Cognitive Task Analysis 1
Administrative

• Today’s plan
  – Toward “big picture” for ed research methods
  – Intro to Cognitive Task Analysis
  – Discuss Zhu & Simon paper
    • Review Assiistment assignment
  – Discuss doing a CTA in your research

• For next time
  – Read Clark et al paper (on wiki site)
  – Discussion posts
  – Assiistment assignment
Unpacking & repacking expertise: Chick sexing

- Experts don’t know, what they know
  - 98% accurate after years of on-the-job training

- Interviews led to design of “pictures in which critical features of various types were indicated”

- After just minutes of instruction, novices brought to 84% accuracy!

Do you know what you know?

Experts can describe <30% of what they know! (Clark et al)

What we know about our own learning

What we do not know we know

You can’t design well for what you don’t know!
Clark on “Automated Knowledge”

- [http://www.youtube.com/watch?v=SSK63nqEbLQ](http://www.youtube.com/watch?v=SSK63nqEbLQ)

Most of all human knowledge is automated and unconscious.

- (See also my TEDx talk [http://www.youtube.com/watch?v=KP6i1sbDcL4](http://www.youtube.com/watch?v=KP6i1sbDcL4))
Definitions of Cognitive Task Analysis (CTA)

- The general term used to describe a set of methods and techniques that specify the cognitive structures and processes associated with task performance.
- The focal point is the underlying cognitive processes, rather than observable behaviors.
- Another defining characteristic of CTA is an attempt to describe the differences between novices and experts in the development of knowledge about tasks.

CTA improves instruction

Studies: Traditional instruction vs. CTA-based

- **Med school catheter insertion** *(Velmahos et al., 2004)*
  - Sig greater pre to post gain; better with patients on all 4 measures (including needle insertion attempts!)

- **Radar system troubleshooting** *(Schaafstal et al., 2000)*
  - CTA group solved 2x malfunctions & in less time

- **Spreadsheet use** *(Merrill, 2002)*
  - Post-test: 89% vs. 64% in half of training time!

Lee (2004) meta-analysis: 1.7 effect size!
Cognitive Task Analysis Methods

- Techniques to specify \textit{cognitive structures \& processes} associated with task performance
  - Think alouds of experts \& novices performing tasks
  - Computer simulations of human reasoning
  - Structured interviews of experts
  - Difficulty Factors Assessments
  - Learning curve analysis

\textit{Newell \& Simon (1972)}

\textit{Clark et al}

\textit{Koedinger et al}
Kinds of Cognitive Task Analysis

- **2 Kinds of Approaches**
  - Empirical: Based on observation, data, exp.
  - Analytical: Based on theory, modeling.

- **2 Kinds of Goals**
  - Descriptive: How students actually solve problems. What Ss need to learn.
  - Prescriptive: How students should solve problems. What Ss need to know.

- **4 Combinations ...**

## Kinds of Cognitive Task Analysis

<table>
<thead>
<tr>
<th></th>
<th>Empirical</th>
<th>Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Descriptive</strong></td>
<td>Think-aloud of novice.</td>
<td>Cognitive modeling of errors, informal strategies.</td>
</tr>
<tr>
<td></td>
<td>Difficulty Factors</td>
<td></td>
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<tr>
<td></td>
<td>Assessment.</td>
<td></td>
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<tr>
<td><strong>Prescriptive</strong></td>
<td>Think-aloud, interviews of experts.</td>
<td>Cognitive modeling of success, normative strategies.</td>
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<td>DFA</td>
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Where does Chick Sexing fit?
### Kinds of Cognitive Task Analysis

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*Where does Zhu & Simon fit?*
Lovett Example: Think Alouds in Statistics Tutor Development

• Task: Exploratory Data Analysis
  – Given problem description and data set
  – Inspect data to generate summaries & conclusions
  – Evaluate the level of support for conclusions

• Example Problem
  In men’s golf, professional players compete in either the regular tour (if they’re under 51 years old) or in the senior tour (if they are 51 or older). Your friend wants to know if there is a difference in the amount of prize money won by the players in the 2 tours. This friend has recorded the prize money of the top 30 players in each tour. The variable money contains the money won by each of the players last year. The variable tour indicates which tour the player competed in, 1=regular, 2=senior. The variable rank indicates player rank, 1=top in the tour.
Task Analysis of Major Goals in Statistical Analysis

- This is an “analytic prescriptive” form of CTA
- Break down task:
  - 7 major goals
  - Each goal has involves multiple steps or subgoals to perform
  - Write if-then rules (productions) that describe how each subgoals is achieved
Sample Transcript

<table>
<thead>
<tr>
<th>L#</th>
<th>Participants words &amp; actions</th>
<th>Annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oh, okay.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>So we need to, he wants to know whether there is a difference in the amount of prize money,</td>
<td>Goal 1</td>
</tr>
<tr>
<td></td>
<td>the amount of money won by players in the two tours.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>So, I think this is the prize money, uh, money contains the prize money won by each of these</td>
<td>Goal 2</td>
</tr>
<tr>
<td></td>
<td>players.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Tour indicates which tour the player competes in.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Well, you don't really need rank, in order to solve this, right?</td>
<td>Goal 4</td>
</tr>
<tr>
<td>6</td>
<td>Cause like, well, I don't know.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Um... I'm gonna do a boxplot... ...</td>
<td>Goal 5</td>
</tr>
<tr>
<td>8</td>
<td>[Subject uses statistics package to make a boxplot]</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>oh, cool (laugh)- I did it.</td>
<td>Goal 6</td>
</tr>
<tr>
<td>10</td>
<td>All right, uh, so just looking at the average.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>It looks like the people in the senior tour get less money.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Um, and there's a lot less variation in the amount of money that, like all the prizes.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A couple little outliers in each which means like, I don't know, like some people won,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>know, like a lot of money at a time...</td>
<td></td>
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Observations about this verbal report

• No evidence for goal 3, characterize the problem
  – Line 10: student simply jumps to selecting a data representation (goal 4) without thinking about why.
• No evidence for goal 7, evaluate evidence
• Minor interpretation error
  – Line 13: student mentions the “average” when in fact boxplots display the median not the mean
• Note: These observations may be indicated in the annotation column of the transcript
Comparing Think Aloud Results with Task Analysis

- Percentages to the right of each step represent the percentage of students in the think-aloud study who showed explicit evidence of engaging in that step.
- Step 3 is totally absent!
  - A tutor can help students to do & remember to do step 3
Using if-then rules to model differences between novices & experts

• Novices make errors either because
  - Lack of knowledge -- modeled as a missing rule
  - Incorrect knowledge -- modeled as a “buggy” rule

• Missing rule (to set goal 3):
  Characterize problem
  If goal is to do an exploratory data analysis
  & relevant variables have been identified then
  set a subgoal to identify variable types

• Buggy rule (skipping from goal 2 to 4):
  Select any data representation
  If goal is to do an exploratory data analysis
  & relevant variables have been identified then
  set a subgoal to conduct an analysis by picking any data representation
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Where does Lovett example fit?
Some textbooks capture elements of the Zhu & Simon approach.

Examples:
(1) \( x^2 + 5x + 6 = (x + 2)(x + 3) \)
(2) \( x^2 + 7x + 6 = (x + 1)(x + 6) \)
(3) \( x^2 + 8x + 12 = (x + 2)(x + 6) \)
(4) \( x^2 + 7x + 12 = (x + 3)(x + 4) \)
(5) \( x^2 + 13x + 12 = (x + 1)(x + 12) \)

Exercises:
(1) \( x^2 + 11x + 18 = (\quad)(\quad) \)
(2) \( x^2 + 9x + 18 = (\quad)(\quad) \)
(3) \( x^2 + 19x + 18 = (\quad)(\quad) \)
More typical textbooks do not ...

Provides one example and then lots of highly similar tasks, with different surface variations and but similar deep structure (mostly same procedure to solve).
Example think aloud from math student

[Student looking at first exercise]

1. According to the example,
2. Exercise 1, \( x^2 + 11x + 18 \) is equal to \( x \) ...
3. [Looking at Example 1] 2 + 3 is equal to the coefficient 5.
4. 2 \( \times \) 3 is equal to the constant 6.
5. [Looking at Example 2] This example is 1 + 6 = 7,
6. 1 \( \times \) 6 = 6.
7. Exercise 1 \( [x^2 + 11x + 18] \) is that \( x + 3 \) multiplies \( x + 6 \).
8. Exercise 2 \( [x^2 + 9x + 18] \) is that \( x + 6 \) multiplies \( x + 3 \).
9. Exercise 3 \( [x^2 + 19x + 18] \) is that \((x + 9)(x + 2)\).

[Reviewing Exercise 1]

10. That is wrong.
11. 3 + 6 is not equal to 11.
12. Exercise 1 is \( x + 2 \) multiplying \( x + 9 \),
13. 2 + 9 = 11
14. 2 \( \times \) 9 = 18
15. This one [Exercise 2] 3 + 6 = 9,
16. 3 \( \times \) 6 = 18.
17. This one [Exercise 3] is also wrong.
18. It should be \( x + 1 \) multiplies \( x + 18 \),
19. 1 + 18 = 19.
20. 1 \( \times \) 18 = 18.

Part I

Examples:
1. \( x^2 + 5x + 6 = (x + 2)(x + 3) \)
2. \( x^2 + 7x + 6 = (x + 1)(x + 6) \)
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3. \( x^2 + 19x + 18 = (\_\_\_\_) (\_\_\_) \)

- Does this protocol show signs of learning?
- If so, where?
  How?
How could you apply CTA to your own research?