Draft for a Dissertation Proposal #1

Effective Hinting Strategy for Learning by Problem Solving

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1. Study on effective hinting

This study investigates an effective hinting strategy for students learning problem solving skills by solving problems. The target students are supposed to know problem solving skills, including domain principles and generic search strategies (i.e., forward/backward chaining and backup), but they need to practice applying those skills to actual problems so that their problem-solving skills reach a mastery level (i.e., always applied when needed).

What makes hints effective?

How effective are the "effective" hints?

How to provide (i.e., automate) the effective hints?

2. Definition of the effectiveness of hinting

"Effective" hints must …

- facilitate problem solving in *speed* and *accuracy*.
- facilitate learning in *the increase of test scores*, *the amount of time needed*, and *transfer*.

3. How to measure effectiveness?

Assign students to different ITS with different hinting strategies, and measure following things:

- Time spent to solve training problems
- Number of errors and irrelevant steps made on training problems
- Difference in pre- and post-tests
- Time to achieve a "mastery" level
- Scores on the transfer problem (what would it be?)

4. Hypothesis: An effective hinting strategy

Based on an experiment conducted in 1999 with Japanese middle-school students (referred to as *the 1999 experiment*, hereafter), we hypothesized an effective hinting strategy in the following three issues: a role of hinting (to provide a clue to complete a problem-solving step), selection of the target step, and a sequencing of hints (to recover a failure of previous hinting, and to provide spontaneous hints).

4.1. Hinting on a proof step

The 1999 experiment shows that the human tutor almost always provides a hint targeted on a single *step* (vs., a hint on a general problem-solving strategy, which is not related to any solution step). We hypothesize that providing hints on solution steps is enough to help students solve problems and learn problem solving skills.

There are several sub-issues to be concerned:

Goal explication: a hint must explicate goal structure

> Theory of reification of problem structure says that explicating goal structure facilitates learning (e.g., Catrambone, 1996). This can be tested by controlling the amount of explanation in hints.

Tutor's self-explanation: implicit steps must be explicated

> There are many studies that show students' self-explanation facilitates learning. VanLehn et al found that only less than 50% of the rules are mentioned in examples, and other rules can be recognized by self-explanation (VanLehn, Jones, & Chi, 1992). What if the tutor explicates all the rules through self-explanation? This can be tested by controlling density of a help message for exhibition-type hint.

Amount of information: question vs. directive

> Many tutors apparently believe that providing too much information spoils learning. But, is it true? This can be tested by changing the *form* of hints (e.g., from pointing to exhibition).

4.2. Selection of the target step

This is an issue peculiar to the next-step hint. The human tutor apparently selects a step to work on next when students requested help at impasse.

Need more analysis to see the pattern of step-selection

4.3. Sequencing of hints

What if a hint failed? Some tutors (e.g., model tracing tutor) increase a degree of concreteness that would eventually end up with a bottom-out hint. Human tutor, on the other hand, tends to change a *focus* of hint by traversing through a solution tree.

To see a pattern of hinting obeyed by the human tutor, 10 next-step hints were analyzed by lining the hints in individual hint sequences up in a row. As shown in Table 1, 6 out of 10 hint sequences consist of only one hint. Although the hint sequence 207-P2-01 has two hints, it is counted as a single hinted hint-sequence, because the first hint `PP-E(A)` is just to repeat what the student had already asserted and the focus of that hint (i.e., A) is not directly related to the main focus of the hint (i.e., Y→X).

Table 1: Sequence of next-step hints

205-P2-04	AW-P(Y->X)	PP-R(X')	AC-W((X'->)X)	PP-R(X)	PP-R(A)	AC-R((A,X->)B)
208-P2-03	AW-P(Y->X)	PP-R(X')	PP-R(Y)	PP-R(Z)		
207-P1-01	AW-P(DE->B)	AW-P(DE->B)				
209-P4-03	AC-W((F->)D)	PP-R(B)				
207-P2-01	PP-E(A)	AW-P(Y->X)				
202-P1-01	AW-P(DE->B)					
202-P2-02	AW-P(Y->X)					
203-P1-02	AW-P(DE->B)					
208-P1-04	PP-P(E)					
208-P2-02	PP-E(M)					

Appendix shows a proof tree for problem P2; you may trace the tutor's hinting for 205-P2-04 and 208-P2-03.

Did a hint sequence go from general to specific? – It's not such a simple matter.

First of all, a hint sequence in our analysis corresponds to a sequence of hints *spontaneously* provided by the tutor. Namely, when a student asked a hint on next-step, the tutor provided a series of hints that did

not cease even when the tutor heard an expected response from the tutee. In other words, the hints might be put in a row not only due to a failure of the previous hint, but also based on a plan of hinting on *multiple steps*.

> I do not think that model tracing tutor provides a sequence of next-step hints for multiple steps spontaneously. On the other hand, human tutor may have a plan for hints over several consecutive steps, and provide a sequence of hints spontaneously.

What happened when a hint failed? – The hint is considered to be failed either when the student's response is wrong, he/she made a long pause, or he/she requested a further help.

When a hint failed, the tutor took one of the following strategies:

> To increase directness by change the focus of hint from whole to specific (i.e., either premise or conclusion). (205-P2-04 x2, 208-P2-03)
>
> To change the target of hint by proceeding a step *backward*. (208-P2-03 x2)
>
> To repeat the same hint (in a case that the student seemed to misinterpret the hint). (207-P1-01)

What happened when a hint succeeded in a planed hint sequence?

When a hint succeeded, the tutor always preceded a step *forward* to spontaneously provide a further hint. (205-P2-04 x2, 209-P4-03)

5. AdvGeo ITS Experiment

To test the hypothesis on effective hinting, I would build an ITS that can change hinting strategy and see how that affect students' performance in problem solving and learning.

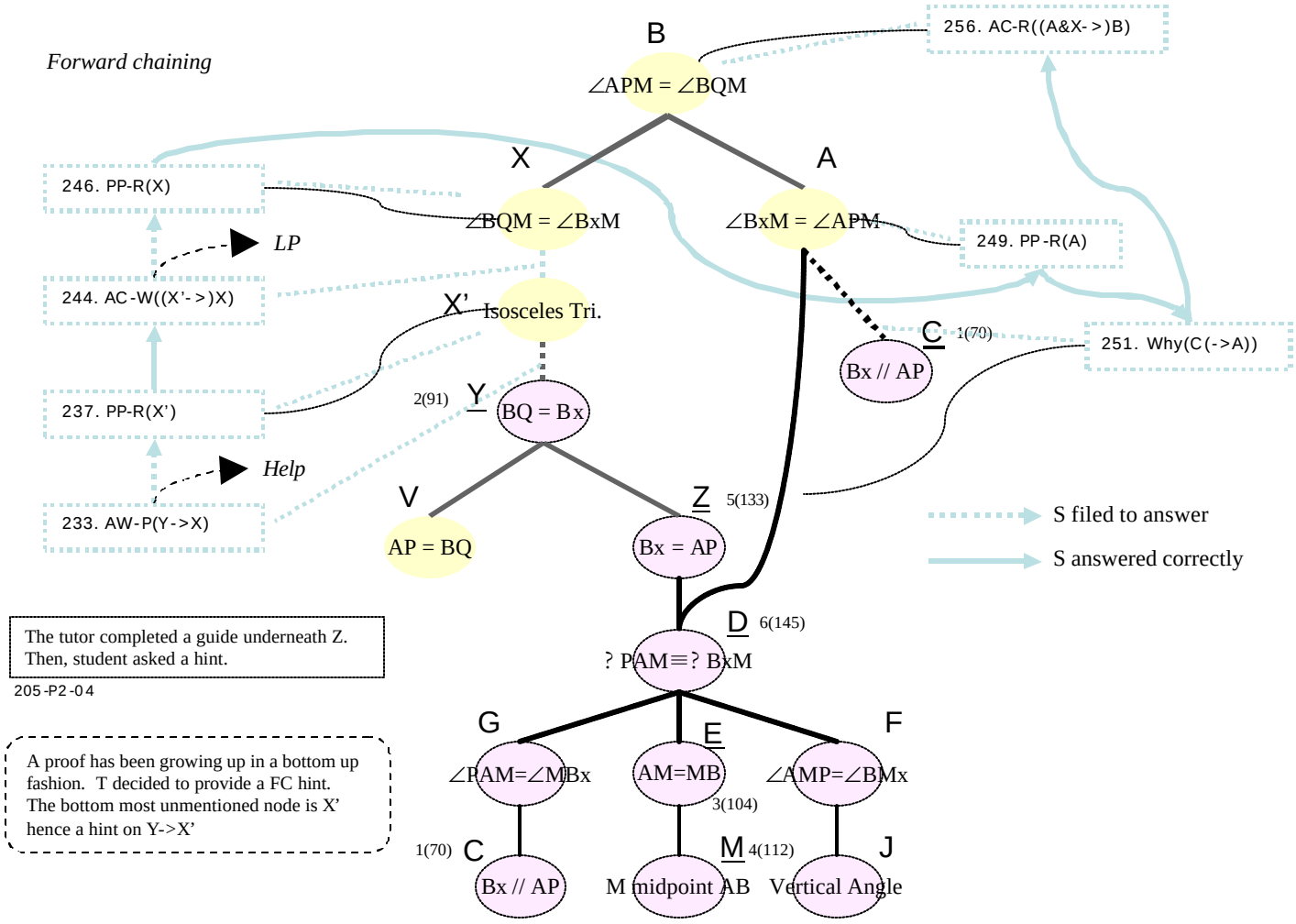
Learning environment

Evaluation

6. Milestone

Appendix:

Growth of a proof tree by #205 on P2 (No.3)



Reference:

Catrambone, R. (1996). Generalizing solution procedures learned from examples. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(4), 1020-1031.

VanLehn, K., Jones, R. M., & Chi, M. T. (1992). A model of the self-explanation effect. *Journal of the Learning Sciences, 2*(1), 1-59.