# Improving Students' Problem-Solving Competence With Think-Alouds

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Employers rate problem solving/ critical thinking as one of the top five "very important" skills for job success and yet most students never receive instruction how to engage in the decision-making needed to solve problems.

**How can we capture the critical thinking and decision-making processes needed to solve problems?**

**And, then how can we help students be conscious of their critical thinking and improve it?**

## ACE 'EM Problem Solving Process

At the heart of the process we encourage students to follow is a three-step process that is similar to Polya's:

- ***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.

Of course, problem-solving is not a linear process as experienced solvers move back and forth between the steps often repeating each one several times. To independently navigate through this non-linear process, a solver must ***Monitor one's own thinking***.

Solvers should also ***Examine their thought process*** after completing a solution. In this reflection process solvers identify what they did well and what they would like to improve upon. It also gives them the chance to identify characteristics of the task so they can be prepared for similar ones in the future.

The ACE 'EM process is not only what we use when instructing students, it is also the basis for our rubric by which we assess student progress.


## Technology

Several different devices have been used to record solutions in real-time. All capture the writing and verbal description provided by the solver. In addition to capturing problem-solving for later analysis, these devices can facilitate asynchronous discussions outside of class.

***iPads***

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.

Pros:
- Saves recordings in common file formats
- Can incorporate outside images or videos

***Livescribe smartpens***

These ballpoint pens contain embedded computers and microphones. When used with Livescribe Dot paper, a pen records and synchronizes pen strokes and audio to create a "pencast". Recordings 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)

## Implementations

### Modeling

**Watching expert generated think-alouds**

Students are shown expert created solutions that have been recorded using a think-aloud protocol. These solutions offer students a more complete and dynamic model than what is found in textbooks, but are still lacking in significant self-regulation and error correction. Generally, there are no specific assignments connected to these recordings.

### Apprenticing

**Watching student generated think-alouds**

Homework assignments ask students to view and critique previously recorded think-aloud pencasts, which typically contain content and/ or problem-solving errors. Students are asked to provide feedback to the recorder as well as reflect on the recorded solution's similarities and differences to their own thought process.

### Scaffolding

**Recording think-alouds**

In addition to the Step 2-type activities, students record their practice using one of the technologies. This facilitates asynchronous discussions outside of class as students can email the instructor any solution with which they were struggling. Students also engage in activities that show them how to analyze their own thought process. In-class activities include instruction and feedback on performing a think-aloud.

## Self-Monitoring

Using grounded theory methodology, we are categorizing students' monitoring events.

### 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…"

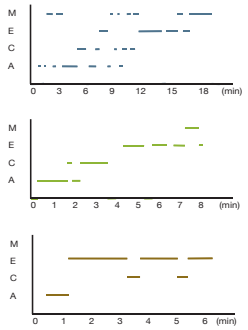
### Assessing readiness

Solvers evaluate whether the solution path is the correct or most efficient.

- "Oh we don't know $v_i$ either. So there's two variables in here. Let's see if we can find one where we just have one."

## Example Analyses

Below are data from three student's solutions to the same question. *Can you guess which corresponds to a correct solution?*




## Case Study from Physics

Isaac had a Lawson Test score that indicated a lack of formal operational thinking & a GPA that was 0.3 lower than the class average. On the first three in-class tests, his 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.

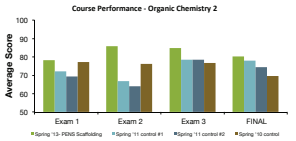
The fourth test, where he reported that he was more aware of his thinking and would engage in metacognitive thinking, was only 6 points below the class average.

On a pre/ post-instruction survey, Isaac shifted his responses from one that showed no self-regulation (or valuing of self-regulation) in problem solving (continuously planning, monitoring and adjusting one's thinking) to a more expert-like position. On the same survey, he reported that his test anxiety also was eliminated.

## Class Results

In physics, the class average Force Concept Inventory normalized gains for sections implementing the Scaffolding instructional methods (2011 & 2012) have been higher than prior years without think-aloud activities (2008-2010): 0.55 vs 0.37.

In organic chemistry, students who viewed and created their own think-alouds, averaged 5- 15 points higher on their in-class tests than students who did not.




## Student Feedback

Many students comment on how the experience of verbalizing their thought process helped them become better problem solvers.

- 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.
- I learned to take several steps in order to help me be successful in solving the problem. I made sure to ask myself right off the bat WHAT exactly it was that I was trying to find out in the problem, and then make a plan how to get there instead of panicking and letting my random thoughts run wild on the paper.
- 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!).

## Pre-service Teachers

Teacher candidates compare their own approaches and strategies to physics and algebra 2 questions. They also analyze recorded solutions; quantifying the time a student spends on understanding the question, creating and executing a strategy as well as the amount and type of monitoring. These recordings give the candidates insights into the challenges they will soon face in the classroom.

**http://PENSproject.com**

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