Essential Problem Solving Skills and How to Teach Them

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Analysis of the situation

- Problem-solving is viewed as necessary for success in STEM fields, with the American Chemical Society (ACS) going so far as to refer to problem-solving as the "ultimate goal."

- Only 28% of employers classify college graduates' problem solving as excellent.
- In 2003, PISA included questions that assessed problem-solving skills. 58% of US 15-year olds possessed only low- level problem-solving skills.

- The Partnership for 21st Century Skills "Are They Really Ready To Work?" (2006) <http://www.p21.org/documents/FINAL_REPORT_PDF09-29-06.pdf>
- "Problem Solving for Tomorrow's World" (2004). <http://www.oecd.org/dataoecd/25/12/34009000.pdf>

What is problem solving?

A typical question

- A police officer who is looking for speeders sits on his motorcycle on the side of the highway. With his radar gun he observes a car pass by at 80mph (35.8m/s). It takes the police officer 5 seconds from the time when the car passed in front of him to when he begins to drive his motorcycle after the car. If the motorcycle can accelerate at $6.5 m/s^2$, where will the police officer catch up to the car (relative to his starting position)?

What is problem solving?

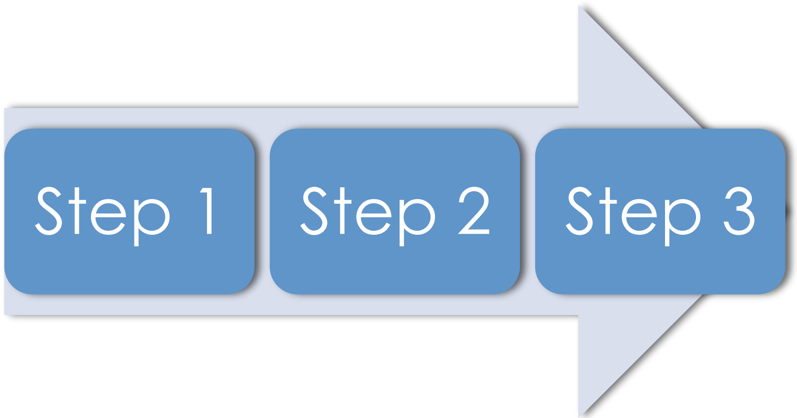
- Polya said that "where there is no difficulty, there is no problem."

- *Exercises* are sufficiently familiar and straightforward that they does not cause disequilibrium.
- *Problems* tend to involve the integration of several concepts and require multiple steps and to transfer to an unfamiliar context.

Problem-solving is a *mental process*.

George Pólya, *Mathematical Discovery*, Wiley, New York (1962)

Models of problem-solving



1. First, you have to understand the problem.
2. After understanding, make a plan.
3. Carry out the plan.
4. Look back on your work.

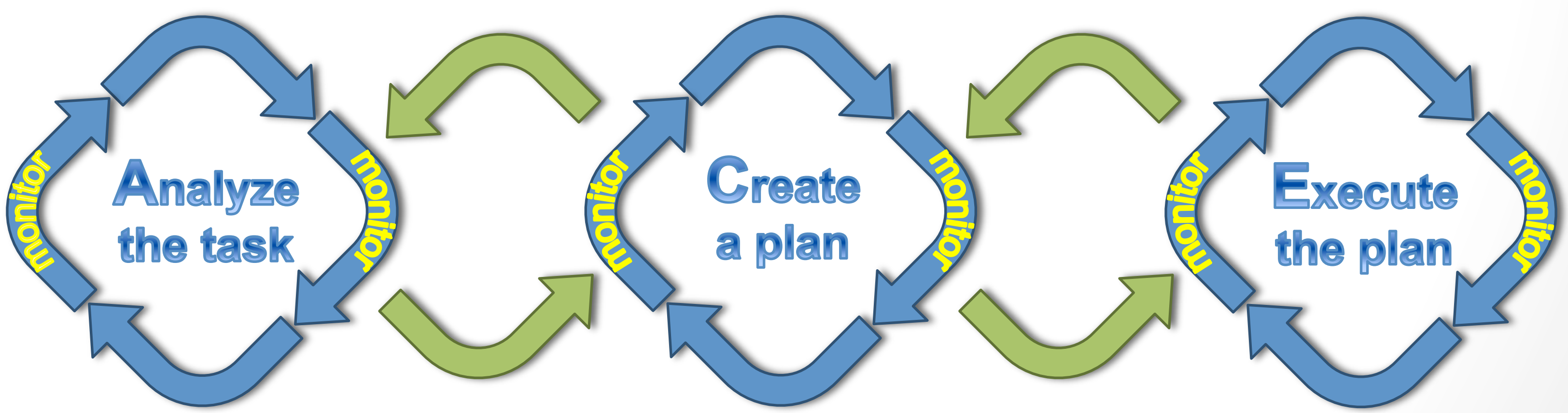
Most models in textbooks are linear.

Identify the problem
Define and represent the problem
Explore possible strategies or solutions
Act on a selected strategy or solution
Look back and evaluate

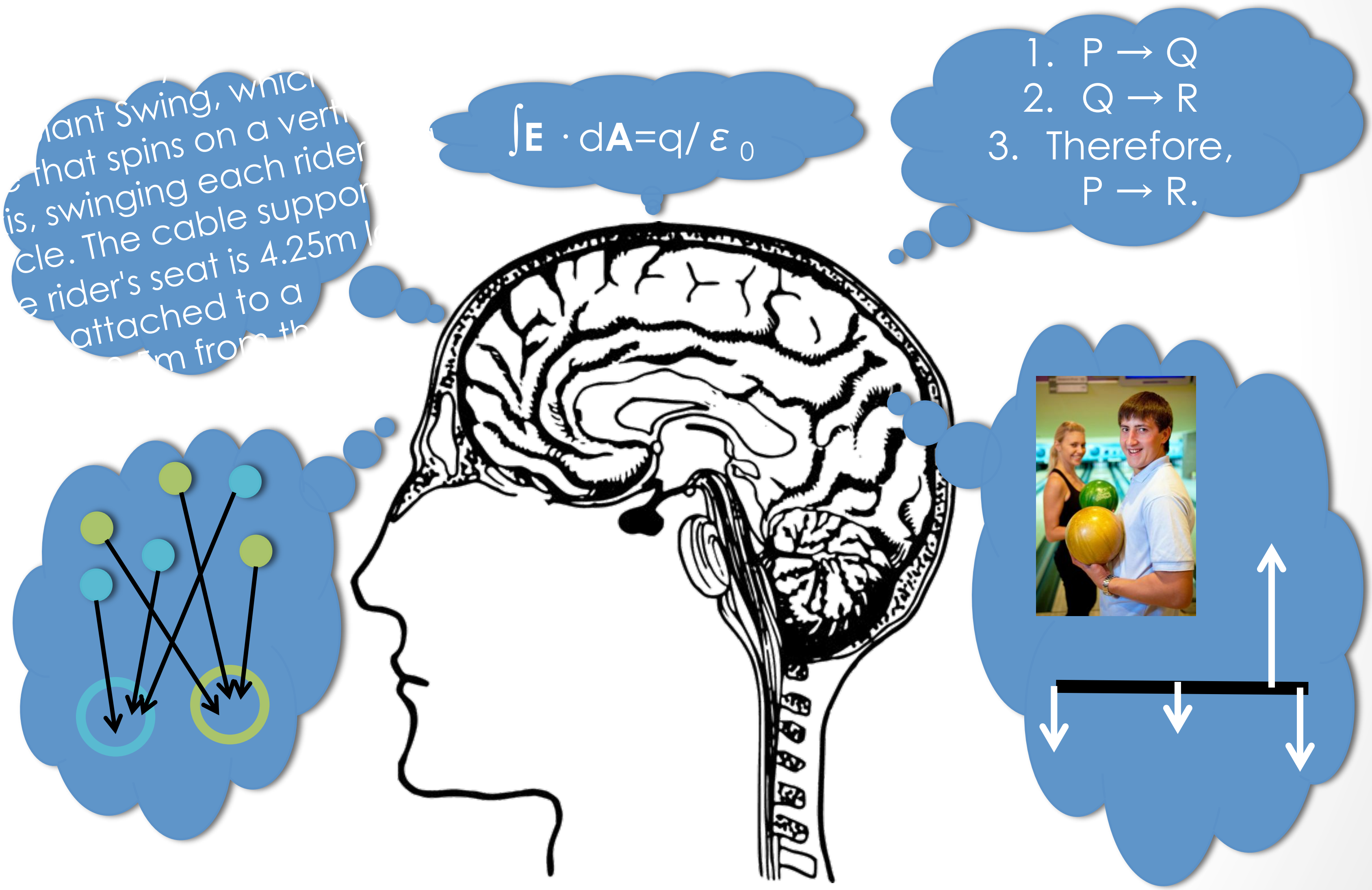
- George Pólya, *How to Solve It*, Princeton University Press (1945)
- Bransford & Stein, *The Ideal Problem Solver: A Guide to Improving Thinking, Learning, and Creativity*, Worth Publishers (1993)

Our model: ACE 'M

- *Analyze the task:* interpret and understand what is provided in the task.
- *Create a plan:* connect the given information and goal with models/concepts/relationships
- *Execute the plan:* follow the plan until the goal is attained
- *Monitoring:* deliberately and frequently paying attention to one's problem solving process and own thinking



ACE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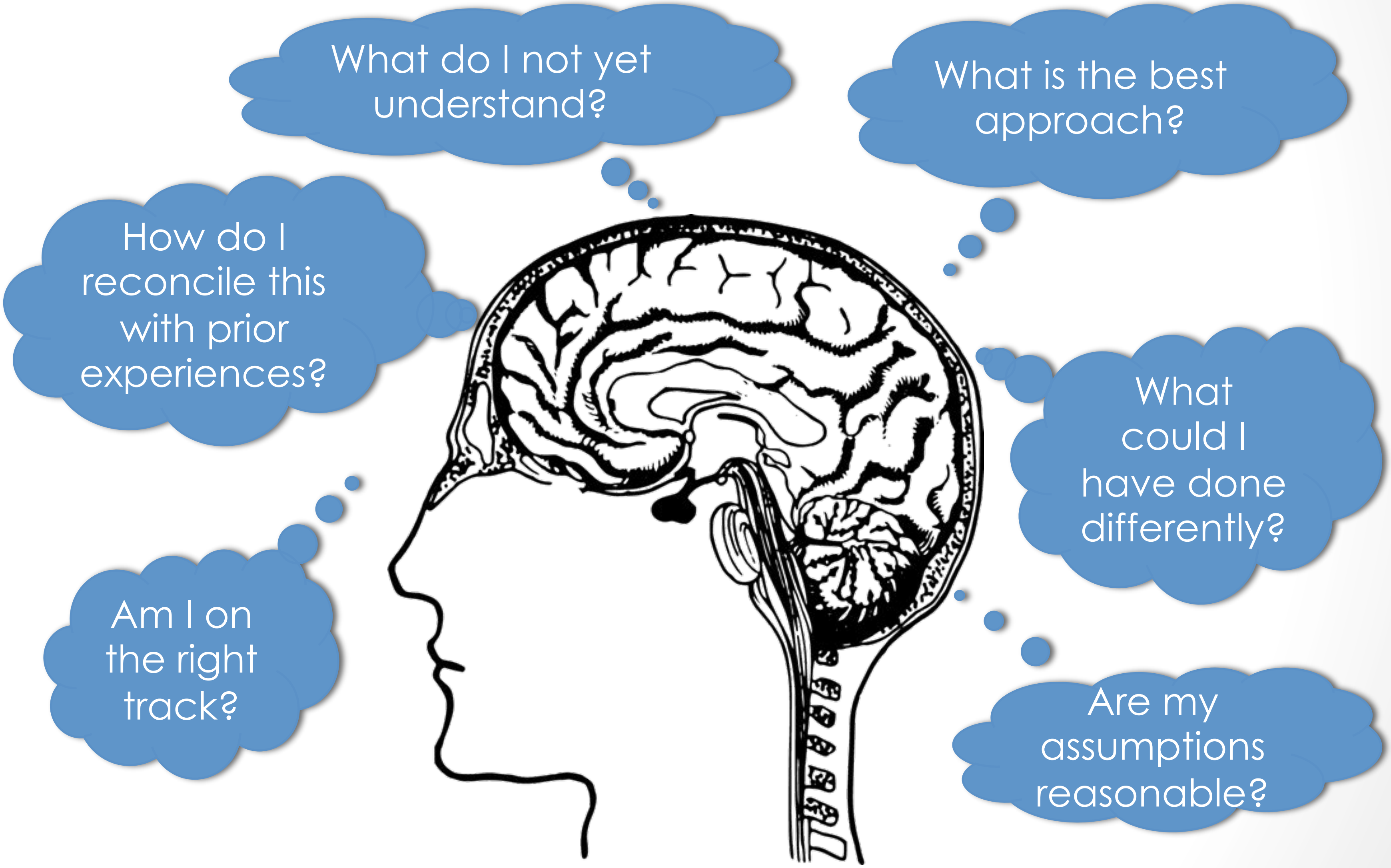
1. P → Q
2. Q → R
3. Therefore, P → R.

M


What do I not yet understand?
What is the best approach?
How do I reconcile this with prior experiences?
What could I have done differently?
Am I on the right track?
Are my assumptions reasonable?

A typical question

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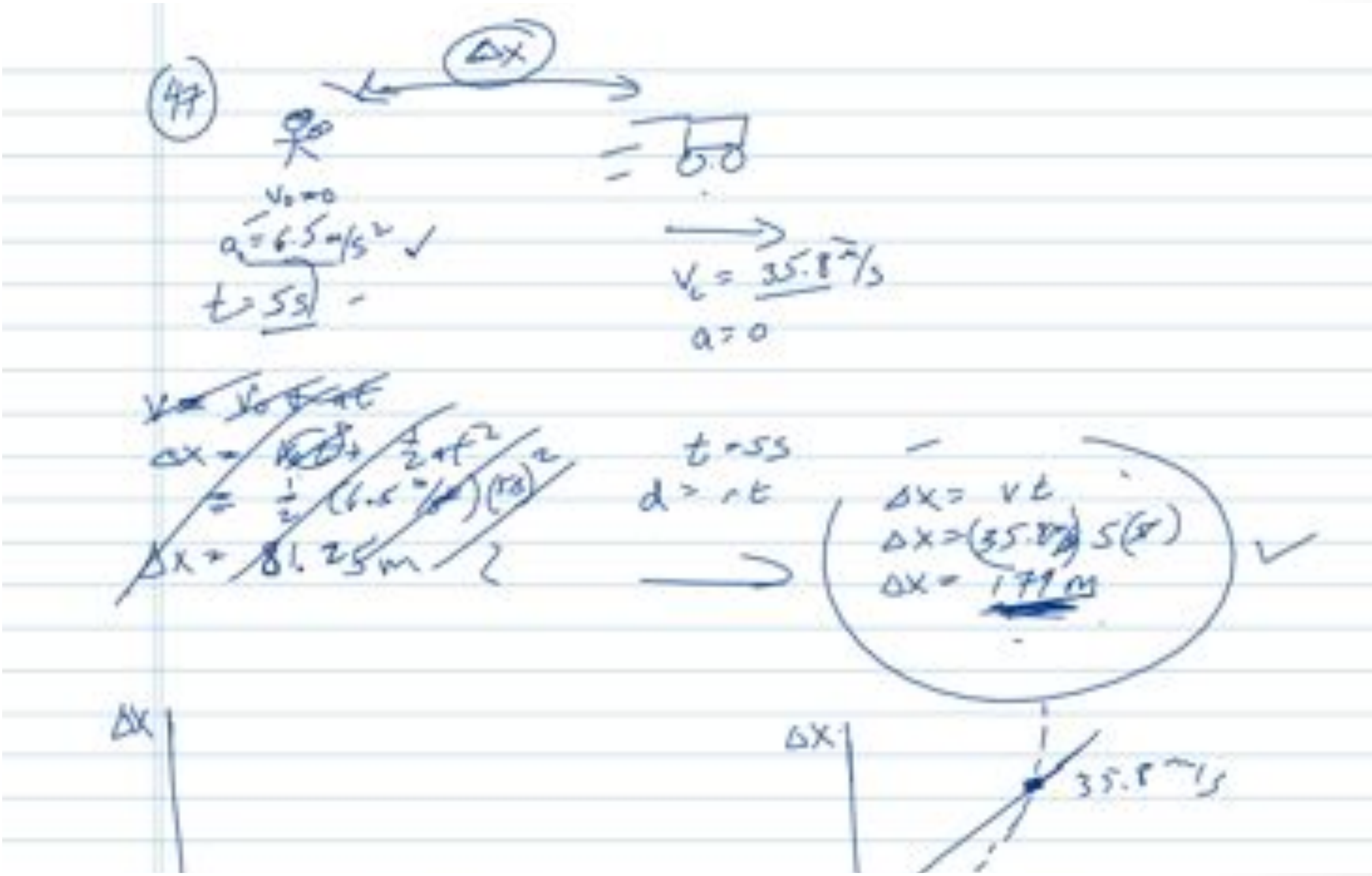
Typical responses

- 708m

- $x_c = x_{ci} + 35.8\text{m/s} * t$
  $x_{ci} = 35.8\text{m/s} * 5\text{s} = 179\text{m}$
  $x_p = ½\ 6.5\text{m/s}^2 * t^2$
  $x_c = x_p$
  so, $35.8\text{m/s} * (t+5) = ½\ 6.5\text{m/s}^2 * t^2$
  $-3.25t^2 + 35.8t + 179 = 0$
  $t = -3.73\text{s}$ or 14.75s
  so, $x_p = 708\text{m}$

(slightly) atypical response



Very different (& useful) response

- http://www.PENSproject.com/videos/347.mov

- Think-alouds: While performing a task a student says out loud what she is thinking and feeling.

- Listen to the first five minutes.
- Jot down times when you hear the student monitoring and/ or adjust his thinking.

Benefits of hearing a think-aloud

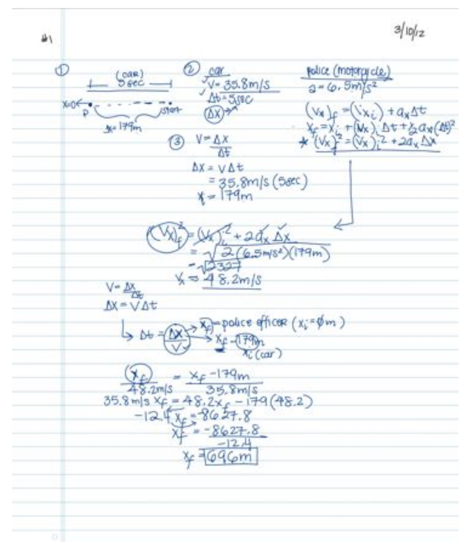
- A recorded think-aloud captures problem-solving much more completely than any static solution
- Now it is possible to hear and see how a student thinks
- Shifts focus from the final product to the *process*
- Central to success in problem-solving is self-monitoring, which is best captured in real-time

Benefits of doing a think-aloud

- Recording not only does helps to make the internal problem-solving process explicit for feedback, it also can shift students.

- Berardi-Coletta showed that with targeted instruction, verbalization led to more effective problem-solving.

- Verbalization helps students become aware of their thought process, thereby improving their ability to identify and correct own errors.



Berardi-Coletta, B., Dominowski, R. L., Buyer, L. S., & Rellinger, E. R. (1995). *Metacognition and problem solving: A process-oriented approach*. Journal of Experimental Psychology: Learning, Memory, and Cognition, **21**, 205-223.

Technology #1: smartpens

- When used with Livescribe Dot paper, a smartpen records and synchronizes pen strokes and audio to create a "pencast."
- Recorded pencasts can be transferred to a computer via a USB connection.
- From there, the recordings can be emailed or posted online.
- Pros:
    - Very portable
    - Less expensive than an iPad
    - Familiar interface (pen and paper)

Technology #2: tablets

- iPads and easy-to-use apps can record and display think-alouds.
- Videos can be shared immediately in the class or uploaded to YouTube, or other webpages.
- Apps:
  - Doceri
  - Educreations
- Pros:
  - Saves recordings in common file formats
  - Can incorporate outside images or videos

Now it's your turn!

Choose someone in your group....

1. ...who will write and speak through the problem solving process (the Solver)

2. ...to act as a listener/ skeptic. This person encourages the solver to make a quality think-aloud.
   - Ask the solver to clarify statement or steps if he/ she is unclear.
   - If the solver is quiet for more than 3 seconds, ask him/ her to explain what he/ she is thinking about.
   - *Responsibilities do not include correcting the solver.* Do not give hints. Do not solve the problem yourself. Do not tell the Solver how to correct an error.

3. ...to write down words/phrases that indicate monitoring during the think-aloud

The task

Below is a bird's eye picture of two checkout lanes at a grocery store. In which lane should you go?

Dan Meyer <http://blog.mrmeyer.com/?p=4646>

Integrating think-alouds into class

Time and instruction on solving problems/ creating think-alouds is required

- Model think-alouds for the students where you explain *every* decision.
- Devote classtime for students to practice explaining their thoughts to classmates.
- Start students with "think-afters", where they explain their reasoning after they have worked on a problem.
- Explicit instruction on all steps- ACE 'M.
- Assign questions that are true problems.

Observations

- Problem-solving is a complex, non-linear process which is often misrepresented by textbooks.
- Think-alouds allow an instructor (or researcher) to gain a much richer picture of a student's thought process.
- In addition to capturing students' thinking, think-alouds can help to improve students' problem-solving skills.
- Integrating think-alouds into class does take some time and energy, but the benefits are significant.

Interested in collaborating?

- Analyzing and using any of our thousands of recorded think-alouds?
- Capturing think-alouds from your students?
- Jointly developing class activities for different student populations?

- Please contact me **jphillips@lmu.edu** if you're interested in working with us.

Thanks!!!

- For more information on our PENS Project:
  - Visit **http://www.pensproject.com**

- Jeff Phillips, jphillips@lmu.edu

PROBLEM-SOLVING
EXAMPLES WITH
NARRATION FOR
STUDENTS

Students' views

- "I actually did enjoy making pencasts. I thought that it greatly improved my problem-solving strategies and helped organize my thoughts a lot more than they would've been without pencasts."
- "It made me slow down and really try to understand the problem long before I simply grab numbers and equations and try to plug them all into each other."
- "At first, I really didn't enjoy making pencasts. I felt that they were very awkward and it messed me up having to say all of my thoughts out loud. However, as time went on I realized that the more I was able to talk out the problem and explain my thinking process, the more I was able to understand concepts. My highest grade on the test came when I did the most practice problems with my Pencast (who would have thought!)."

Case study

- On the first three in-class tests, Isaac's scores were 18-24% below the class average.

At the beginning of the semester I was quite skeptical of the livescribe pen and how following a few simple guidelines/ approaches to problem solving could change the way I think….I stubbornly have to admit that the whole process took much longer than I had anticipated due to my unwillingness to embrace the pen as well as the process of talking out my actions…. It took almost the whole semester but I have finally come to a point where I find myself automatically dictating my comprehension process to prove to myself that I truly understand what is happening and the best method to approach a problem while utilizing key concepts.

- The fourth test, where he reported that he was more aware of his thinking and would engage in metacognitive thinking, was only 6 points below the class average.
- On a post-instruction survey Isaac reported that his test anxiety was eliminated.

Self-monitoring

- **Checking for external consistency**- Solver compares an element of her problem solution with something outside of this solution.
  - "I guess we're not dealing with world class sprinters. I know a little track and I'm pretty sure that's pretty slow."
- **Checking for internal consistency**- Solver compares an element of her solution to something else in the same solution.
  - "hmmm… interesting… 81.25m… interesting… how to reconcile these two…"
- **Assessing readiness**- Solver evaluates whether the solution path is the correct or most efficient.
  - "Oh we don't know v_f either. So there's two variables in here. Let's see if we can find one where we just have one."

Using ACE 'EM to help students