Effects of Erroneous Examples

Results of a Preliminary School Experiment [1]

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1. Introduction

Erroneous examples have rarely been investigated or used as a learning intervention in mathematics learning, either within a technology-enhanced learning (TEL) system or within a classroom. Here, 'erroneous examples' are (worked) solutions including one or more errors that the student is asked to detect and to correct.

Still, an intelligent system could use its potential to help students to work with errors productively. Therefore, a line of research for the learning environment ACTIVEMATH [3] is to develop content and technology that stimulates students to detect, reason about, and correct errors and help students in this process. The ultimate goal is to provide the erroneous example intervention adaptively.

This paper describes a preliminary classroom experiment, in which we investigated how students respond to erroneous examples and how a (singular) treatment with an erroneous example affect performance for students who are not confronted with erroneous examples in their mathematics lessons otherwise.

2. Classroom Experiment

The experiment had a pretest-treatment-posttest-delayedPosttest control group design. It was conducted in a classroom with 25 students of grade 7 in the German 'Gymnasium Elbingen', teacher Dieter Kriesell. The (percentage) concepts needed for the experiment had been taught several months ago. That is, we did not use erroneous examples in the first phase of acquiring a concept.

Main session The main session took place 7 days after the pre-test and had three phases.

1. an example was discussed and solved together with the teacher as usual in the classroom.
2. the class was randomly split into two groups, GE and GT. The control group GT had a problem to solve. GE-students received the same problem as an erroneous example and were asked to find the error and then correct it.

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3. all students participated in an immediate post-test.

Post-tests. The problems in immediate and delayed post-test were more difficult than the pre-test and similar to the problem/erroneous example provided in the main session of the experiment.

3. Results and Discussion

The results are summarized in the following table.

group	math grades	pre-test	immediate post-test	delayed post-test
GE	2,74	85,71%	68,37%	64,29%
GT	2,68	86,36%	41,56%	64,94%

Because the problems in the post-test were harder than in the pre-test, the average students' results post-test results were worse than their pre-test with a slight difference between males 52.86% and females 59.05%. A closer look into gender differences revealed a striking difference: the success of female students is rather independent of their group (60.00% vs. 57.14%) while GE male students (90.48%) performed considerably better than GT male students (36.73%). This difference could be an artifact of the distribution in groups or due to the small number of participants - in any way, the differences between male and female students needs further investigation. The delayed post-test did not show a significant difference between the GE and GT groups.

An additional observation is that students who are not trained in error detection have great difficulties to detect errors if the erroneous example does not match 1-1 with their own solution path/algorithm so that a direct comparison of steps does not work. That is, if the erroneous example exhibits another way to solve a problem and contains an error, it is unlikely that students will find the error without help.

The striking differences between the groups in the immediate post-test can be explained by different hypotheses, which we will explore further: the better results of the GE group could be due to the erroneous examples treatment which either (a) improved procedural knowledge or (b) drew the students' attention to more self-monitoring.

The delayed post-test does not seem to be influenced by the one erroneous example experience of the GE group. This is not surprising in case of a singular event of working with an erroneous example. In addiiton, this could be explained by the fact that the error in the erroneous example was quite an arbitrary one rather than one caused by a typical misconceptions or a typical buggy procedure. The results encourage us to repeat the experiment with more fundamental/typical errors.

We suspect that the pretest was too simple (as compared with the post-test problem) to differentiate so that the groups' mastery would be properly characterized and may have hidden mastery differences between the GE and GT groups. The additional consideration of mathematics grades, however, does not support this hypothesis because it rather indicates similar averages in both groups.

4. Related Work

We know only of little research in educational psychology [2,7] which targets learning with erroneous examples.As opposed to our goals, none of this research targeted an adaptive learning environment and adaptation of aspects of erroneous examples. Some pedagogic approaches exist for learning from errors in mathematics. Mostly, they are inspired by observations of innovative teaching and describe creative reactions of teachers to student errors in classroom [6,4] or individual tutoring [1]. The pedagogical work also investigates cognitive conflicts (e.g., Tall, Vinner, Watson, Rolka) as a means to weaken misconceptions and an interpretation of (systematic) errors as symptoms for misconceptions. Some of these approaches may be hard to implement in a computer environment.

The ITS-community used erroneous examples in few instances, e.g., the SWAP intervention in the LISTEN reading tutor and in the [5] Physics tutor. However, the investigations and usage of errors is somewhat different from our's in ACTIVEMATH. Also, debugging tasks in learning to program, e.g. LISP, take (own) errors as a source of learning. Less closely related is Mathan and Koedinger's work on the intelligent novice strategy with Excel-tasks.

Future Work. We are continuing with controlled experiments investigating the influence of user and situational variables on the effect of erroneous examples on performance, learning orientation, and motivation. The results will then be used to adapt the presentation of and student interactions with erroneous examples in ACTIVEMATH.

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