Training in Experimental Design (TED): Developing Scalable and Adaptive Computer-based Science Instruction (Year 3)
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**Background**

The ability to design and evaluate experiments is critical in both science classes and in the real world. Although elementary and middle school students often do not have these skills, they can be taught with relatively brief direct instruction (e.g., Chen & Klahr, 1999; Klahr & Nigam, 2004). However, in schools with more challenging student populations, such instruction is less successful.

**Instructional goals:**
- Significantly increase elementary and middle school children’s understanding of scientific experimentation, including procedural (how to design good experiments) and conceptual (i.e., why experiments aren’t always informative) understandings. Students will develop general schemas for designing and interpreting experiments that will enable them to correctly answer achievement test questions on experimental design.
- Close the achievement gap between high- and low-SES students in this specific, yet broadly applicable, area of science education.

**Design goal:** Develop a computer-based intelligent tutor for Training in Experimental Design (TED) that will provide adaptive instruction based on individuals’ reading level, knowledge state and mastery in real-time across a variety of tasks and science content domains.

Participants: Fifth through seventh graders from five local Catholic schools serving a diverse student population in terms of SES, reading ability, and experience in experimental design.

**Institutional components of TED**
- Story pre/post-test (6 questions): evaluate and design experiments in three domains and explanations.
- ramps pre/post-test (4 questions): design experiments for four different ramps variables.
- Introduction: Purpose of lesson, term definitions, etc.
- Explicit CVS instruction, or EI (e.g., Klahr & Chen, 1999).
- Remedial CVS instruction (e.g., “step-by-step” walk-through of setting up and formatting experiments) for students showing difficulty understanding explicit instruction.
- CVS practice: Students apply their CVS knowledge to problems selected based on their assessment of student knowledge prior to instruction will allow automatic scoring and diagnoses for students showing difficulty understanding explicit instructions.

**A brief history of TED Development**

- **Starting point:** “explicit instruction” (EI): TED was based on evidence that EI that focuses on the logic of CVS has high levels of CVS mastery and transfer. Key components of the EI include presentation of “good” and “bad” experiments, probes for student explanations of why an experiment is good or bad, feedback from the tutor, modifications to “bad” experiments to make them “good”, final probe for student to explain why the experiment is “good”.
- **Teacher-delivered explicit instruction (V1):** Discussion-based EI was delivered in three fifth-grade classrooms (two low-SES and one middle-SES). The rates of CVS mastery gained were 80%, in the middle-SES classroom, but only 33% and 38% in the two low-SES classrooms.
- **Student-generated CVS practice in Year 2:** Students apply their CVS knowledge to problems selected based on their assessments of student knowledge prior to instruction will allow automatic scoring and diagnoses for students showing difficulty understanding explicit instructions.
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**Far transfer:** Initial explicit instruction was better for all but low-reading and low-pretest students.

**Future work (Year 4 goals):**
- Complete development of and test Wizard of Oz tutor (V3.3). The purpose of V3.3 is to test TED architecture and provide further information about the pedagogical actions to take given the student’s current knowledge state.
- It will be a full TED tutor with computerized pre- and post-tests, introduction, CVS instruction, remediation, and problem-solving. Artificial intelligence (AI) component will be present.
- Through a computer interface, a human tutor (acting as the AI component) will observe a student as he works through TED instruction. Based on the student’s current actions and knowledge state (visible to the tutor), the computer and human tutor will jointly determine instruction.
- Complete development of final intelligent TED tutor (V4), which will be identical in format to final Wizard of Oz versions, but will have the AI component in place of the human tutor (refer below for architecture).

**Acknowledgments**

This research was supported by the Department of Education, Institute of Education Sciences (R305F000015).