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The effect of the timing of instructional support in a computer-supported problem-solving program for students in secondary physics education

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Abstract

Many students experience difficulties in solving applied physics problems. Researchers claim that the development of strategic knowledge (analyze, explore, plan, implement, verify) is just as necessary for solving problems as the development of content knowledge. In order to improve these problem-solving skills, it might be profitable to know at what time during problem solving is the use of instructional support most effective: before, during or after problem solving.

In an experiment with fifth-year secondary school students, one experimental group ($n = 18$) received hints during and worked examples after problem solving, and another experimental group ($n = 18$) received worked examples only after problem solving. Both groups used versions of a computer program to solve a variety of problems. The control group ($n = 23$) used a textbook. There was a pre-test to estimate the measure of prior expertise of the students in solving physics problems. The results of a problem-solving post-test indicated that the version of the program providing hints during and examples after problem solving was the most effective, followed by the version which only supplied examples afterwards. There was no difference in effect for students with more than average prior knowledge or less prior knowledge.

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1. Introduction and research questions

In developing computerized instruction for problem solving, several design issues have to be addressed. The most important design issues relate to the type of knowledge to be developed in problem solving, the delivery of problem-solving instruction content, its timing, and student characteristics that may influence learning to solve problems (Jong, 1986; Mestre, 2002). This paper addresses the issue of timing of instruction.

1.1. Type of problems and knowledge involved

Learning to solve physics problems is an important goal of secondary education. Students, however, have great difficulty in solving problems in which physics knowledge about facts and rules of physics (declarative and procedural knowledge) has to be applied. Although they often possess this knowledge because it has recently been taught, they still cannot apply it to fresh problems dissimilar to the ones they have studied. For instance, when the formula 'velocity = distance/time' is taught, many students find it hard to apply this knowledge to a situation in which the runners start from opposite directions with different average speeds and the question is where they will meet. Students can use several strategies to solve such a problem (Bransford, Brown, & Cocking, 2000). Problems that ask for the application of knowledge are difficult for students because they may not recognize the knowledge to be used or they may not be able to combine different pieces of their knowledge into a solution plan. Jong (1986) calls the ability to match a new problem situation with existing knowledge 'strategic knowledge'. He defines strategic knowledge as the ability to use solution methods in relatively new situations for the students. Strategic knowledge tells students how to analyze a problem situation, find relevant content knowledge, make a plan and solve a problem. Other researchers (e.g. Mestre, 2002) also stress the importance of strategic knowledge in learning to apply physics knowledge to new problems.

1.2. The timing of instruction

An important question in designing instruction to develop problem-solving abilities is: 'At what time is support most effective for the development of strategic knowledge in solving problems?' Supporting students in solving applied problems can be accomplished by giving instructions or examples before the problem-solving process begins, during the problem-solving process or after the student's final answer.

Supporting students in advance can be done with worked-out examples in which students are clearly instructed about the way to solve types of problems *before* starting to work out these problems for themselves (Owen & Sweller, 1985; Renkl, 2002). In using worked-out examples, a student learns to solve one type of problem at a time, step-by-step with less reliance on help, thus learning to solve problems independently (the decrease of