported by the finding that adding meta-level feedback to the BF method promoted near and far transfer. Finally, S feedback promoted near transfer as compared to T feedback, supporting the idea that it is less taxing to allow learners to immediately verify the correctness of a solution attempt while the corresponding problem step is still in working memory. Although the difficulty ratings of S and T groups were not different, the self-report measure used in this study has not been found to reliably predict perceived difficulty from computer-based instruction in the past.

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: Back to 2009 Spring/Summer Issue Vol. 4, No. 3

: Back to List of Issues

: Back to Table of Contents