# Further results on gender and cognitive differences in help effectiveness

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**Abstract.** We explored the effectiveness of help for 350 students of different genders and cognitive developments, in an arithmetic intelligent tutoring system. We conclude that girls were more sensitive to the amounts of help fitting their needs than to the level of abstraction. On the other hand, boys were affected by the abstraction level, and ignored help more.

## Introduction

Past research suggests that what constitutes good teaching will not be the same for students of different genders [Carr, 97; Royer, 99] and cognitive developments [Suydam&Higgins,77; Fuson&Briars,90]. Cognitive development research suggests that concrete-operational students benefit from concrete teaching materials more than numeric-procedures to learn arithmetic. Meanwhile, the two genders seem to choose different approaches to problem solving, girls using more concrete and overt strategies, boys using covert approaches and retrieval from memory. These concepts can be extended to the kinds of help that the two genders need from educational software. However, questions arise when looking at the interactions of cognitive development and gender research. Research suggests that providing concrete help would benefit concrete students. Still, it is not clear how ineffective would be to provide low cognitive development girls abstract help with high amounts of structure and interactivity, or how beneficial concrete representations in the help would be for low cognitive development boys when provided in a structured interactive fashion. This paper extends previous results [Arroyo, 00] to provide a thorough analysis of the interaction between these two student characteristics, with a controlled evaluation involving 350 students. We explore how differently the genders and students of different cognitive developments reacted to the help in our mathematics intelligent tutor, AnimalWatch. Four different versions of AnimalWatch were evaluated. This paper analyzes help impact along different measures. It then analyzes patterns across them to decide what would be the best kind of help to provide girls, boys, concrete operational and formal operational students.

## 1. AnimalWatch

AnimalWatch is an Intelligent Tutoring System for whole number arithmetic and fractions, for 9-11 year olds [Beal, 02]. Four different versions of AnimalWatch have been developed, which vary in the kind of immediate help provided when students make mistakes. In a reduced help version, students get short help messages providing little feedback. In a concrete manipulatives version, students see interactive hints involving concrete manipulatives (base-10 blocks, bars for fractions). In a formal version, the help emphasizes numeric procedures, where interactive numeric hints are provided. In a concrete+formal version, students get both kinds of hints, one after the other. All versions of AnimalWatch eventually “bottom-out” the help by providing the correct answer.

## 2. Experiment design

Cognitive development was determined with a computer-based cognitive development pre-test, which tests for concrete and formal-operational thought [Arroyo, 01]. Students were classified into low and high cognitive development, the latter ones displaying abilities involving hypothetical thought and systematic thinking, while low cognitive development students did not show evidence of such abilities. In addition, pre and post-test assessment of self-confidence in math, liking and value of math was carried out. Data for this analysis comes from three studies carried in urban and suburban area schools in Massachusetts, with 350 children ranging from 9 to 11 years old. Students first took the Piaget and the math attitudes pre-test, used AnimalWatch, and then took the attitudes post-test. Because the studies involve different populations, study effects are accounted for in every analysis.

## 3. Results

ANOVA models were built for mastered topics, mistake reduction rate for different topics, and attitude change. Then, Bonferroni contrasts were created to test for specific hypotheses. We considered average mistake change for students receiving help at the 1st, …, 6th problem on different topics. The mistake reduction rate for multiplication problems was analyzed. We found that the formal version produced a significantly worse mistake reduction rate than all other help modes for low cognitive development boys. Formal help was also significantly worse for low than for high cognitive development boys. For high cognitive development boys, reduced-help was significantly worse than all other help modes. Low cognitive development girls were also harmed by reduced help. This effect was significantly worse for girls of low cognitive development than for boys of the same cognitive development. When analyzing the mistake reduction rate for subtraction problems we found a very similar pattern. There were no significant differences for mastered topics. However, the highest and lowest means reflect this same pattern.

Self-confidence and math liking increased significantly. The presence of formal help affected students' self-appreciation of math abilities. When formal help was present, low cognitive development students didn't improve their math self-confidence, while high cognitive development students increased it the most. At the same time, there was a significant *decrease* in mathematics value, partly because of a ceiling effect. We confirmed that girls' math value was significantly lower after using reduced-help. This effect is not seen on boys, where reduced-help actually produced an increase in math value for boys.

We analyzed the time students spent within each hint, and found gender differences. Girls stayed 25% more time than boys in hints, despite of the fact that girls mastered similar amount of topics than boys. Many students spent less than 4 seconds in-between responses, suggesting students were intentionally ignoring help. The largest difference is between high cognitive development girls and boys. Boys were more selective about the help they saw. We wondered if there were specific hints that each group of students ignored. The main difference was for low cognitive development boys, who spent significantly less time in formal than concrete hints.

## 4. Discussion

Table 1 shows significantly best and worst help types for the genders and cognitive development levels. Girls of low cognitive development worked well most interactive support (what harmed them most was reduced-help), and the presence of formal help was generally not a problem. We conclude that girls of low cognitive development benefited from structured interactive help. For boys of low cognitive development, formal interactive help was consistently the worst. We think these students may have been confused by formal help, and decided to ignore it. Concrete help was the most beneficial for this group.

**Table 1. Significantly best and worst help types for different measures**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **C, F, F+C** | **C, R, C+F** |
| High cog. Level | ? | ? |

**a. Best help-types for subtraction**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **R** | **F** |
| High cog. Level | ? | ? |

**b. Worst help-types for subtraction**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **C, F, F+C** | **C, R, C+F** |
| High cog. Level | ? | **F+C, F, C** |

**c.Best help-types for multiplication**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **R** | **F** |
| High cog. Level | ? | **R** |

**d. Worst help-types for multiplication**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | C, F+C | C |
| High cog. Level | F+C | F+C |

**e. Most amount of mastered topics**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | R | F |
| High cog. Level | C,F,R | R |

**f. Least amount of mastered topics**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **F+C, F, C** | ? |
| High cog. Level | **F+C, F, C** | ? |

**g. Best help-types for math value**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **R** | ? |
| High cog. Level | **R** | ? |

**h. Worst help-types for math value**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | ? | ? |
| High cog. Level | **F+C, F** | **F+C, F** |

**g. Best help-types for self-confidence**

| Gender | Girls | Boys |
|---|---|---|
| Low cog. Level | **F+C, F** | **F+C, F** |
| High cog. Level | ? | ? |

**h. Worst help-types for self-confidence**

There are not many significant differences among high cognitive development students. However, we find interesting that the major differences in time spent on hints is for high cognitive development girls and boys. Girls spend plenty of time within hints, while boys of high cognitive development spent less time, and ignored hints the most.

What does this imply for the design of gender and cognitive sensitive ITS? We conclude that girls tend to be more sensitive to the amounts of help than to the abstraction level. In addition, concrete-operational boys should be provided concrete representations within help and, in general, boys will ignore help if they don't feel comfortable with it.

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