Teaching Metacognition

Marsha C. Lovett, Ph.D.

Lovett@cmu.edu

Trojan Horse

Metacognitive Lesson: Check your assumptions!

Titanic

Metacognitive Lesson: Know your weaknesses!

Maginot Line

Metacognitive Lesson: Know when to adapt!

Critically important, yet overlooked

- *Metacognition* involves thinking about one's own cognitive processes
  - Thinking about one's thinking, learning, reasoning, problem solving, …
- Metacognition is essential for effective learning in complex situations

Teaching Metacognition = Improving Learning

- Effective learning involves
  - Planning and goal-setting
  - Monitoring one's progress
  - Adapting as needed

- These skills tap into metacognition

- **Implication: Teaching students these skills will improve their learning**

Overview of Talk

0. Setting the target
1. Changing students' beliefs about learning
2. Teaching planning and goal setting
3. Giving practice at monitoring/adapting

Expert vs. Novice Learner

Emily: slightly worried

- test on day after playoffs
- essay tests a challenge
- sets a plan: start early
  - outline key ideas
- notes cause->effect
- stops to self-assess

Monica: also anxious

- essay tests hard
- so study harder
- read/re-read text
- memorize vocabulary
- no explicit plan
  - starts night before

(Ertmer & Newby, 1996)

The ideal: Self-regulated learning (SRL)

(Butler, 1997; Pintrich, 2000; Winne & Hadwin, 1998)

Can expert learners be made?

- Early attempts to “teach metacognition” failed
  - Abstract study strategies taught, but students couldn’t apply them
  - Concrete study strategies taught, but students couldn’t transfer them or generalize beyond training
  - Attitudes/beliefs difficult to change
- Researchers concluded that metacognitive performance is a stable trait

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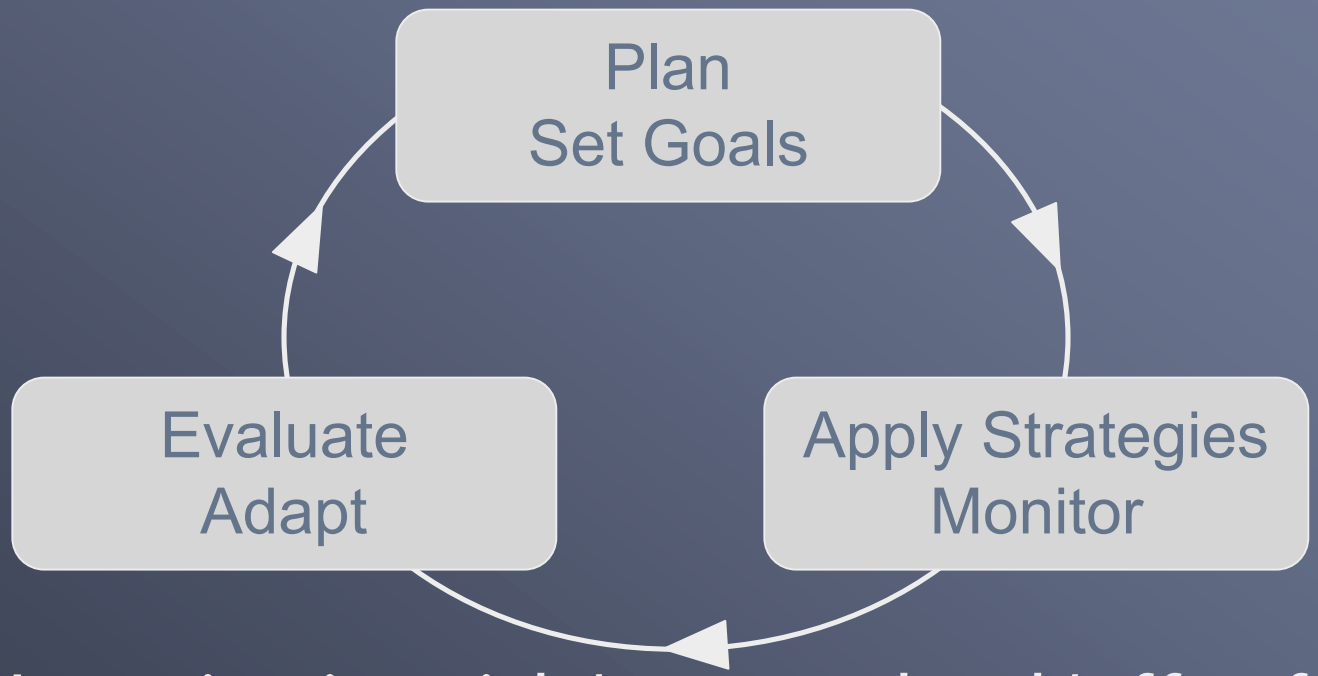
“Math is hard.”

Beliefs have consequences!

- Beliefs about learning impact SRL cycle:



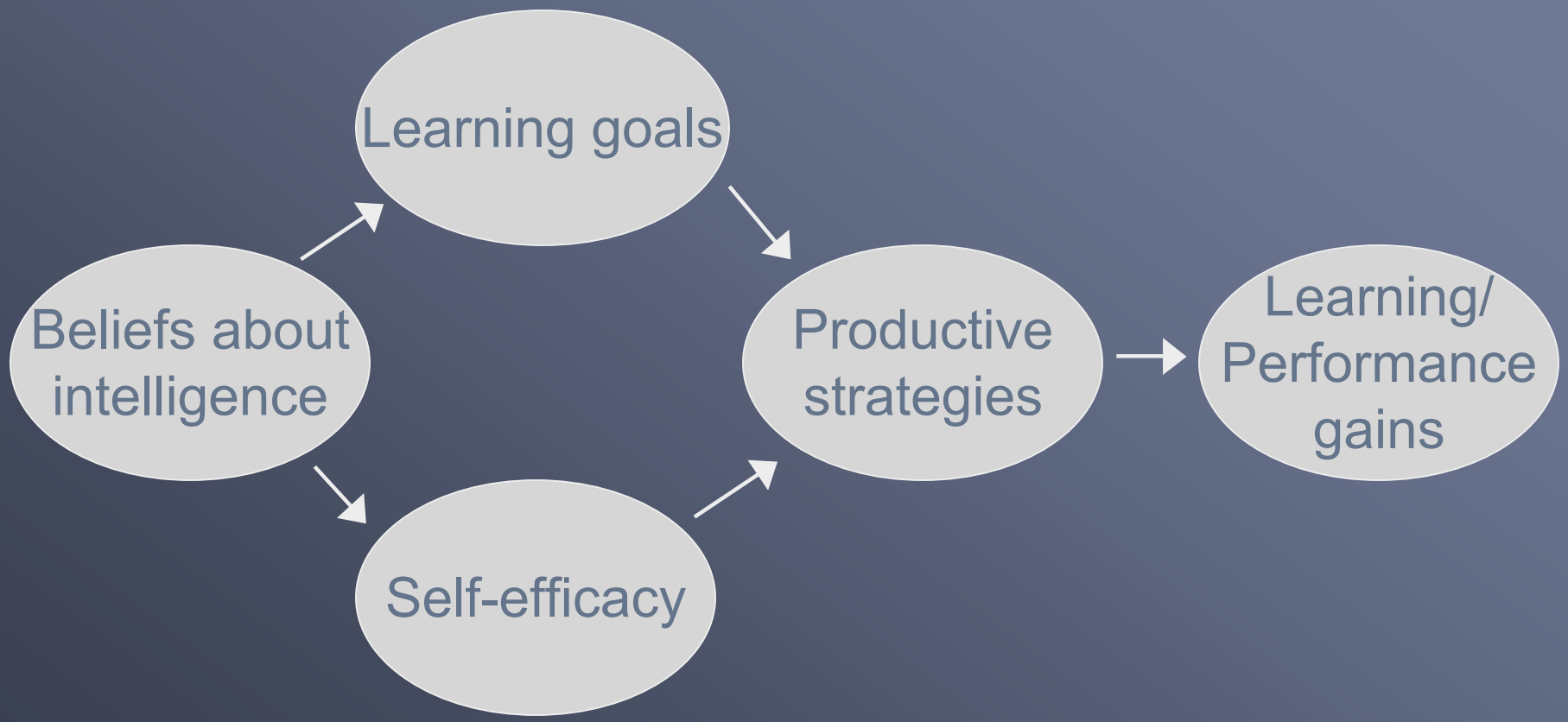
  - Learning is quick/easy vs. hard/effortful
  - Being a good learner is innate vs. develops

Beliefs predict performance

- Research Method
  - Students' beliefs assessed: "incremental" vs. "fixed" view of intelligence
  - Students' scores (grades + achievement) collected in 6th-7th grade
- Key Result
  - Students who endorsed more of an "incremental" view earned higher grades, even after controlling for prior achievement

(Henderson & Dweck, 1990)

Path Model


Learning goals
Beliefs about intelligence
Productive strategies
Learning/ Performance gains
Self-efficacy

Changing beliefs

- Research Method
  - Students in an 8-week workshop on learning received either 2 lessons on “brain as muscle” (experimental) or “memory strategies” (control)
  - Students’ beliefs assessed before and after
  - Students’ math grades collected
  - Teachers’ (blind) ratings of effort collected

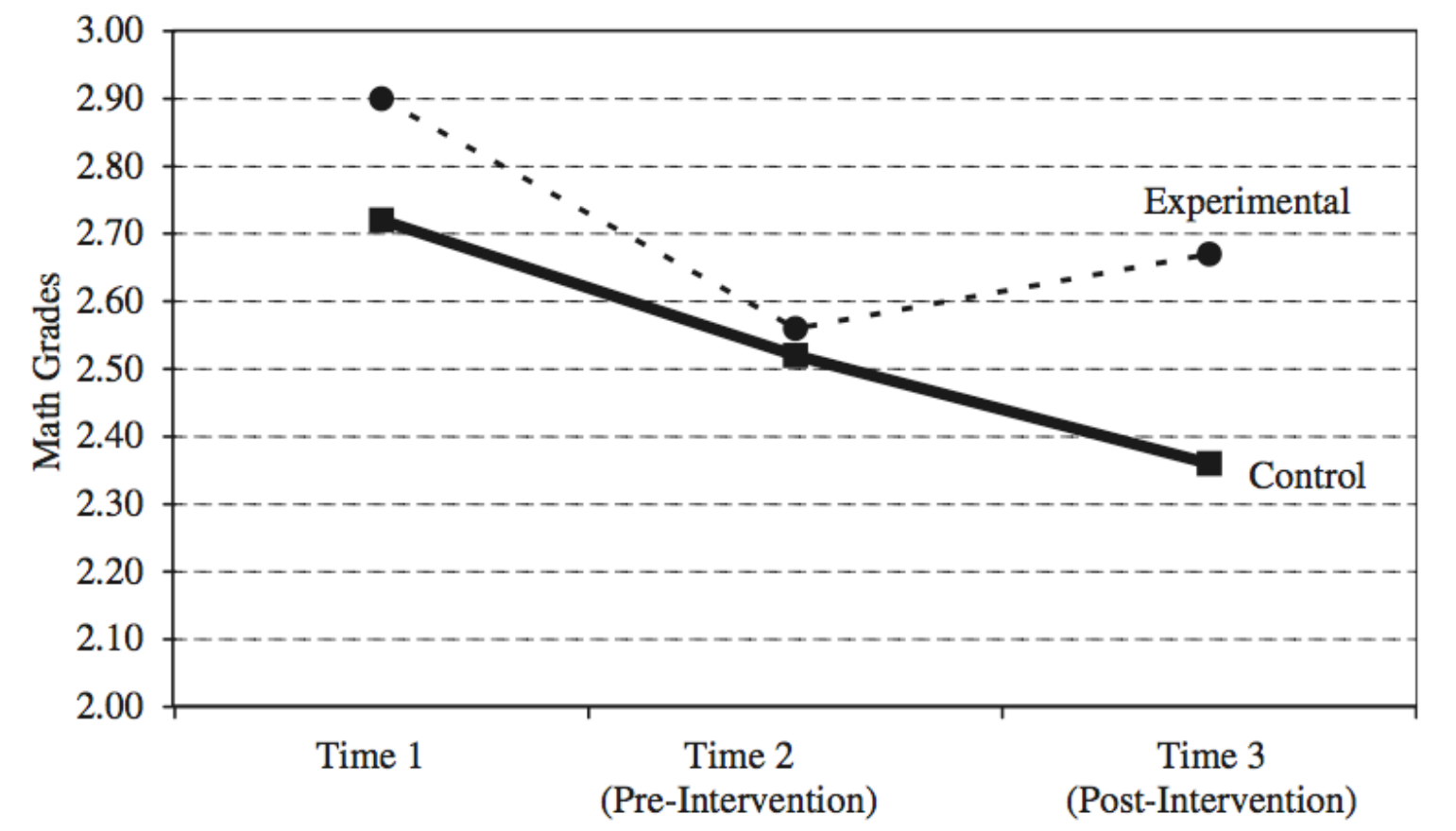
(Blackwell et al, 2007)

Changing beliefs

- Key Results: Experimental vs. control
  - Experimental group endorsed “incremental” beliefs more after intervention
  - Experimental group showed more increases in motivation, according to teacher ratings
  - Experimental group showed upturn in their math grade trajectories

(Blackwell et al, 2007)

Changing beliefs: Results (cont'd)



(Blackwell et al, 2007)

Changing beliefs: College level

- Research Method
  - Stanford University students recruited for pen pals program promoting either “malleable” or “fixed” intelligence – plus a baseline control condition
  - Pen pals met three times to write letters
  - Race (African American, White) used as a blocking variable

(Aronson et al, 2002)

Changing beliefs: College level

- Key Results
  - Short term effects on beliefs, as predicted
  - Long term effects – end of school year:
    - Belief changes between conditions maintained
    - Enjoyment of academics condition differences*
    - Condition differences in Spring quarter GPA, controlling for prior SAT

*Condition differences larger for African American students

Changing beliefs: Summary

- By working to change students' beliefs about learning/intelligence, we can see:
  - Sustained changes in belief (for months)
  - Increased motivation/effort
  - More positive attitudes
  - Improved performance (even after a delay)

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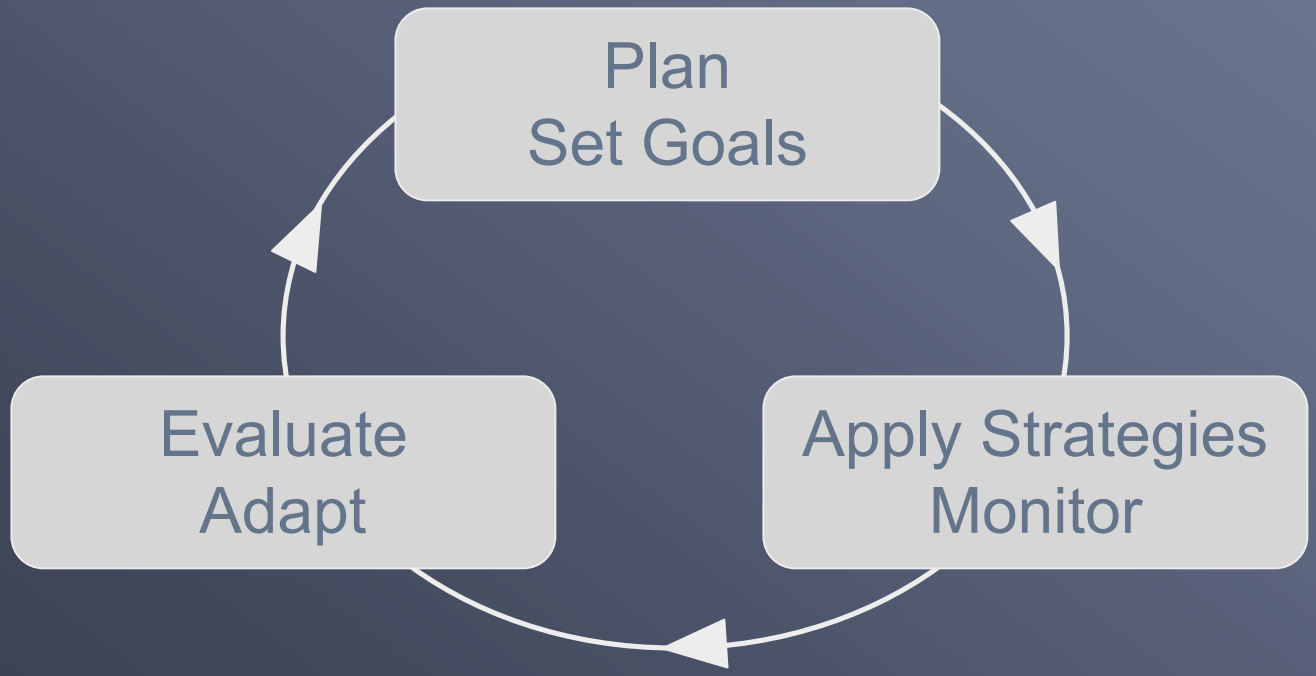
Students often fail to plan…

- Transcript of Student Solving Statistics Problem

  "Oh, okay. Um, I'm not really sure if- do I need to uh we can just, like, graph it, right? Uh line plot, I guess. … oh, uh histograms, bar charts maybe a boxplot? Uh, no... Uh, uh histogram, um data table, um…in statistics class that always worked when you got stuck, just make a boxplot, and see what happened. So uh, I'll boxplot them, um, y by x. [bleep] Uh oh, it says the variable rank has 30 categories, shall I continue? Usually that was bad, so I cancel that, because it shouldn't come out like that…"

Teaching students to plan

- Consider student as an independent learner (e.g., in online learning environment)
- Critical skills: Setting learning goals, planning



Teaching students to plan

- Research Method
  - Students recruited to learn about circulatory system using a hypermedia environment
  - 30-minute training session (1:1 tutoring)
    - Explained components of SRL to students
    - Exemplified them for the current learning task
    - Control group received no training
  - Talk-aloud protocols collected during learning
  - Pre- & posttests on conceptual understanding

(Azevedo & Cromley, 2004)

Teaching students to plan

- Main Predictions
  - Students trained in SRL would show better conceptual learning
  - Students trained in SRL would exhibit more SRL-related behaviors, especially
    - Planning their approach
    - Setting goals for their own learning

(Azevedo & Cromley, 2004)

Teaching students to plan

- Key Results: Predictions met!
  - Students trained in SRL learned more: > 70% improvement (< 50% for control)
  - Students trained in SRL showed more effective learning behaviors
    - Time and effort planning
    - Prior knowledge activation
    - Goal-directed search
    - Evaluating content as an answer to current goal
    - Reminding themselves of the current goal

(Azevedo & Cromley, 2004)

Teaching students to plan

- Comments
  - Control condition had no training
  - Very near transfer: training to application context
- But the potential in online learning is great:
  - Data on students' learning behaviors are collected
  - Students' progress is assessed
  - Give students feedback on their learning effectiveness
  - Carnegie Mellon's OLI project we're working to do this! (www.cmu.edu/oli)

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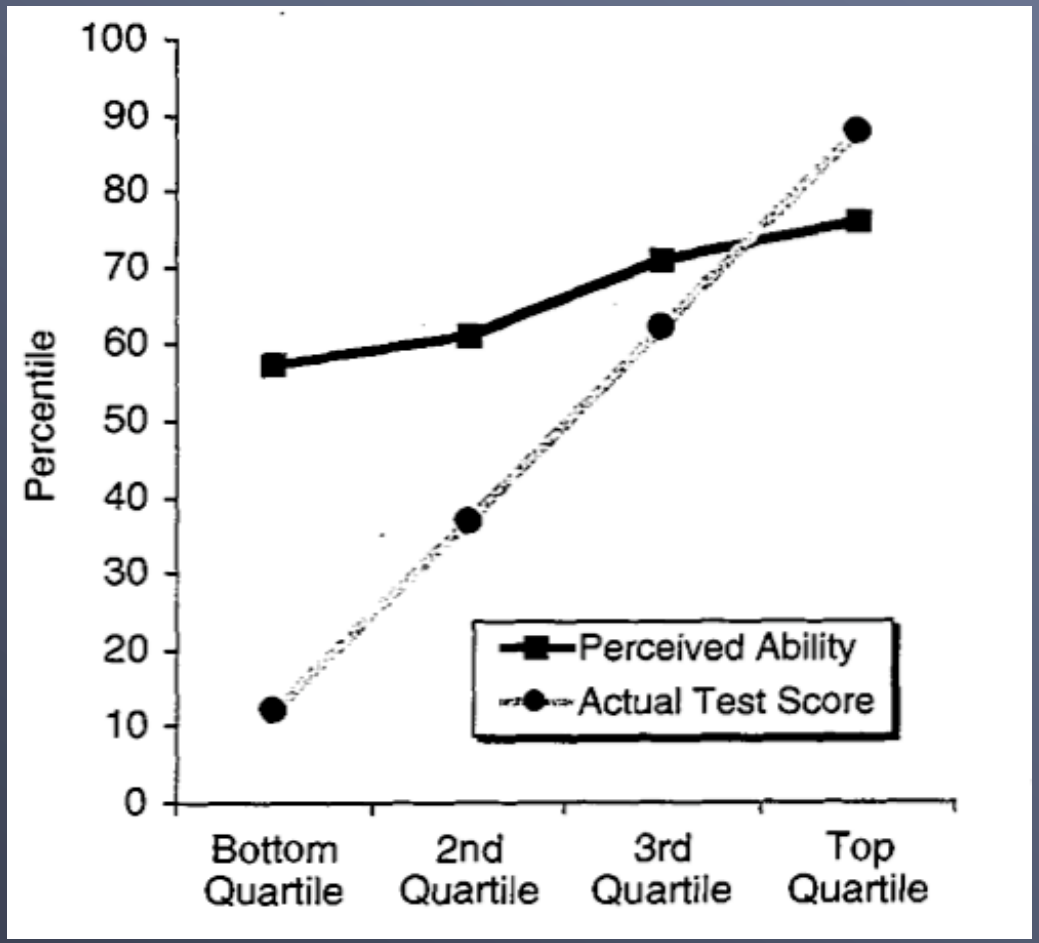
Accurate self-monitoring is hard



"Ignorance more frequently begets confidence than does knowledge."

– Darwin

(Kruger & Dunning, 1999)

Case Study: Metacognitive Intervention at Carnegie Mellon

- Carnegie Mellon first-year math/science students often struggle, even though they are academically strong
- Professors lament students' ineffective study behaviors and poor performance
- Students' history of success may be creating obstacles
  - Not used to having to work hard to learn
  - Resistant to adapting because high school strategies were so successful (though no longer)

What metacognitive skills do they lack/need?

- Analyze their beliefs about learning
  - Beliefs in intelligence as incremental, value of effort
  - Expectations of performance show overconfidence

Biology

Grade Expectations		
A	108	71%
B	45	29%
Grand Total	153	100%

Chemistry

Grade Expectations		
A	109	50%
A/B	25	12%
B	68	31%
B/C	2	1%
C	10	5%
D	2	1%
Grand Total	216	100%

Physics

Grade Expectations		
A	67	54%
A/B	4	3%
B	48	39%
B/C	2	2%
C	3	2%
Grand Total	124	100%

Calculus

Grade Expectations		
A	149	63%
A/B	14	6%
B	68	29%
C	6	3%
Grand Total	237	100%

What metacognitive skills do they lack/need?

- Analyze their planning/goal-setting skills and their use of study strategies
  - Report little use of planning skills
  - Report only moderate use of study strategies
  - Rate goal-setting/adapting less than effort
- After a semester in college, their belief in the value of effort significantly decreases
- Conclusion: Teach monitoring/adapting as a habit of mind

My Approach with 1st-year Science Students at CMU

- Teach monitoring/adapting as a habit of mind
- Design for transfer: Introduce that skill and offer practice applying it in multiple contexts – all of which are ***in*** the math/science courses
- Minimize costs: Find quick and easy ways to incorporate this training (so students and faculty are more likely to engage)

A New Tool: Wrappers

- A *wrapper* is an activity that surrounds a pre-existing learning or assessment task and fosters students' metacognition
- One can build a self-monitoring wrapper around any pre-existing part of a course (lecture, homework, test)

Why Wrappers Work

- Time efficient (Students and faculty will use them)
  - Students are doing the task anyway
  - Wrapper only adds a few minutes of time
- Metacognition practice is integrated with the task
  - Students are self-monitoring in the context where it is needed
  - Feedback on accuracy can be built in
  - Wrapper support can be gradually faded
- Other research shows even minor interventions that frame a task in a new way can significantly change behavior

Lecture Wrappers

- How they work:
  - Before lecture, present tips on active listening
  - After lecture, students get index cards on which to write 3 key ideas from lecture
  - Instructor gives his list of 3 key ideas for students to self-check

Homework Wrappers

- How they work:
  1. Instructor creates self-assessment questions that focus on skills students should be monitoring
  2. Students answer questions just before homework
  3. Complete homework as usual
  4. After homework, answer similar self-assessment questions and draw their own conclusions

  "This homework is about vector arithmetic… How quickly and easily can you solve problems that involve vector subtraction?"

  "Now that you have completed this homework, how quickly and easily can you solve problems…?"

Exam Wrappers

- How they work
  - Upon returning graded exam, students completed exam reflection sheet in class
    - Report study strategies, analyze errors, identify new approaches as needed
  - Before the next exam, sheets returned to students for review and consideration, and students made a study plan

Study Design

- Data collected from variety of sources
  - Pre- and post-semester surveys of beliefs, strategies, etc.
  - Standard assessments (quiz & test scores)
  - Wrapper responses
  - Additional measures (online learning data)
- Experimental Design
  - Population of current first year science students as study base
  - Different number of interventions in different courses plus students take different combinations of courses => dose response

Lecture Wrapper Results

- Across 3 successive lecture wrappers, students' responses for "key ideas" in the lecture increasingly matched instructor's: 45%, 68%, 75%
- Moreover, lecture wrappers were faded across time
  - First: with mini-lecture on active listening
  - Second: just a prompt at beginning of lecture
  - Third: no advanced warning

Homework Wrapper Results

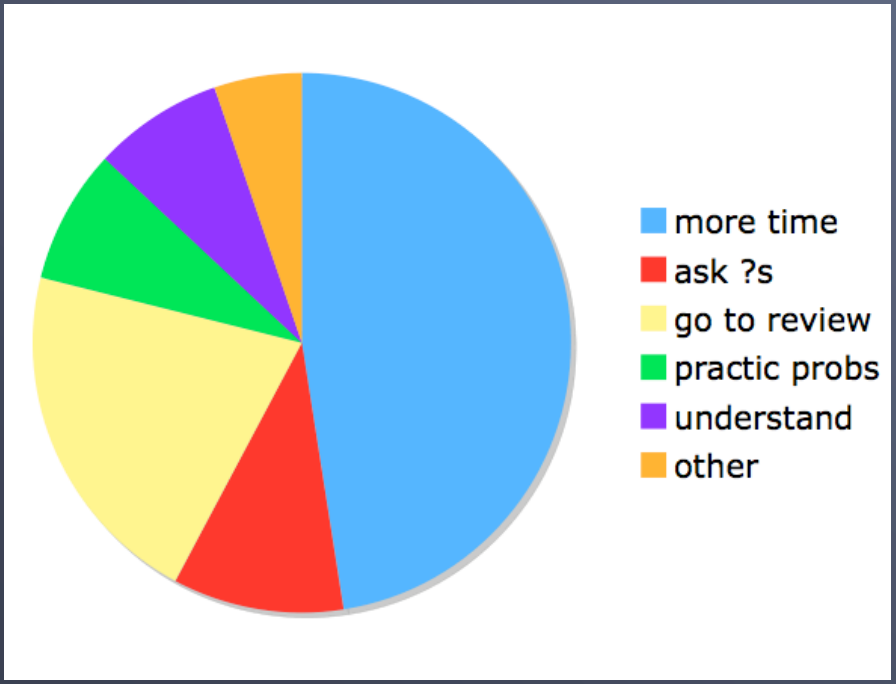
- Most students' self-ratings ↑ pre-homework to post
- They noted effort as helpful
- Some students' ratings ↓ pre-homework to post
- They noted overconfidence and the need to do more

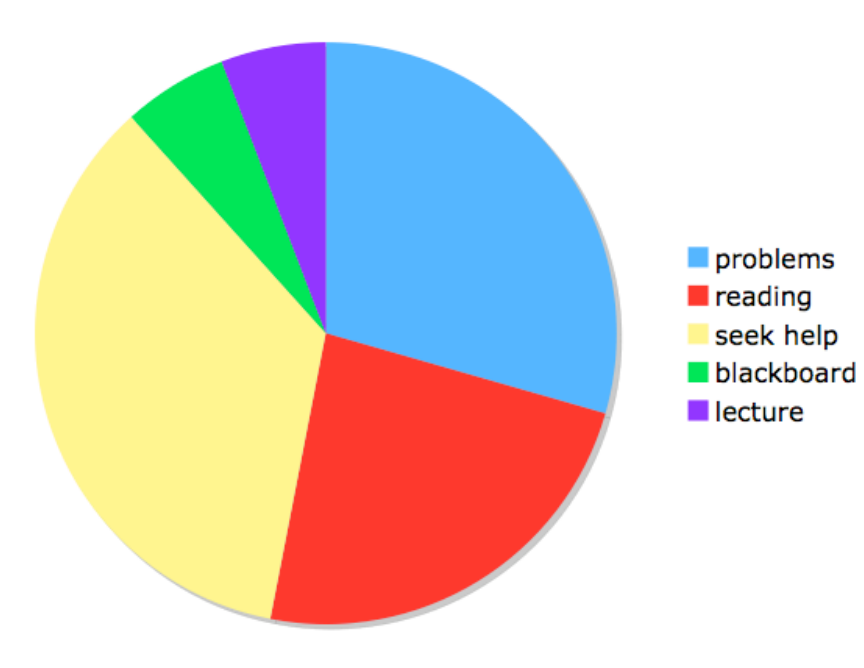
Sample Student Comments from Homework Wrapper

- "I had some confusion at first on some of the details but this helped clear that up."
- "I realized that I was a little slow at subtracting vectors…, and now I understand it better and can find the difference more quickly."
- "At the beginning of the exercise, I was more confident in using vectors than I probably should have been."
- "I feel like I haven't achieved progress, so I plan on attending course center and looking over the problems again."

Exam Wrapper Results

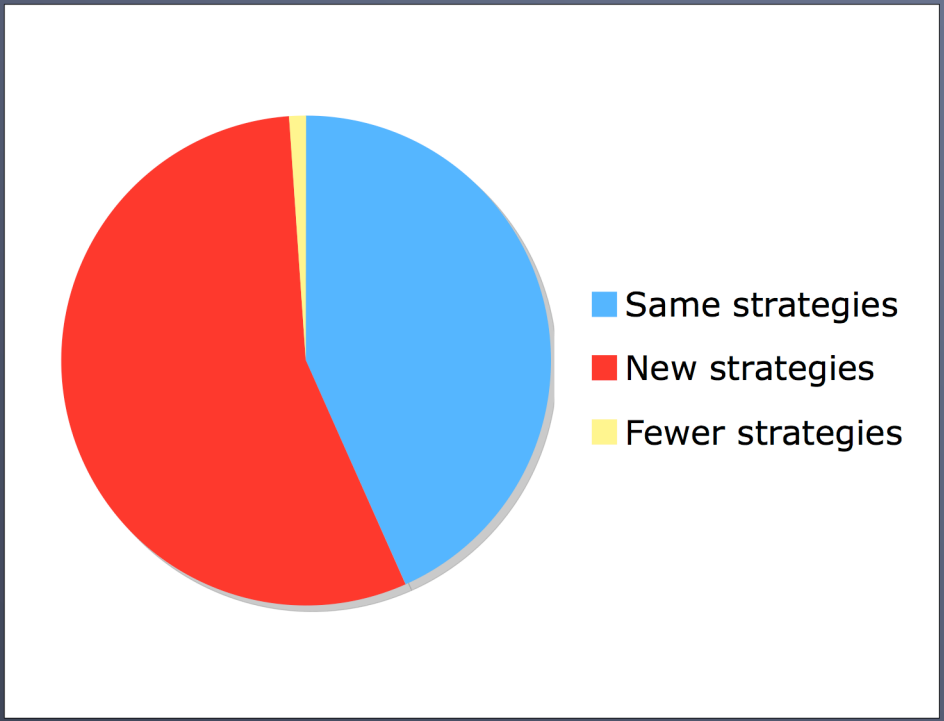
- Students self-identified new approaches for exam preparation.





Overall Impact of Intervention

- Did self-monitoring lead to change?
  - Majority of students reported using new strategies



New Strategies Highlight Monitoring

- "I didn't really know how well or not well I knew the material until I put myself to the test: really doing the problems on practice tests and re-solving homework problems without looking at the answer."
- "I went over previous tests and practice exams. Completing the practice exams in college help me to gauge what I still needed to focus in on in my study."

New Strategies Also Address Overconfidence

- "I began solving problems much more often, going to extra help sessions and, while I was reading or listening to lecture, looking for what I'm supposed to be getting out of it… actively reading/listening, instead of just reading/listening."
- "There is a big difference between actually doing problems and trying to memorize a particular solution while looking at examples. I have to say my advice is: do a lot of practice problems."

Conclusions

- Metacognitive skills and beliefs about learning have consequences for students' learning and performance.
- Teaching metacognition – introducing these new skills and beliefs, and giving students practice at applying them – improves students' learning.
- Low-cost interventions can have big payoffs, so try it!

Thank You!

For more information, email: Lovett@cmu.edu