DeepTutor

Promoting Deep Learning of Science

Principal Investigator: Vasile Rus, PhD
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The University of Memphis
Sponsor: Institute for Education Sciences
DeepTutor

- Ongoing: started September 2010
- IES funded
- Dialogue-based Intelligent Tutoring Systems
- Current Target Domain: Conceptual Physics
- Web-based, accessible 24/7 from anywhere
  - Works from any browser with Flash support including Android-based tablets
  - HTML5 interface and iPad access available soon
Student Testimonials

• First trials with high-school students this Spring
  – About 90 students so far (30 this very morning)
• “I absolutely love DeepTutor”
DeepTutor Team

TEACHERS:
Evie Cornell - Bartlett High School
Hanley Hasseltine - Briarcrest Christian School

Graduate Students: Brinkley Matthews, Aman Patel
DeepTutor: LP-based ITS

• The first intelligent tutoring system based on Learning Progressions (LPs)
• LPs have been proposed by the science education research community as a way forward in science education
• LPs play a central role in the way we handle the following core tasks in DeepTutor
  • modeling the target domain
  • tracking students’ knowledge states
  • selection of instructional tasks
  • and the feedback mechanism.
LPs

- Could be used to **align curriculum, assessment, and instruction**
DeepTutor’s Main Dogma

2-D Learning Progression

Levels of Understanding

Pre-Test (Initial Assessment)

Pre-Test
Problem 1: Answers A, B, C, D
Problem 2: Answers A, B, C, D
Problem 3: Answers A, B, C, D

Student Model

Student Model Update

Instructional Tasks (Formative/Embedded Assessment)

Problem 1: Answers A, B, C, D
Problem 2: Answers A, B, C, D
Problem 3: Answers A, B, C, D
DeepTutor

• Promoting deep learning of complex science topics through quality instruction and quality interaction

• Quality instruction based on advanced domain and student models (using Learning Progressions) and tutorial strategies

• Quality interaction through advanced dialogue and language processing methods and multimedia elements
DeepTutor: Quality Instruction and Interaction

• highly effective, highly-adaptive intelligent tutoring system through
  – powerful domain and student modeling techniques based on Learning Progressions
  – accurate assessment
  – advanced instructional and tutorial strategies
  – advanced dialogue and language processing methods and multimedia elements
Learning Progressions (LPs)

- *Learning Progressions describe students' natural paths to mastery*
- Traditional LPs are vertical, single-strand structures
  - We moved to a 2-D, multi-strand LP structure
- Each level in the LP represents a model, i.e. a set of coherent ideas that students use to reason about the target domain
LPs’ Central Role
<table>
<thead>
<tr>
<th>Alternative Conceptions</th>
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<tbody>
<tr>
<td>a = dv/dt and may vary with time</td>
<td>The student understands that all forces arise out of an interaction between two objects and that these forces are equal in magnitude and opposite in direction.</td>
<td>The student identifies equal force pairs, but indicates that both forces act on the same object. (For the example of a book at rest on a table, the gravitational force down on the book and the normal force up by the table on the book are identified as an action-reaction pair.)</td>
<td>A net force applied may change both an object's speed and direction of motion depending on the direction of motion and the direction of the net force.</td>
<td>The student thinks that all unbalanced forces on an object will either cause the object to speed up or slow down.</td>
<td>The student thinks that only forces exactly in the direction of motion (or opposite) can speed up or slow down an object. All other forces just change the direction of motion.</td>
</tr>
<tr>
<td>a as speeding up or slowing down or changes in direction</td>
<td>Newton's second law</td>
<td>The student uses the effects of a force as an indication of the relative magnitudes of the forces in an interaction.</td>
<td>The student indicates that the forces in a force pair do not have equal magnitude because the objects are dissimilar in some property (e.g., bigger, stronger, faster).</td>
<td>Separating different components of the motion, and there’s always nonzero acceleration in one direction and zero acceleration in the other.</td>
<td>For an object moving in a curved path, the student thinks that once the sideways force is removed, the object will continue to move along a path that is curved.</td>
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<tr>
<td>a as speeding up or slowing down, direction not a factor</td>
<td>Student understands that an object is stationary either because there are no forces acting on it or because there is no net force acting on it.</td>
<td>Student believes that motion implies a force in the direction of motion and that non-motion implies no force. Conversely, student believes that force implies motion in the direction of the force.</td>
<td>For objects on frictionless surfaces, regardless of mass, the same force applied for the same amount of time produces the same motion.</td>
<td>Separating different components of the motion, and there’s always nonzero acceleration in one direction and zero acceleration in the other.</td>
<td>The student thinks that only forces exactly in the direction of motion (or opposite) can speed up or slow down an object. All other forces just change the direction of motion.</td>
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<td>No disambiguation between v and a</td>
<td>Student knows that forces in a force pair do not have equal magnitude because the objects are dissimilar in some property (e.g., bigger, stronger, faster).</td>
<td>Mass has no impact on motion</td>
<td>The student believes that inanimate/passive objects cannot exert a force.</td>
<td>Projectile speed is affected by gravitational force - the direction doesn’t matter.</td>
<td>The student thinks that an outward force exists with all curved motion.</td>
</tr>
<tr>
<td>No disambiguation between x and v</td>
<td>Student understands force as a push or pull which may or may not involve motion.</td>
<td>The student identifies equal force pairs, but indicates that both forces act on the same object. (For the example of a book at rest on a table, the gravitational force down on the book and the normal force up by the table on the book are identified as an action-reaction pair.)</td>
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**Kinematics** | **Force and Motion** (Alonzo & Steedle) | **Mass and Motion** | **Newton's 3rd law** | **2D Motion** | **Circular Motion**
Assessment: Set of Levels in the LP-strands
Assessment: Cloud Model

• Based on recent science education research
  – Different models co-exist in students’ minds
• Inspired from electron’s cloud model

• We can only say where students are in the LP with a certain probability
Instructional Tasks

2-D Learning Progression

Levels of Understanding

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Student Model

Student Model Update

Instructional Tasks (Formative/Embedded Assessment)

Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks Tasks

Topic Complexity

Kinematics Force and Motion (Moments/Impulse) Newton’s 3rd law 2D Motion Circular Motion

strand
### LP-driven Instructional Tasks

<table>
<thead>
<tr>
<th>Level</th>
<th>Tasks</th>
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<tr>
<td>5</td>
<td>A toy car is traveling in a straight line with a constant acceleration. What’s happening to its speed?</td>
<td>Chris (70 kg) and Paul (100 kg) are sumo wrestling and Paul is winning. How does Chris’s pull compare to Paul’s pull?</td>
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<td>4</td>
<td>If you throw a basketball straight up in the air, what is the ball’s velocity and acceleration at the ball’s highest point?</td>
<td>Lauren (65 kg) and Ashley (65 kg) are sumo wrestling and Lauren is winning. How does Lauren’s push compare to Ashley’s push?</td>
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<td>3</td>
<td>Two cars pass an speed limit sign at the same time. If one car is going faster than the speed limit, is the other car also speeding?</td>
<td>Jennifer (65 kg) is pushing on a desk (50 kg) but it doesn’t move. How does the force Jennifer exerts on the desk compare to the force that the desk exerts on Jennifer?</td>
<td></td>
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<td>2</td>
<td>Alice and Bob are riding bicycles, and Alice is in front of Bob. Is Alice going faster than Bob?</td>
<td>Chris (70 kg) and Paul (100 kg) are sumo wrestling and no one is winning. How does Chris’s push compare to Paul’s push?</td>
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<td>The picture below shows a series of photos taken of two balls on some ramps. Successive photos of each ball were taken at equal time intervals (light a strobe light photo). Do these balls ever have the same speed?</td>
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### Kinematics
- Force and Motion (A&S)
- Mass and Motion
- Newton’s 3rd law
- 2D Motion
- Circular Motion
Instructional Tasks

• Also serving as embedded assessment
• Two types
  – Within-strand or drilling tasks/questions
  – Cross-strand or deep questions/tasks
Hypothetical Instructional Path

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<td>The student uses the effects of a force as an indication of the relative magnitudes of the forces in an interaction.</td>
<td>Separating different components of the motion (e.g., horizontal and vertical). Components may vary differently.</td>
<td>The student thinks that unbalanced forces on an object will cause the object to speed up or slow down.</td>
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Advanced Tutorial Strategies

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LP-Inspired Instructional Cube

Within-Topic LP

Instructional Tasks

Topic LP
LP-driven Instructional Path

Within-Topic LP

Instructional Tasks

Topic LP
The Language Dimension of LPs

• Novices: non-technical language
• Experts: scientific language
• While guiding students towards higher levels of the LPs their language should change too
  – Students should be able to talk “Physics” at higher levels of understanding
Adaptive Tutor

- Curriculum adaptation (automatically or instructor-driven)
- Task adaptation
- Semantic processing adaptation
- Adaptation of materials (teachers can load the pictures which could automatically be incorporated in some simulations or multimedia elements)
- Teachers can configure the scaffolding component, e.g. if using the force-diagram strategy with low-knowledge students then more feedback and adjunct aids must be activated
Thank You!

www.deeptutor.org