Problem-Solving with Think-Alouds

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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 6.5m/s^2, where will the police officer catch up to the car (relative to his starting position)?

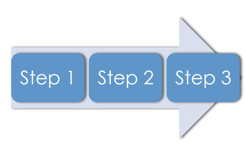
What is problem solving?

- 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.

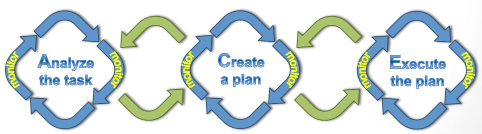
Most models in textbooks are linear.

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

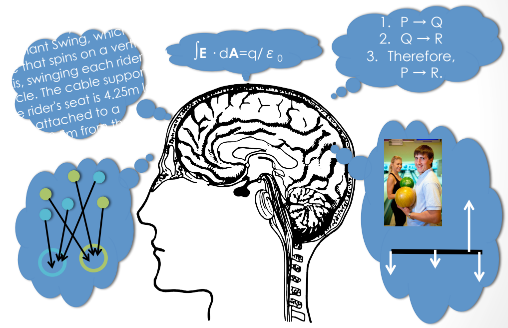
- George Pólya, *How to Solve It*, Princeton University Press (1945)
- Bransford & Stein, *The Ideal Problem Solver: A Guide to Improving Thinking, Learning, and Creativity*, Worth Publishers (1993)

Our model: ACE–M

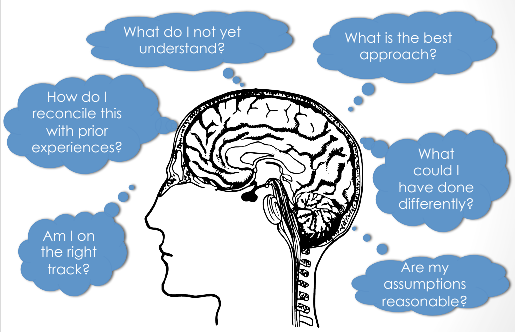
- *Analyze the task:* interpret and understand what is provided in the task.
- *Create a plan:* connect the given information and goal with models/concepts/relationships
- *Execute the plan:* follow the plan until the goal is attained
- *Monitoring:* deliberately and frequently paying attention to one's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



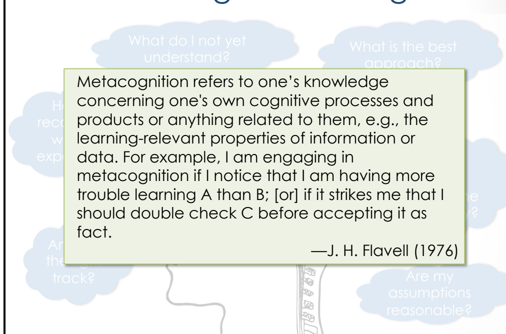
ACE



M



M=Monitoring or Metacognition



Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; [or] if it strikes me that I should double check C before accepting it as fact.

—J. H. Flavell (1976)

Creating a Plan

Once we had defined the goal (Analyzed the Situation), we were ready to create a plan

- Collaborate with faculty in other STEM departments
- Commit to restructuring courses and class time
  - Model problem-solving for students
  - Instruct students, and provide feedback, on all components of ACE-M
  - Base grades largely on performance on ACE-M

A typical question

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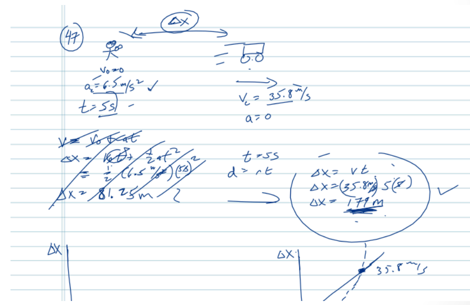
Typical responses

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

(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.

Benefits of hearing a think-aloud

- A recorded think-aloud captures problem-solving much more completely than any static solution
- With a recorded think-aloud, 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
- When students listen to other students they hear true problem-solving, not an instructor solving an exercise

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.

Implementing think-alouds (E)

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.

Improving monitoring

"Because metacognition often takes the form of an internal dialogue, many students may be unaware of its importance unless the processes are explicitly emphasized by teachers."

How People Learn (pg. 21)

- On tests, students can report their monitoring for partial credit
- Assignments after each test that ask students to reflect on their learning
- Test and exam wrappers

- *How People Learn: Brain, Mind, Experience, and School*, The National Academies Press, Washington, DC (2000).

Students' views (M)

- "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!)."

Some class data (M)

- In last year's general physics course, thirty-three of the thirty-seven students describing ACE-M as "helpful".
- In physics, the class average FCI normalized gains for sections that recorded think-alouds have been higher than prior years without think-aloud activities: 0.55 vs 0.37.
- In organic chemistry, sections that viewed and created think-alouds, averaged 5- 15 points higher on their in-class tests than those who did not.

Case study (M)

- 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 action**s…. 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.*

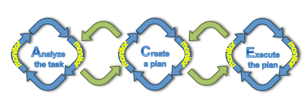
- The fourth test, where he reported that he was more aware of his thinking and would engage in metacognitive thinking, was only 6 points below the class average.
- On a post-instruction survey Isaac reported that his test anxiety was eliminated.

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, particularly their monitoring or metacognition

Thanks!!!

- Thank you, NSTA, CSTA and AAPT
- Physics teachers-
  - make your plans for the Winter AAPT Meeting in San Diego
  - get involved in the the local AAPT section **http://www.scaapt.org**
- For more information on our PENS Project:
  - Visit **http://www.pensproject.com**
- Jeff Phillips, jphillips@lmu.edu



PROBLEM-SOLVING EXAMPLES WITH NARRATION FOR STUDENTS