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# Should We Use Examples in Intelligent Tutors?

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**Abstract:** Although examples are frequently used by human tutors, they are not common in Intelligent Tutoring Systems (ITS). Previous research studies over the last three decades compared learning from examples to unsupported problem solving. Only recently there have been studies comparing learning from examples to problem solving in ITSs. This paper reviews those studies. We discuss unsolved issues such as when and how examples should be provided in intelligent tutoring systems, and some options to improve learning from examples.

**Keywords:** Learning from examples, problem solving, self-explanation

## Introduction

In this paper, we review related work on using examples compared to both unsupported and tutored problem solving. We also review studies comparing different combination of problems with examples, and come up with our idea on how we can reinforce examples and problems with an appropriate Self-Explanation (SE) prompts. An SE prompt is a question that encourages the student to explain the knowledge encapsulated in a problem or an example. We look at previous studies from two different angles: studies comparing examples with unsupported problem solving, and studies comparing examples with supported problem solving in ITSs. In unsupported problem solving, learners do not get any feedback, while in tutored problem solving students receive feedback on their solution steps and final answers. First we start with those studies comparing learning from examples with unsupported problem solving.

There has been no agreement on how much assistance should be provided to students. However, it has been shown that maximum assistance (e.g. examples) is more efficient than minimal assistance (e.g. unsupported problem-solving) for novices [1]. Recently researchers focused on different example-based learning strategies. van Gog, Kester, & Paas [2], investigate the difference between worked examples only (WE), worked examples/problem pairs (WE-PS), problem/worked examples pairs (PS-WE) and problem solving only (PS) on novices. They show that the participants in WE and WE-PS had a higher performance in the post-test than PS and PS-WE. van Gog [3] conducted a study using Modelling Examples (ME) (i.e. the problem solution is demonstrated to learners by a model , who can be an expert or not) in two conditions PS-ME-PS-ME and ME-PS-ME-PS in the Frog Leap game. Result showed no difference in learning performance since the students learnt most after studying the second worked example.

Most of the prior studies showed the example effect in well-defined problems. Well-defined tasks are those for which there is an algorithm for solving problems [4] (e.g. mathematics, physics). Nevertheless , it has been shown that the worked-examples effect can be obtained in ill-defined problems like well-defined problems [5].

Kalyuga [6] show that instructional support which is enhanced with SE and self-visualization technique, may improve students' abilities to transfer their skill and knowledge. Hilbert & Renkl [7] investigated the best structure of examples to teach concept mapping. They found that students learn more when the examples are presented with SE than without it.

Now we review those studies compared worked-examples with ITSs. Schwonke et al. [8] compared a cognitive tutor (Geometry Tutor) with a new version which was enriched with faded worked examples. They conducted two experiments. In the first experiment, they found an improvement in learning time from using examples. In the second experiment, they used the think-aloud protocol in order to study relevant cognitive processes. According to the result, the efficiency advantage of worked examples was replicated.

McLaren and colleagues [9] discuss their three studies on example-based strategy using the stoichiometry tutor. In all the studies, the problem and example conditions were compared while students were given SE prompts after examples. The result showed no significant difference learning gains. McLaren and Isotani [10] show that the students benefit most by learning with worked examples only, at least with respect to learning time They found no significant difference in learning gain between the students who worked with examples only, problems only, or a mixture of examples and problems. However, the examples were followed by SE prompts while the problems were not. Salden and colleagues [11] compared fixed worked-out examples with adaptive ones. Fixed faded examples are the same for all students, but the adaptive faded examples are adapted with respect to the student's prior knowledge. The lab results indicate that adaptive examples led to a better learning gain compared to the other conditions. In contrast, the classroom results depict no significant difference in immediate post-test, but in the delayed post-test students who used adaptive examples learned more.

Most of the studies show that using worked examples in ITSs results in reduced learning time. Although there are some studies showing the higher learning gain or the faded examples, most studies have found no differences in the amount learnt. In addition, all the prior studies on using examples in ITSs were in Geometry, Chemistry and Algebra domains. All these tutors teach well-defined tasks. Therefore, there is a need for more research in order to explore the usage of examples in ill-defined tasks.

## How should we design examples for ITSs

This section covers the design of examples when used in conjunction with problem solving in ITSs. In the following subsections we discuss a number of issues when we use examples with tutored problem solving.

*When to give examples?* It has already been shown that novices benefit more from the example strategy than learners who have enough prior knowledge to start practicing using the problem-solving strategy [12]. Traditionally, systems with tutored problem-solving strategy have indirectly followed this idea, and students with a high expertise level can solve a problem without using any hint level while students with a low level of expertise have to transfer the problem to an example gradually, until they can solve the problem. Although the research contributions are not conclusive to decide whether to use the combination of examples and problems or not, it is important to know whether novices benefit more from instant solutions (i.e. examples), or gradually solved problems (tutored problem solving).

*How to design examples?* Mayer [13] proposed seven principles for designing multimedia messages. Modeling examples and worked examples emphasize differently on these principles; therefore, using each of these two types of examples has its own advantage and drawbacks. Perhaps an adaptive example (worked-example/modeling example) may

improve learning more than a fixed example, but when and how should ITSs switch between a worked example and a modeling example? We also can adapt examples based on their difficulty level. For instance, in a faded example, the solution steps can gradually be faded until an example (low difficulty) transforms to a problem (high difficulty). Prior studies like Schwonke and colleagues [8] show that students learn more effectively by using adaptive examples compared to tutored problem solving.

*How to scaffold examples?* Self-explanation, as an effective scaffolding strategy, is a potential option to scaffold examples, so a good future research question is to find an appropriate SE design to reinforce learning from examples. We think that SE prompts designed for problem solving are not appropriate for examples. Therefore, it is a good idea to categorise SE prompts into two new types named: example-adapted and problem-adapted prompts.

In conclusion, while many human tutors use different combinations of examples and problems, the previous studies that compared tutored problem solving with examples are not conclusive to replace this new teaching strategy with traditional problem-solving strategies in ITSs. Shareghi Najar & Mitrovic [14] suggest a new approach to use examples with tutored problems. In this model, for each example or problem, a corresponding SE prompt is provided that reinforces examples for procedural and problems for conceptual knowledge acquisition. Future research on using examples in ITSs will draw on three perspectives: when to give examples, how to design examples, and how to scaffold examples as the prior studies are not enough to show the best approach.

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