Problem Solving Coaches in Physics Tutoring
Part 1: Background and Model

Andrew Mason, Qing Xu, Leon Hsu, Kenneth Heller

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http://groups.physics.umn.edu/phyled/index.html
Background Considerations

- Problem solving is considered a highly desirable skill by educators (Carney 2006) and employers (National Academies Press 2007, Martinez 1998, Jonassen 2007) alike.

- Specific interest in introductory physics course to teach problem solving (Foster, Heller and Heller 1998)
  - Survey of faculty teaching calc-based introductory physics - engineering, science, computer science, etc.
"Raising the Bar: Employers' Views on College Learning in the Wake of the Economic Downturn" (January, 2010) –

- **Hart Research Associates** – survey of 302 employers, 2009
- percentage of employers who wanted colleges to “place more emphasis” on the following:
  - *Intellectual and practical skills*
    - The ability to communicate effectively, orally and in writing (89%)
    - Critical thinking and analytical reasoning skills (81%)
    - The ability to analyze and solve complex problems (75%)
  - Teamwork skills and the ability to collaborate with others in diverse group settings (71%)
  - The ability to innovate and be creative (70%)
  - The ability to locate, organize, and evaluate information from multiple sources (68%)
  - The ability to work with numbers and understand statistics (63%)
<table>
<thead>
<tr>
<th>Goal</th>
<th>Weighted Average</th>
<th>Unweighted Average</th>
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<tbody>
<tr>
<td>Know the basic principles behind all physics (e.g. forces, conservation of energy, ...)</td>
<td>4.5 ± 0.1</td>
<td>4.7 ± 0.1</td>
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<tr>
<td>Solve problems using general qualitative logical reasoning within the context of physics</td>
<td>4.5 ± 0.3</td>
<td>4.7 ± 0.2</td>
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<tr>
<td>Solve problems using general quantitative problem solving skills within the context of physics</td>
<td>4.3 ± 0.3</td>
<td>4.6 ± 0.2</td>
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<tr>
<td>Apply the physics topics covered to new situations not explicitly taught by the course.</td>
<td>4.2 ± 0.3</td>
<td>4.5 ± 0.2</td>
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<tr>
<td>Use with confidence the physics topics covered.</td>
<td>4.2 ± 0.3</td>
<td>4.1 ± 0.2</td>
</tr>
<tr>
<td>Know the range of applicability of the principles of physics (e.g. conservation of energy applied to fluid flow, heat transfer, plasmas, ...)</td>
<td>3.9 ± 0.4</td>
<td>4.3 ± 0.3</td>
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Foster, Heller and Heller 1998
Experts vs. Novices

- Experts look for the basic principles underlying the problem, while novices tend to focus on the surface features of the problem (Chi et al, 1981)

- Experts tend to do a qualitative description about the problem features and expectations before writing down quantitative relationships, while novices tend to plug in pieces of information and write miscellaneous equations (Chi et al., 1981; Larkin, 1979; Larkin, 1982; Larkin et al., 1980; Larkin & Reif, 1979, Reif & Heller, 1982).

- It is possible to improve students’ problem-solving skills significantly through targeted efforts
Cognitive Apprenticeship - Basis

- A model of instruction that is accessible within the framework of the typical American classroom.
- A model that goes back to apprenticeship but incorporates elements of schooling
  - Based on traditional apprenticeship
  - Difference between visible training (e.g. how to cut someone’s hair) and invisible training (e.g. problem-solving)
Cognitive Apprenticeship elements

- **Modeling**—Minnesota framework/framework in computer coaches
- **Coaching**—Discussion & lab section/Coaching provided by computer
- **Fading**—Withdraw of help from the instructor/withdraw help from computer

- **Scaffolding**—Support the instructor gives the students/support from the computer (could be hint, could be feedback)

Collins, Brown, and Newman, 1989
Farnham-Diggory, 1990
Motivation & Background

- “Competent Problem Solver” and the Minnesota problem solving framework (Heller and Heller, 1995)

The **modeling** framework is based on the heuristics and strategies that expert problem solvers use to attack problems (e.g. Polya 1945).

It externalizes the steps experts take to plan, execute, and evaluate a solution.

**FIGURE 1.** The Minnesota problem-solving framework.
Motivation & Background

- After such a process is modeled, students practice using the framework to solve problems, getting ‘coaching’ from an instructor or peers.
- However, individual coaching is limited and not necessarily always available for students to practice solving problems while receiving feedback.

So that’s why we design computer coaches.
Considerations in Designing Coaching

• Reciprocal teaching (Palincsar and Brown 1984)
  • Initially reading comprehension exercise but works for many subjects
  • “Best way to learn is to teach”

• Context-rich problems (Heller and Hollabaugh 1992)
  • avoid “surface feature” focus, force students to make decisions
  • In cognitive apprenticeship, the challenge is to situate the abstract tasks of the school curriculum in contexts that make sense to students
  • Students need to be able to transfer their knowledge learned from one problem to another
Computer Tutor Systems (aka Intelligent Tutoring Systems) - Examples

- Earlier work with physics problems
  - PLATO (Sherwood 1971, Smith and Sherwood 1976) – command prompt system for specific topics in physics
  - ALBERT (Oberem 1987, 1994) – specific topics in physics (1-d kinematics), expanded to free-body diagrams and other areas outside of physics
  - HAT (Dufresne et al. 1992) – guided students through a conceptual expert-like problem solving strategy that seemed to aid categorization of problems (also see Chi et al. 1981)

- More recent work
  - Andes (VanLehn et al. 2005) – intensive feedback and guide through problems while allowing the student to work independently as much as possible
  - Web-based tutoring, Socratic method:
    - Tycho (Stelzer and Gladding 2001) – step-by-step heuristics
    - Cybertutor (Pritchard and Morote 2002) – emphasis on fair grading mechanism
PALs (Personal Assistants for Learning)

- Reif and Scott (1999), Scott (2001)
- Employed a cognitive analysis of the thought processes required and were based on the cognitive apprenticeship approach
- Computers and students alternately coach each other (Palincsar and Brown 1984)
- PALs specifically designed to teach the application of Newton’s laws
Our tutor
(Hsu and Heller 2009)

• Based on the Competent Problem Solving framework used at the University of Minnesota (Heller and Heller 1995)

• Draws upon cognitive apprenticeship (Collins et al. 1989)

• Uses context-rich problems (Heller and Hollabaugh 1992)

• System of coaching: 3 types of tutors based on ideas used by Reif and Scott (1999, 2001)
Coming up in Part 2

• Description of the 3 types of tutors
  – Computer coaches student
  – Student coaches computer
  – Independent solution

• Proposal of a study
  – Will students benefit from the availability of tutors based on specific approaches (e.g. dynamics)?
  – Using a designed performance rubric (Docktor 2009) to determine effect on student performance
References

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System diagram for the car

Situation (Side view)

Known: m, R, θ

All forces on system
- Long-range forces
  - Interacting objects?
  - Forces on system
- Contact forces
  - Touching objects? Label contacts

Components (Directions?) (Vectors?) (Draw)

Specify the force on the car by the road.

> Direction (Click on an arrowhead or other choice.)
- Into screen
- Out of screen
- Horizontal or vertical
- Parallel or perpendicular to road
- None (Vector = 0)

> Magnitude (Click on choice.)
- mg
- T
- N

Think again. (Look at the hint.)