Cognitive Task Analysis 1

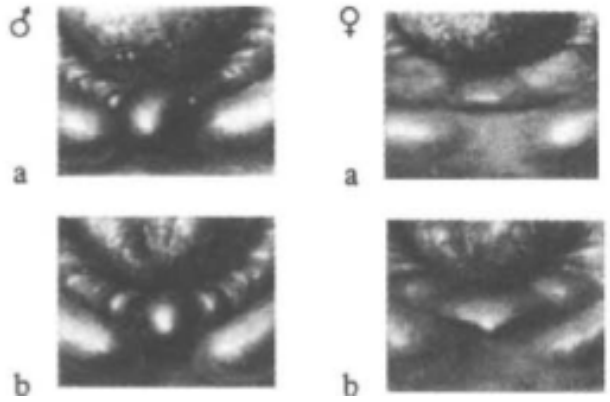
Administrative

- Today's plan
  - Toward "big picture" for ed research methods
  - Intro to Cognitive Task Analysis
  - Discuss Zhu & Simon paper
    - Review Assistment assignment
  - Discuss doing a CTA in your research
- For next time
  - Read Clark et al paper (on wiki site)
  - Discussion posts
  - Assistment 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!



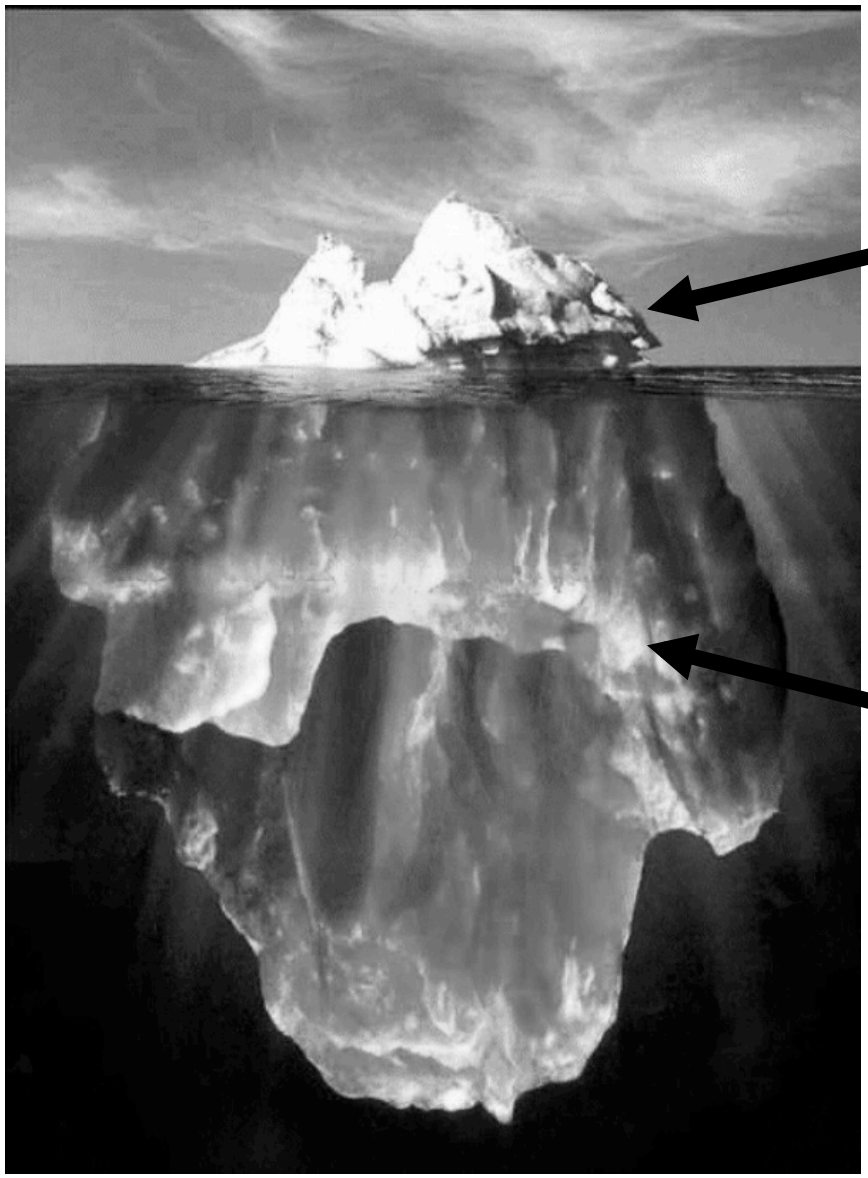
Male chicken genitals tend to look round and fullish like a ball or watermelon. Here are two examples:

Female chicken genitals can take on two different appearances. They can look pointed, like an upside down pine tree, or flatish. Here are two examples:

Biederman & Shiffrar (1987). Sexing Day-Old Chicks: A Case Study and Expert Systems Analysis of a Difficult Perceptual-Learning Task. JEP: Learning, Memory, & Cognition.

Do you know what you know?

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



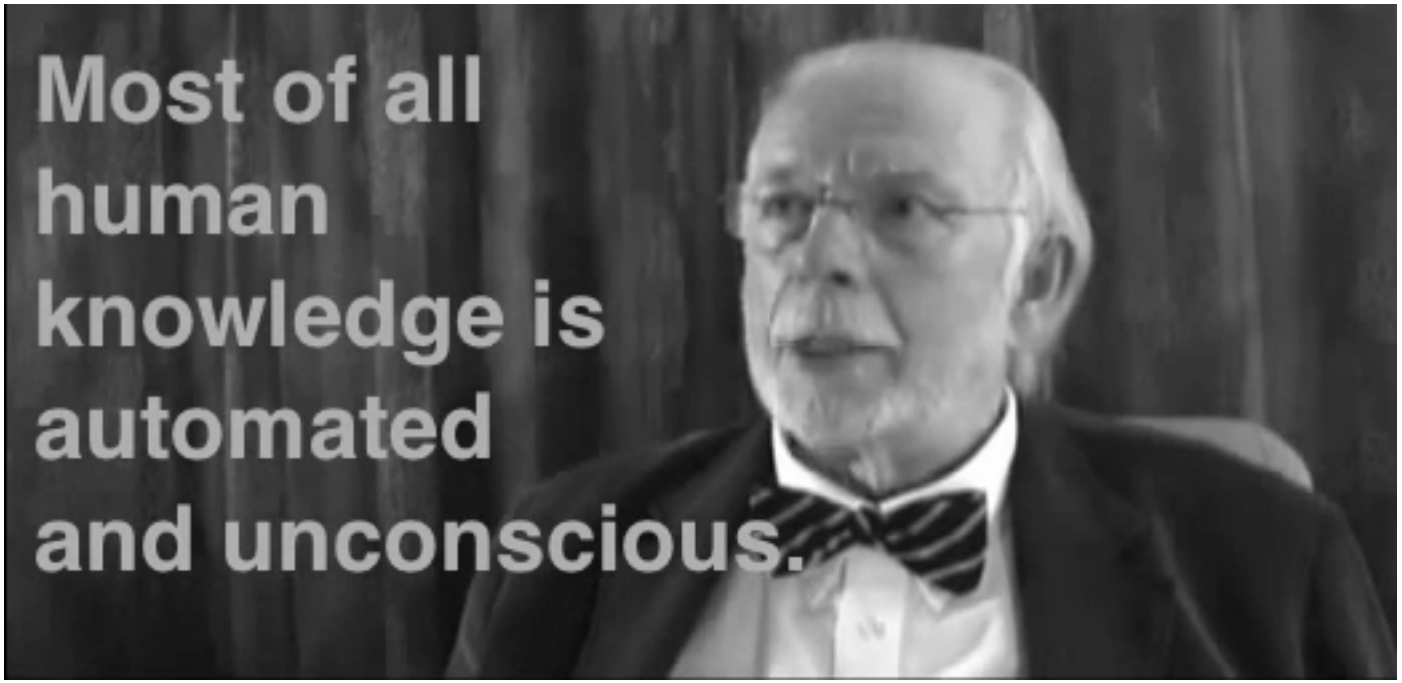
What we know about our own learning

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



- (See also my TEDx talk 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

From: Clark, R. E., & Estes, F. (1996). Cognitive task analysis. *International Journal of Educational Research, 25(5), 403–417.*

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 *cognitive structures & processes* associated with task performance
  - Think alouds of experts & novices performing tasks — Newell & Simon (1972)
  - Computer simulations of human reasoning
  - Structured interviews of experts — Clark et al
  - Difficulty Factors Assessments — Koedinger et al
  - Learning curve analysis

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 ...

From: Lovett, M. C. (1998). Cognitive task analysis in service of intelligent tutoring system design: a case study in statistics. In Intelligent Tutoring Systems, Proceedings of the Fourth International Conference. (pp. 234-243).

Kinds of Cognitive Task Analysis

	Empirical	Theoretical
Descriptive	Think-aloud of novice. Difficulty Factors Assessment.	Cognitive modeling of errors, informal strategies.
Prescriptive	Think-aloud, interviews of experts. DFA	Cognitive modeling of success, normative strategies.

Where does Chick Sexing fit?

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Where does Zhu & Simon fit?

Lovett Example: Think Alouds in Statistics Tutor Development

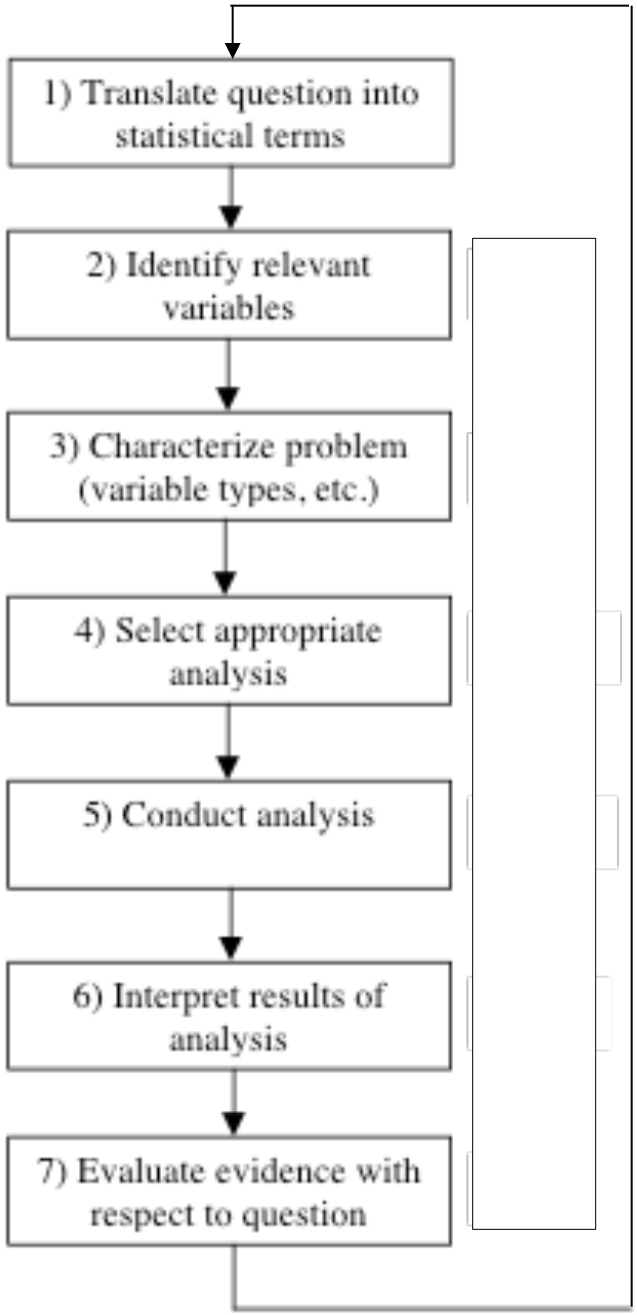
- Task: Exploratory Data Analysis
  - Given problem description and data set
  - Inspect data to generate summaries & conclusions
  - Evaluate the level of support for conclusions

- 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

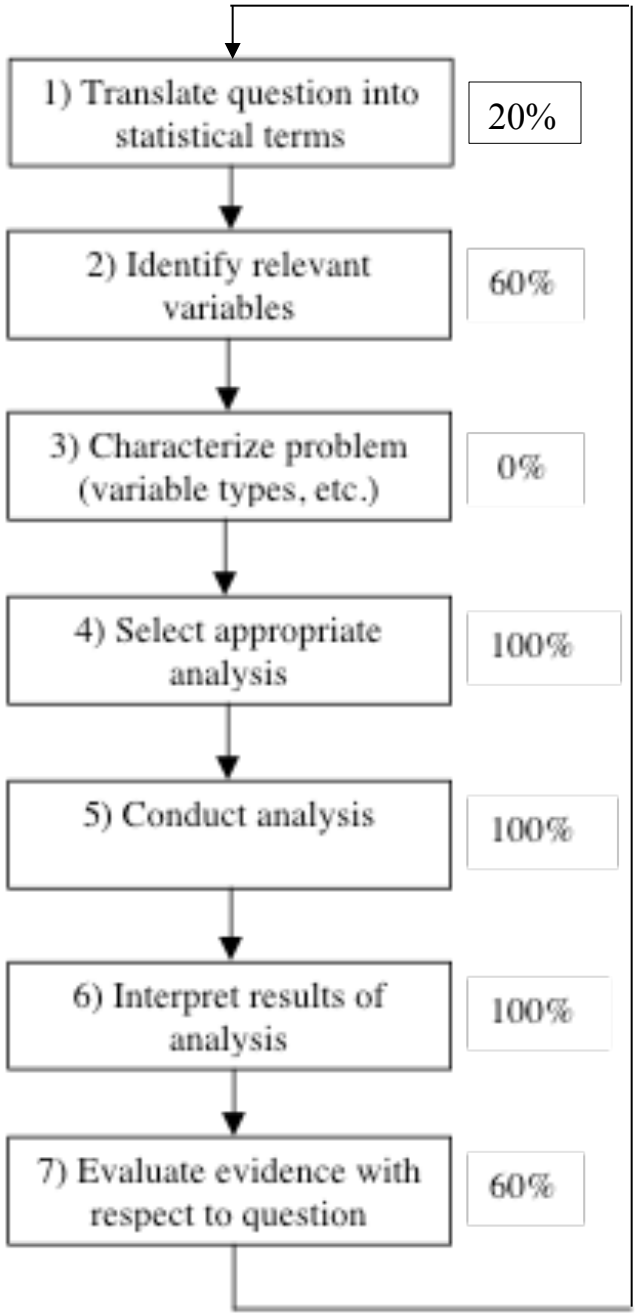
L#	Participants words & actions	Annotation
1	Oh, okay.	
2	So we need to, he wants to know whether there is a	Goal 1
3	difference in the amount of prize money, the amount of	
4	money won by players in the two tours.	
5	So, I think this is the prize money, uh, money contains the	Goal 2
6	prize money won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

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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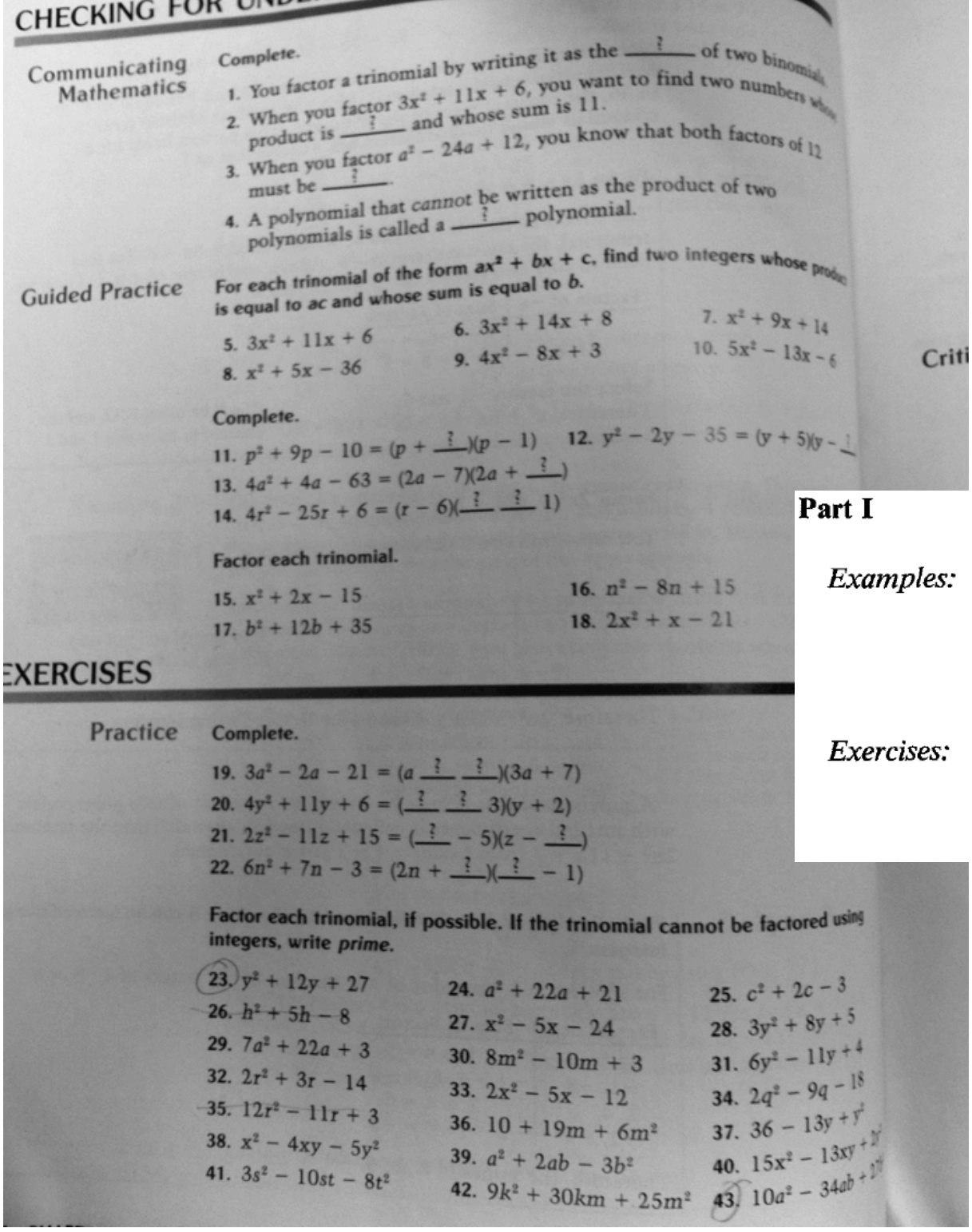
Where does Lovett example fit?

Zhu & Simon paper

Zhu, X., & Simon, H. A. (1987). Learning mathematics from examples and by doing. *Cognition and Instruction*, *4*(3), 137-166.



CHECKING FOR UNDE

Communicating Mathematics

Complete.

1. You factor a trinomial by writing it as the ___ of two binomials.
2. When you factor $3x^2 + 11x + 6$, you want to find two numbers whose product is ___ and whose sum is 11.
3. When you factor $a^2 - 24a + 12$, you know that both factors of 12 must be ___.
4. A polynomial that *cannot* be written as the product of two polynomials is called a ___ polynomial.

Guided Practice

For each trinomial of the form $ax^2 + bx + c$, find two integers whose product is equal to ac and whose sum is equal to b.

5. $3x^2 + 11x + 6$
6. $3x^2 + 14x + 8$
7. $x^2 + 9x + 14$
8. $x^2 + 5x - 36$
9. $4x^2 - 8x + 3$
10. $5x^2 - 13x - 6$

Criti

Complete.

11. $p^2 + 9p - 10 = (p + \_\_)(p - 1)$
12. $y^2 - 2y - 35 = (y + 5)(y - \_\_)$
13. $4a^2 + 4a - 63 = (2a - 7)(2a + \_\_)$
14. $4r^2 - 25r + 6 = (r - 6)(\_\_ \_\_ 1)$

Factor each trinomial.

15. $x^2 + 2x - 15$
16. $n^2 - 8n + 15$
17. $b^2 + 12b + 35$
18. $2x^2 + x - 21$

EXERCISES

Practice

Complete.

19. $3a^2 - 2a - 21 = (a \_\_ \_\_)(3a + 7)$
20. $4y^2 + 11y + 6 = (\_\_ \_\_ 3)(y + 2)$
21. $2z^2 - 11z + 15 = (\_\_ - 5)(z - \_\_)$
22. $6n^2 + 7n - 3 = (2n + \_\_)(\_\_ - 1)$

Factor each trinomial, if possible. If the trinomial cannot be factored using integers, write *prime*.

23. $y^2 + 12y + 27$
24. $a^2 + 22a + 21$
25. $c^2 + 2c - 3$
26. $h^2 + 5h - 8$
27. $x^2 - 5x - 24$
28. $3y^2 + 8y + 5$
29. $7a^2 + 22a + 3$
30. $8m^2 - 10m + 3$
31. $6y^2 - 11y + 4$
32. $2r^2 + 3r - 14$
33. $2x^2 - 5x - 12$
34. $2q^2 - 9q - 18$
35. $12r^2 - 11r + 3$
36. $10 + 19m + 6m^2$
37. $36 - 13y + y^2$
38. $x^2 - 4xy - 5y^2$
39. $a^2 + 2ab - 3b^2$
40. $15x^2 - 13xy + 2y^2$
41. $3s^2 - 10st - 8t^2$
42. $9k^2 + 30km + 25m^2$
43. $10a^2 - 34ab + 28b^2$

Some textbooks capture elements of the Zhu & Simon approach

Part I

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) $x^2 + 19x + 18 = (\quad)(\quad)$

$\sqrt{(x - 3.7)^2} = \sqrt{8.3}$ — Take the square root of each member.

$|x - 3.7| = \sqrt{8.3}$ — Square root of a perfect square.

$x - 3.7 = \pm\sqrt{8.3}$ — Definition of absolute value.

$x = 3.7 \pm \sqrt{8.3}$ — Add 3.7 to each member.

$S = \{6.58, 0.82\}$ — Do the arithmetic and write the solution set.

Check (of 6.58):

$(6.58\ldots)^2 - 7.4(6.58\ldots) + 13.69 \stackrel{?}{=} 8.3$ — Substitute 6.58 . . . for x.

$8.3 = 8.3$ ✔ — Answer checks. (Your calculator may show a slightly different value.)

ORAL PRACTICE

Give the result after the first step in solving the equation.

EXAMPLE

$x^2 - 10x + 25 = 41$ — *Answer* $(x - 5)^2 = 41$

A. $x^2 - 6x + 9 = 13$

B. $x^2 + 8x + 16 = 7$

C. $x^2 - 2x + 1 = 11$

D. $x^2 + 12x + 36 = 22$

E. $x^2 + 4x + 4 = 51$

F. $x^2 - 14x + 49 = 0$

G. $x^2 + 5x + 6.25 = 17$

H. $x^2 - 7x + 12.25 = 9.5$

I. $x^2 - 3.8x + 3.61 = 2.4$

J. $x^2 + 7.6x + 14.44 = 2$

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

Part I

[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 × 3 is equal to the constant 6.
5. [Looking at Example 2] This example is 1 + 6 = 7,
6. 1 × 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 × 9 = 18
15. This one [Exercise 2] 3 + 6 = 9,
16. 3 × 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 × 18 = 18.

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) $x^2 + 19x + 18 = (\quad)(\quad)$

- Does this protocol show signs of learning?
- If so, where? How?

How could you apply CTA to your own research?