

Toward Understanding When Tutoring Meta-cognition Enhances Domain Learning

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We have been pursuing various efforts to extend Cognitive Tutors to support different kinds of meta-cognitive and reflective thinking processes (e.g., Schoenfeld, 1983; White & Frederiksen, 1998). We have had various levels of success in demonstrating enhanced student learning from such meta-cognitive support relative to control conditions without such support. We will summarize work across studies targeting four kinds of meta-cognitive processes:

1. Self-explanation (Alevan & Koedinger, 2002)
2. Error self-correction (Mathan & Koedinger, 2005)
3. Avoiding “gaming” the instruction (Baker et al., 2007)
4. Help-seeking skills (Roll et al., 2007)

These studies illustrate features of “in vivo learning experiments”. All had tight control of the instructional manipulation as it is implemented in computer software within Cognitive Tutors. All involve collection and ‘micro-genetic’ analysis of fine-grained longitudinal data logs. All but #2 were performed in real classrooms. In addition to straightforward post-assessments, measures of robust learning were employed, including transfer (#1-4), long-term retention (#2), and preparation for future learning (#4),

The results are summarized as follows:

1. High school students receiving self-explanation support in a Geometry Cognitive Tutor had improved domain knowledge and transfer relative to control students who were able to do more practice problems without explanation in the same amount of instructional time. Log data provides further evidence that self-explanation support results in less shallow knowledge than problem-solving practice alone.
2. Temporary employment workers receiving tutoring on error self-correction in an Excel Spreadsheet Cognitive Tutor had improved domain knowledge, transfer, and long-term retention relative to controls using the same tutor, but with immediate error feedback. Learning curve analysis of log data shows that the effect was early and probably more relevant to students’ initial declarative knowledge construction than later refinement through practice.
3. Middle school students using a Data Analysis Cognitive Tutor enhanced with a gaming detector and two kinds of responses to detected gaming behavior, emotional and supplementary exercises, had a non-significant improvement on domain knowledge relative to controls using the same tutor without the gaming responses. Treatment students did show reduced overall gaming behavior relative to controls and the number of supplementary exercises received was correlated with learning.
4. High school students using a Geometry Cognitive Tutor enhanced with a help-seeking meta-level tutor did not demonstrate improvement in domain knowledge relative to controls, nor better help-seeking behavior on a transfer environment.

Treatment students became better at deciding when to use help on a declarative help-seeking assessment.

We speculate on what factors may differentiate between larger (#1-2) and smaller (#3-4) impacts on learning. One is whether the goal is primarily a) to support meta-cognitive processes during instruction in order to improve domain learning (#1-2) or b) to improve the meta-cognitive behaviors themselves (#3-4). Another is the extent to which the meta-cognitive process has connections with affect and motivation. It may be that the more connected the meta-cognitive process is to motivational issues (#3-4), the less chance that a scaffolding, monitoring, and tutoring approach will work. A source of suggestive evidence comes from the gaming studies (#3) where surveys of students indicate that a high correlation between negative affect toward mathematics and high levels of gaming.

References

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