Abstract Title Page

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Title: The effect of scaffolded causal identification in the transfer of experimental design skills

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Abstract Body

Limit 4 pages single spaced.

Background / Context:

Description of prior research and its intellectual context.

A central goal of instruction is to enable learners to transfer acquired knowledge to appropriate future situations. One factor that likely promotes far transfer is conceptual coherence (cf. Murphy & Medin, 1985). For elementary and middle-school school children in middle-high-SES schools, "explicit" instruction on the Control of Variables Strategy (CVS) that emphasizes understanding of the rationale behind CVS has proven to be effective at promoting transfer to different contexts, even after extended time delays (e.g., Strand-Cary & Klahr, 2008; Klahr & Nigam, 2004; Chen & Klahr, 1999). An understanding of this rationale may increase conceptual coherence by providing linkage between the procedural rules of CVS (i.e., by explaining why only the focal variable should be contrasted). However, when the same instruction was delivered to students in low-SES schools, near—but especially far—transfer rates were much lower (e.g., Klahr & Li, 2005). We hypothesized that the poorer performance on far transfer assessments was primarily due to students' failure to develop a generalized understanding of the rationale for controlling variables, resulting in weakly-integrated procedural knowledge.

Purpose / Objective / Research Question / Focus of Study:

Description of the focus of the research.

The purpose of the study was to see whether the addition of more focused questions in computerized instruction would improve far transfer performance of low-SES students. These additional questions prompted students to consider whether the causality of a variable could be determined from various experimental set-ups and thereby an understanding of the rationale for controlling other variables.

In addition, we compared learning and transfer outcomes of these two versions of computerized instruction to what we considered to be an instructionally good control lesson. The focus of this control lesson was also on the rationale for controlling variables. However, the overall percent of time devoted to considering the rationale for controlling variables was less in this control lesson than in the computerized instruction.

Setting:

Description of the research location.

Research was conducted at a local Pittsburgh science and technology magnet school serving students in grades six through nine. Students given the computerized instruction worked in the school's computer lab, and the curricular Control lesson primarily took place in students' regular science classroom. Each phase of the study occurred during students' regular science class period.

Research Design:

Description of the research design.

The overall design was quasi-experimental, where all students in one class were given the regular curriculum lesson, and all students in the other class were given the computerized instruction (delivered by the "TED" tutor, for "Training in Experimental Design").

In the class given the computerized TED instruction, students were randomly assigned to either the baseline or "added-questions" version of the computer tutor. TED instruction consisted primarily of evaluating presented experiments. The added-questions condition was identical to the baseline version, but included five additional questions throughout the instruction focusing on the causal logic of CVS.

Population / Participants / Subjects:
Description of the participants in the study: who, how many, key features, or characteristics.

Thirty-three students in two sixth-grade science classes participated and completed all parts of the intervention and assessments (19 completed the computerized TED instruction, and 14 completed the Control lesson, a teacher-delivered hand-on curricular lesson, from the textbook "Foundations of Physical Science" published by the Cambridge Physics Outlet and approved by the Pittsburgh Public School District). By administrative design, the classes given the computerized TED and Control instruction were similar in terms of such variables as gender composition (32% and 36% female, respectively) and ethnicity (58% African American, 37% Caucasian, and 5% Asian; 50% African American, 43% Caucasian, and 7% Asian, respectively). The majority of students (55%) were eligible for free or reduced-price lunch; thus, this was a primarily low-SES population.

Intervention / Program / Practice:
Description of the intervention, program, or practice, including details of administration and duration.
For Track 2, this may include the development and validation of a measurement instrument.

<u>All students</u>: The procedure is summarized in Table 1. On Day 1, all students were first introduced to the lesson topic by individually answering questions on the scientific method by referencing textbook content, and then discussed their answers as a whole-classroom activity. Following this, all students completed the computerized story pretest to assess initial understanding of experimental design.

<u>TED conditions instruction</u>: After completing the story pretest, students in both computerized TED conditions began the computerized instructional phase, in which they first completed a ramps pretest in which they designed four experiments, one for each of four ramps variables. Afterwards they were presented with three different experimental comparisons using ramps. For each they responded to whether or not it was a "good way" to find out about the focal variable, typed an explanation for their response, then responded to whether or not it would allow them to "know for sure" whether the focal variable caused a hypothetical different outcome, and typed an explanation for this response. Then students received feedback on their responses.

Afterwards, students in the added-questions condition were asked to select all of the variables that could have caused this outcome. They received feedback on their response. Students in the baseline condition heard a procedural explanation instead.

All students then heard a full explanation for why the given set-up was or was not a good experiment.

On Day 2 of instruction, the evaluation instructional sequence was repeated for the second and third virtually-presented set-ups. For both the second and third set-ups, which were confounded, after the above instructional sequence was completed, the experimental confounds were fixed. Then the whole sequence was repeated for the unconfounded designs. Thus, in total, students in the added-questions condition responded to five additional prompts.

Finally, students in both computerized conditions completed the ramps posttest to assess near-transfer performance.

Control condition instruction: After completing the story pretest, the teacher led the class in reviewing the next section of the CPO textbook that included activities such as identifying the variables in an experiment of carts rolling down ramps, discussing "controlled experiments" (and why controlling variables is necessary).

Day 2 began with a class discussion of the relationship between a ramp's height and speed at which something rolls down it. The class predicted a positive relationship between these variables. Then students were assigned to groups and to a ramps apparatus. Each ramp was preset to a different height (though other variables were not controlled). Students were asked to time how long the cart took to roll down the ramp. Once all groups were finished, the class reconvened and each group stated their result. The positive relationship they initially predicted was contradicted by their results. This led to a discussion of the problems with the experiment, which focused on experimental confounds. After the class came to an agreement about how to fix the experimental confounds, students worked in their original groups to re-run the experiment. The class again reconvened to discuss their results, which were consistent with their initial prediction.

All students: On Day 3, all students completed the computerized story posttest (identical to the story pretest) to assess their ability to apply what they learned to several other domains.

Three weeks later, all students completed a paper far-transfer follow-up posttest, which required application to three novel domains and included more variables per problem than in the story pre- and posttests. Two standardized test items were also included in the follow-up posttest. This test was administered in the regular science classroom rather than in the computer lab to remove any possible context effect advantages for students in the TED conditions.

Data Collection and Analysis:

Description of the methods for collecting and analyzing data.
For Track 2, this may include the use of existing datasets.

All students' interface responses (on the story pretest, the ramps pretest, during the instructional phases, ramps posttest, and story posttest) were saved as log files, imported into spreadsheets, and later analyzed. Students' responses on the follow-up posttest were scored by a human coder. The teacher-delivered Control lesson was video-taped.

For the TED conditions, each unconfounded experiment testing the given focal variable that students designed on the ramps pre- and posttests was scored as one point (for a maximum score of 4). For all students, story pre and posttests were scored by assigning one point for each unconfounded experiment students designed (out of 3 points), one point was given for each set-up students converted into an unconfounded design (out of 2 points), and one point was given for students correctly evaluating the unconfounded design as a good experiment, for a maximum score of 6. The delayed posttest was scored in a similar manner.

Analysis of covariance (covarying for pretest scores and a measure of deductive reasoning ability) was conducted to determine condition effects and to test for any interactions.

Findings / Results:

Description of the main findings with specific details.

TED conditions: As predicted, there was no difference between the baseline and added-questions versions of the computerized instruction on the measure of near-transfer performance, the ramps posttest. Mastery rates (i.e., designing at least 3 out of 4 unconfounded set-ups) were similarly high for the added-questions and baseline conditions (88% and 83%, respectively).

All conditions: However, there was a significant main effect of condition for the immediate story posttest. Pairwise comparisons indicate that students in the added-questions condition scored significantly higher than students in the Control condition, and marginally higher than students in the TED baseline condition. Furthermore, students in the baseline TED condition scored marginally higher than students in the Control condition.

On the delayed posttest, there was a condition by story pretest interaction (shown in Figure 1), where there was no relationship between story pretest and delayed posttest for students in the added-questions condition ($r(8) = +.22$, $p = .57$), but similar positive correlations for the baseline TED and Control conditions ($r(9) = +.67$, $p = .03$; $r(13) = +.79$, $p = .001$, respectively).

This benefit of the added-questions manipulation over the other conditions was greatest for the lowest-knowledge students, or those students who initially showed no understanding of any aspects of CVS (i.e., identifying the focal variable, contrasting the focal variable and controlling all others). However, students with the most initial knowledge may have benefited more from the TED baseline and Control conditions.

Conclusions:

Description of conclusions, recommendations, and limitations based on findings.

The results of this study are consistent with the hypothesis that understanding the rationale for controlling variables in CVS increases the likelihood that students will remember and apply it in novel domains. And the benefit of emphasizing this rationale seems to be greatest for students who initially had the least knowledge of CVS (i.e., did not demonstrate understanding of any aspects of CVS). Thus, the benefit of conceptual coherence may be greater when students do not have anchoring knowledge in long-term memory. However, students with more initial knowledge may benefit more from the baseline form of instruction. It is possible that the baseline and CPO control instruction requires more effort to understand, leading to better retention (cf. Slamenka & Graf, 1978).

However, due to the small sample size used in this study, these results need to be replicated. Planning of a replication study is underway (and should be completed in time for the conference).

Appendices

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Appendix A. References

References are to be in APA version 6 format.

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Appendix B. Tables and Figures

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Table 1. Summary of procedure.

	Computerized "TED" lesson (two versions: "Baseline" and "Added-questions")	"CPO" control lesson
Day 1	Introduction to lesson	
	Story pretest (computerized)	
	Part 1 of TED lesson (ramps intro, ramps pretest, remedial, evaluate Exp A)	Review textbook (identify carts variables, review of "controlled experiment," etc.)
Day 2	Part 2 of TED lesson (evaluate Exp's B & C, ramps posttest)	CPO ramps lesson (Identify confounds; discuss controlling variables; re-run experiment)
Day 3	Story posttest (computerized)	
3 weeks later	Delayed Story test (paper)	

Figure 1. Condition by Story pretest interaction.