# Metacognition

## Effective Learners . . .

- Metacognition
  - "accurately monitor their learning"
  - "control and flexibly apply their strategies"
  - "learn through scaffolded apprenticeship"

# Metacognition

- Executive processes; oversees the memory system
- Is rather late developing
- Can be improved through direct instruction & modeling
- Is largely independent of general ability

# Metacognition

## Knowledge of Cognition

**Declarative**
Knowledge of memory limitations

**Procedural**
Knowledge about Strategies

**Conditional**
Knowledge about When and Why to use Strategies

## Regulation of Cognition

**Planning**
Setting goals, Activating Background Knowledge, Budgeting Time

**Monitoring**
Observation of Performance

**Evaluation**
Reevaluating Goals, Revising Predictions

## Examples of Metacognition

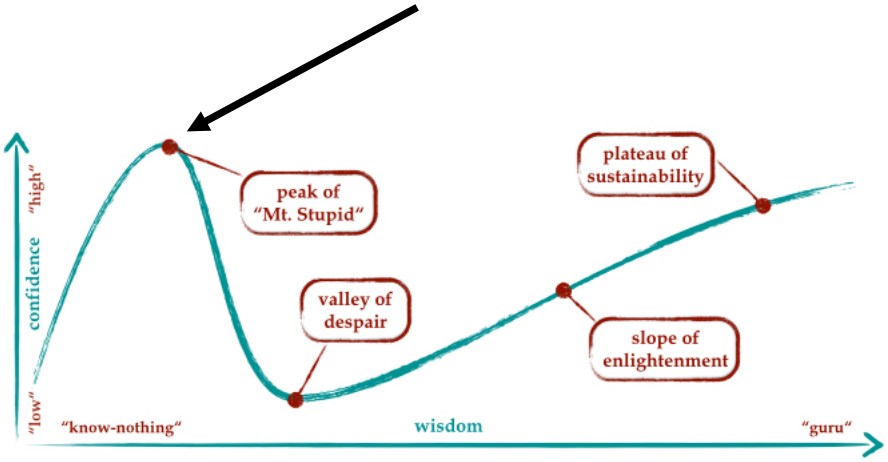
- Knowing how well you are doing on your psychology test
- Predicting how difficult a chemistry project will be
- Understanding how much you know about makes and models of cars
- Knowing what information is important to take away from class lecture
- Knowing how well you can ski

## Examples of Metacognition cont.

- Choosing one strategy over another when playing a board game
- Knowing if you have studied enough for the history exam
- Understanding and utilizing strategies that will make you a better setter in volleyball -- example
- Knowing when your performance on the trumpet was up to par
- Knowing which Trivial Pursuit categories you are strong and weak at

# Dunning-Kruger Effect

**"Unskilled and Unaware"**




http://www.understandinginnovation.wordpress.com

***"Having knowledge is only part of effective learning. It also is important to use one's knowledge strategically and to understand the strengths and limitations of one's knowledge."***

**(Bruning, Schraw, Ronning, 1999; p. 102)**

**This is the key distinction between metacognition and cognition.**

## Effective learners . . .

. . . accurately monitor and control their learning.

## Monitoring and Calibration

**Calibration is the degree to which one can match their *perception* of their performance with their *actual* level of performance.**

**Calibration is one measure of metacognitive monitoring accuracy**

**Is calibration related to performance?**
**Does prior knowledge improve calibration?**
**Can training and/or feedback improve calibration?**

## Is calibration related to performance?

**TABLE 2. Correlations Among Grade Point Average (GPA), Test Score, and Local Monitoring Accuracy**

| Test | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 GPA | — | .59** | –.76** | .67** | –.68** | .50** | –.44* | .64** | –.63** |
| 2 Test 1 score | | — | –.79** | .59** | –.62** | .63** | –.36** | .64** | –.58** |
| 3 Test 1 accuracy | | | | –.63** | .77** | –.60** | .46* | –.69** | .61** |
| 4 Test 2 score | | | | — | –.80** | .40* | –.32 | .69** | –.52** |
| 5 Test 2 accuracy | | | | | — | –.54** | .48* | –.74** | .69** |
| 6 Test 3 score | | | | | | — | –.64** | .70** | –.53** |
| 7 Test 3 accuracy | | | | | | | | –.36 | .69** |
| 8 Test 4 score | | | | | | | | — | –.63** |
| 9 Final exam accuracy | | | | | | | | | |

*$p < .05$. **$p < .01$.

Nietfeld, J. L., Cao, L., & Osborne, J. W. (2005). Metacognitive monitoring accuracy and student performance in the classroom. *Journal of Experimental Education, 74*(1), 7-28.

## Does prior knowledge improve calibration?

**Design:**

- **3 Groups with varied math background**
  - **Low Knowledge N=31**
  - **Mid Knowledge N=34**
  - **High Knowledge N=28**
- **Completed a test of math probability and general intelligence**
- **Provided monitoring judgments for each item**
- **The High Knowledge group significantly outperformed the other two groups *and* made significantly more accurate monitoring judgments**
- **No differences were found in general ability between the 3 groups**

Nietfeld, J. L., & Schraw, G. (2002). The role of knowledge and strategy training on metacognitive monitoring. *The Journal of Educational Research, 95*, 131-142.

## Can training and/or feedback improve calibration?

Monitoring accuracy on math probability problems by college students – Session 1=pretest, Session 2=after training (for Training group only), Session 3=after one week. Lower numbers equal higher accuracy.

**Table 3.—Means and Standard Deviations for Experiment 2**

| | Raven test performance | | Probability performance | | Probability confidence | | Probability bias | | Probability accuracy | | Self-efficacy | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Training | | | | | | | | | | | | |
| Session 1 | .64 | .23 | .58 | .12 | .70 | .13 | .14 | .15 | .37 | .09 | 35.02 | 8.79 |
| Session 2 | | | .68 | .13 | .79 | .12 | .10 | .15 | .29 | .08 | 33.88 | 9.01 |
| Session 3 | | | .62 | .10 | .78 | .13 | .16 | .15 | .35 | .08 | 34.07 | 8.82 |
| Control | | | | | | | | | | | | |
| Session 1 | .69 | .23 | .59 | .15 | .66 | .17 | .10 | .14 | .32 | .10 | 36.61 | 8.93 |
| Session 2 | | | .58 | .15 | .69 | .16 | .11 | .14 | .34 | .08 | 35.79 | 8.63 |
| Session 3 | | | .60 | .09 | .69 | .16 | .09 | .16 | .36 | .08 | 36.81 | 9.96 |

*Note*. Performance, confidence, and accuracy ranged from 0 to 1. Bias ranged from –1 to 1.

Nietfeld, J. L., & Schraw, G. (2002). The role of knowledge and strategy training on metacognitive monitoring. *The Journal of Educational Research, 95*, 131-142.

## Can training and/or feedback improve calibration?

No change in monitoring accuracy (calibration) in the absence of training or feedback.

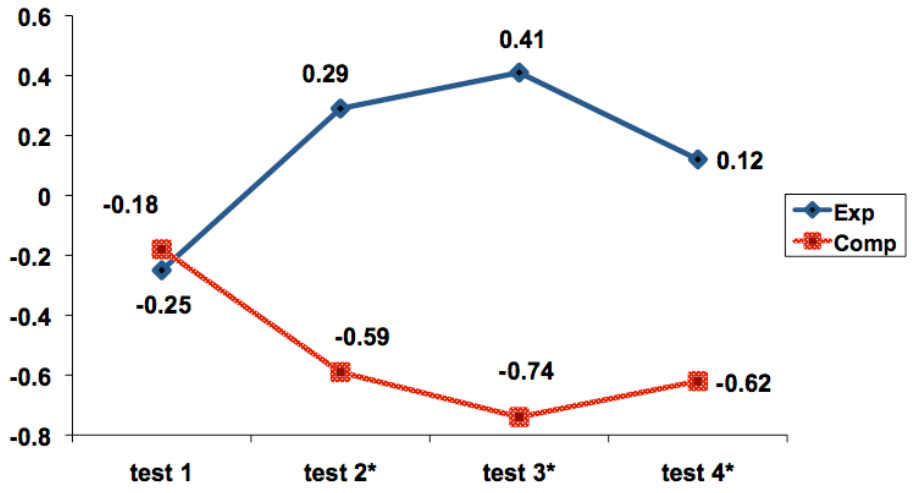
**TABLE 1. Means and Standard Deviations of Monitoring Accuracy, Bias, and Confidence, by Test**

| | | | Monitoring accuracy | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Score | | Local | | Global | | Bias | | Confidence | | |
| Item | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *n* |
| Test 1 | .78 | .13 | .29 | .11 | .13 | .10 | –.03 | .11 | .75 | .13 | 27 |
| Test 2 | .81 | .09 | .29 | .10 | .13 | .12 | –.05 | .12 | .76 | .13 | 27 |
| Test 3 | .76 | .13 | .35 | .12 | .26 | .18 | –.07 | .19 | .68 | .18 | 27 |
| Final | .81 | .12 | .28 | .11 | .11 | .11 | –.02 | .17 | .78 | .16 | 26 |
| GPA | 3.35 | .41 | | | | | | | | | 27 |

*Note.* GPA = grade point average.

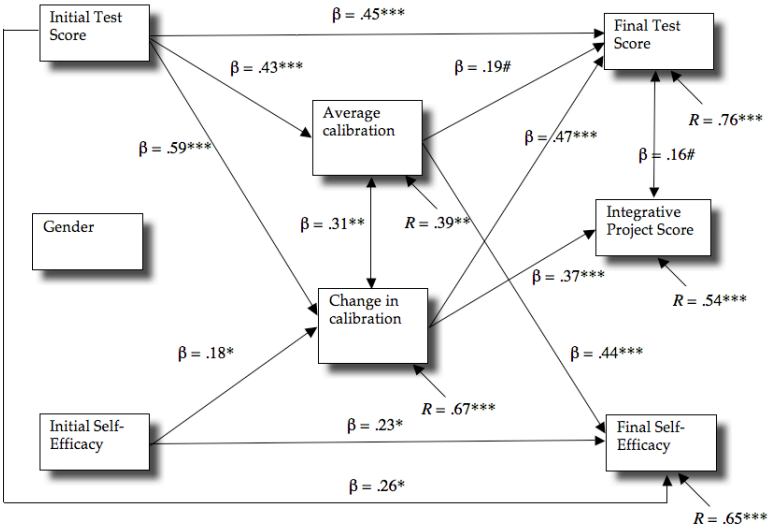
Nietfeld, J. L., Cao, L., & Osborne, J. W. (2005). Metacognitive monitoring accuracy and student performance in the classroom. *Journal of Experimental Education, 74*(1), 7-28.

## Can training and/or feedback improve calibration?



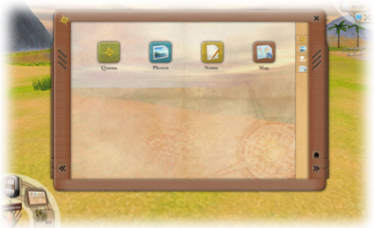

Nietfeld, J. L., Cao, L., & Osborne, J. W. (2006). The effect of distributed monitoring exercises and feedback on performance and monitoring accuracy. *Metacognition and Learning, 2,* 159-179.

## Can training and/or feedback improve calibration?




Nietfeld, J. L., Cao, L., & Osborne, J. W. (2006). The effect of distributed monitoring exercises and feedback on performance and monitoring accuracy. *Metacognition and Learning, 2,* 159-179.

# Crystal Island: Uncharted Discovery




## Overall Problem: Establishing Village Life

| Quest 1: Landform Identification | Quest 2: Map Navigation | Quest 3: Modeling |
|---|---|---|
| **Level 1** | **Level 1** | **Level 1** |
| The geographer asks the student to label three landforms (waterfall, dam, plateau). | The student is asked to navigate to three locations on the island using map coordinates and to pick up a flag at each location. The student can only carry three flags at a time. Flags can be picked up and dropped anywhere. Decoy flags are also present. | The student is asked to match a photo of the island with a model meant to represent that part of the island. |
| **Level 2** | **Level 2** | **Level 2** |
| The geographer asks the student to photograph three landforms (lake, delta, and tributary) that are identified on her blackboard by definition only. For example, the student would have to know that "a stream or river that flows into another river" is a tributary. | The student is asked to navigate to three locations on the island using compass points, map coordinates, and a map scale. The student must then take a picture of an animal at each location. Decoy animals are also present. | The student is asked to create a virtual model of the village. The cartographer gives the student an app for the virtual tablet that allows the student to arrange the hut models into the correct configuration. |

## What SRL variables predict performance in *Crystal Island – Uncharted Discovery* ?

***If Calibration is replaced by response bias $R^2$ increases to .62***

Note: Mastery Approach and Strategies Attribution were significant if using $p < .10$

*Regression Results Predicting Efficiency in*

Crystal Island - Uncharted Discovery

| Predictors | B | SE | β |
|---|---|---|---|
| Constant | 2548.65 | 868.18 | |
| Calibration | 2504.64 | 465.14 | .39*** |
| Treasure Chest Time | 2.85 | .79 | .25*** |
| Interest | -379.37 | 115.05 | -.24** |
| Luck Attribution | 186.28 | 70.85 | .19* |
| Mastery Approach | 151.04 | 79.99 | .16 |
| Strategies Attribution | -191.25 | 105.60 | -.14 |
| Map Access | -22.87 | 19.41 | -.09 |
| Prior Knowledge | -34.52 | 30.26 | -.09 |
| Effort Attribution | -87.46 | 118.90 | -.06 |
| Performance Approach | -21.00 | 40.48 | -.04 |
| Science Self-Efficacy | 91.88 | 200.69 | .04 |
| $R^2$ | | .521 | |

*Note.*

*$p < .05$, ** $p < .01$. *** $p < .001$.

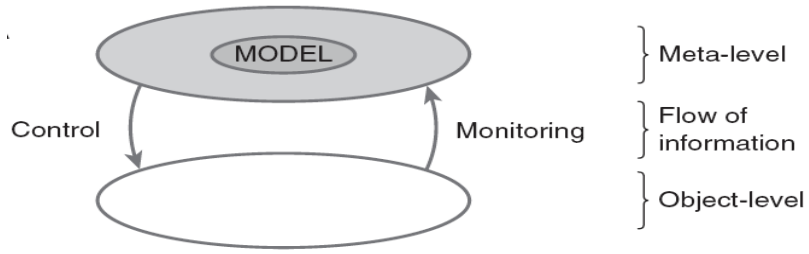
## Some Conclusions:

- ✓ **It appears that monitoring accuracy (calibration) is not strongly related to general ability, perhaps not related at all**
- ✓ **Background knowledge (at least within the domain of probability) appears to be an essential component in the development of accurate monitoring skills**
- ✓ **Strategy training appears to be an effective means by which to increase skill *and* monitoring accuracy**
- ✓ **Distributed strategy training over time appears to be necessary to ensure the maintenance of gains in monitoring accuracy**

## Effective learners . . .

. . . flexibly apply strategies.

## The "Knowing" and "Adjusting" Processes:




Adapted from Nelson & Narens (1990)

# A Good Strategy User . . .

- Has a broad repertoire of strategies
- Metacognitive knowledge about why, when, and where to use strategies
- Has a broad knowledge base
- Ignores distractions
- Is automatic in the four components described above

Pressley, Borkowski, and Schneider (1987)

**Description of Written Response Categories.**

| Category | Definition | Example |
|---|---|---|
| Externally-focused thoughts | Thoughts not directly related to the task | "Is there spit on my face?"; "My mind wonders,"; "I may think about school or a friend." |
| Planning | Thoughts related to pre-race preparations | "First I start warming up, usually to fast music, for it gets me pumped up to run." |
| Information Management Strategy (IMS) | Thoughts that reflect strategies that the runner employs during the competition | "Usually, I am thinking about dividing the race up into smaller parts, for instance, four 200s because it's easier to get through." |
| Monitoring | Thoughts runners have about their energy level, pain tolerance, or form | "I am thinking about how much I have left." |
| Debugging | Thoughts that reflect changes in strategies or adjustments during the race | "If it is not going well I am trying trying to fight negative feedback from my body and mind." |
| Evaluation | Thoughts that reflect back on a race | "I sometimes think that I am running hard and then when I finish I know that I could have gone harder." |

Nietfeld, J. L. (2003). An examination of metacognitive strategy use and monitoring skills by competitive middle distance runners. *The Journal of Applied Sport Psychology, 15*, 307-320.

External thoughts represented only 12% of the total recorded. In contrast, 41% of the responses were information management strategies, 42% of the responses involved monitoring, and more broadly, ***88% of the responses were internally-focused and metacognitive in nature***.

Runners missed their target mile time by an average of 9 seconds

The relationship between the Racing the Mile Questionnaire and the mile performance task (*r = –.44*). This correlation indicates that ***participants who report being more strategic when preparing for and racing a mile also show a tendency to be more accurate at monitoring their pace on a performance task***

4. Do you make adjustments in your running during the race?
5. Do you visualize and/or meditate about the race after you run?
6. If you are not racing well after a half-mile do you just finish without changing anything about your performance?
7. Do you make changes in your racing after watching highly successful runners?
8. Do you have a race plan when you are on the starting line?
9. Does the type and amount of training you do affect the way you race?
10. Do you adjust your pace to fit the race and the other runners?

Nietfeld, J. L. (2003). An examination of metacognitive strategy use and monitoring skills by competitive middle distance runners. *The Journal of Applied Sport Psychology, 15*, 307-320.

## A Self-Regulatory Approach to Study Strategies:

- Self-Checking
- Creating a productive physical environment
- Goal setting and planning
- Reviewing and organizing information after learning
- Summarizing during learning
- Seeking assistance
- Determining how much information to learn

## A Self-Regulatory Approach to Study Strategies:

- Determining how new information relates to existing knowledge
- Determining how information will be used
- Identifying main ideas and important information
- Predicting
- Monitoring
- Reflecting on previous learning

## 3 Levels of Cognitive Study Strategies

- **Basic Study Strategies**
  - Highlighting/Underlining/Note Taking
  - Don't take for granted that students know these!
- **Comprehension Monitoring Strategies**
  - Self-questioning/Summarizing
  - These are things you do "on-line" while learning
- **Critical Thinking**
  - Most important level--this is your goal!
  - What is critical thinking?

## Ten Essential Critical Thinking Skills

- Distinguishing between verifiable facts and value claims
- Distinguishing between relevant and irrelevant information, claims, or reasons
- Determining the factual accuracy of a statement
- Determining the credibility of a source
- Identifying ambiguous claims or arguments

## Ten Essential Critical Thinking Skills

cont.

- Identifying unstated assumptions
- Detecting bias
- Identifying logical fallacies
- Recognizing logical inconsistencies in a line of reasoning
- Determining the strength of an argument or claim

Taken from Beyer (1988)

## Teaching Metacognitive Strategy Regulation

- Model strategies that cut across domains
- Encourage students to transfer strategies (eliminate inert knowledge)
- Demonstrate why some strategies are better than others
- Explain when and where a strategy will be used
- Use checklists to help monitor

## Teaching Metacognitive Strategy Regulation

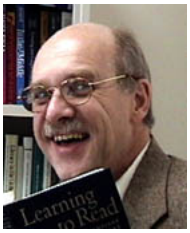
*cont.*

- Ask students to look back on their performance and determine what they did well and not so well on
- Provide students with cues such as SQ4R (survey, question, read, reflect, recite, review)
- Encourage the use and practice of many different strategies
- **Strategies are most effective when integrated within the curriculum as opposed to being taught as a stand-alone unit**

## Metacognitive Readers

- Readers Low in Metacognitive Abilities:
  - Lack awareness of process
  - Unconsciously incompetent
  - "Don't know that they don't know"
- Readers High in Metacognitive Abilities:
  - Realize there is a problem with reading
  - Don't know how to fix the problem
  - Consciously incompetent
  - "Know they don't know, but…"

## What the experts say:



**". . . In Vygotskian (1978) terms, the internalization of comprehension strategies involves long-term practice with the strategies, including opportunities to reflect on strategies used with others."**

**Michael Pressley, in *What Research Has to Say About Reading Instruction*, p. 291.**

## Some characteristics of the most successful reading comprehension programs:

- Emphasize direct explanation of cognitive strategies
- Introduce strategies gradually
- Maintain strategy instruction over an extended period of time
- Emphasize teacher modeling and think alouds
- Provide students with skills to make them successful independent readers
- Promotes reading as an active process of meaning making

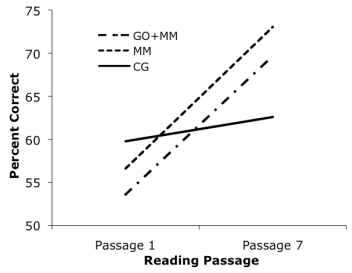
## Give metacognitive strategy instruction a chance to "sink in" . . .

Study in how 5th graders comprehend expository science text

In 4 conditions:
1) Graphic organizer + Metacognitive instruction
2) Metacognitive instruction
3) Graphic Organizer instruction
4) Traditional instruction

After 6 weeks an effect is found

Comprehension Score Change over Time, Controlling for Prior Knowledge




Hoffmann, K. F. (2010, dissertation)

## Using strategy instruction and confidence judgments to improve metacognitive monitoring skills

| Condition | Gates-MacGinitie Tests | Gates Confidence Judgments | Practice Passages | Prompted Self-Monitoring | Monitoring Accuracy Training |
|---|---|---|---|---|---|
| 1 Control | * | | * | | |
| 2 NI | * | * | | | |
| 3 CMT | * | * | * | * | |
| 4 CMT+MAT | * | * | * | * | * |

**CMT = Comprehension Monitoring Training**
**MAT = Monitoring Accuracy Training**

**Sessions every day for 2 weeks with 5th graders**

### Spider Specialties

*Read the following paragraph carefully, then answer the questions.*

Some spider webs are simply a tangle of silk threads that run in various directions between supports such as walls or furniture. Other webs, called orb webs, are made up of silk threads that form an intricate geometric pattern. Such webs can be over two feet wide. Some spiders create wide flat webs with a funnel shape in the center. The spider hides inside the funnel until an insect lands on the flat part of the web. The spider then runs from the funnel to grab the insect. Sheet webs are flat sheets of web that hang below crisscrossed threads of silk. When an insect flies into the crisscrossed threads, it falls onto the sheet of silk and the spider traps it.

**Self-Monitoring Statements**

a. This text makes sense to me and I understand it well.

*Strongly Agree* *Agree* *Disagree* *Strongly Disagree*

b. I am using fix-up strategies while reading this selection.

*Strongly Agree* *Agree* *Disagree* *Strongly Disagree*

c. I am confident that I could explain the main idea(s) of this text to someone else.

*Strongly Agree* *Agree* *Disagree* *Strongly Disagree*

**Comprehension Questions "Spider Specialties"**

1. In the selection, the word *intricate* means
   A. Shape
   B. Design
   C. Complicated
   D. Simple

0% Accurate _____ 100% Accurate

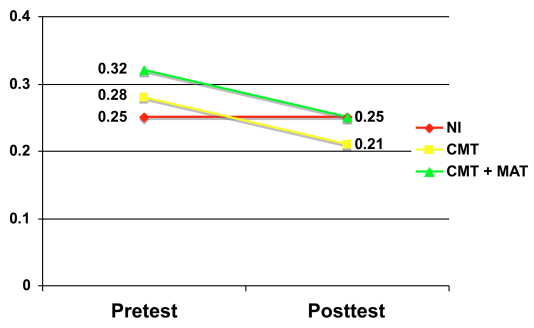
2. What is the main idea of this selection?
   A. Spiders are intelligent animals.
   B. There are many different kinds of spider webs.
   C. Spiders eat man types of insects.
   D. Spiders are excellent hunters.

0% Accurate _____ 100% Accurate

3. What is the purpose of the funnel shape in the center of wide flat webs?
   A. to keep the spider from scaring away possible meals
   B. to trap insects inside
   C. to make the webs pretty
   D. to hide insects

0% Accurate _____ 100% Accurate

**Both treatment conditions became more accurate than control condition**




**However, monitoring accuracy training became more biased towards overconfidence**

| Pretest calibration bias | | Posttest calibration bias | |
|---|---|---|---|
| *M* | SD | *M* | SD |
| 0.03 | (0.14) | 0.03 | (0.14) |
| −0.04 | (0.12) | 0.01 | (0.16) |
| 0.01 | (0.17) | 0.14 | (0.12) |
| 0.00 | (0.14) | 0.06 | (0.15) |

CMT + MAT

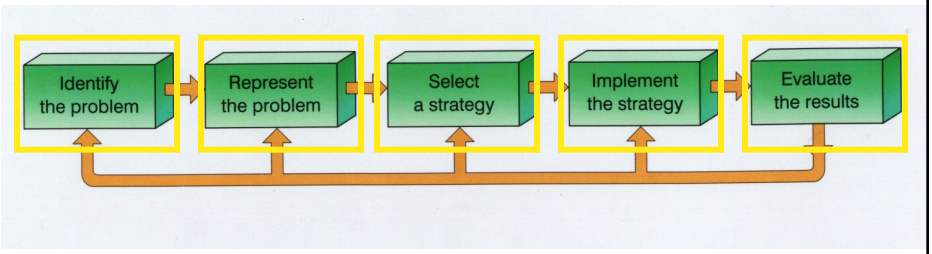
CMT

Huff, J. D., & Nietfeld, J. L. (2009). Using strategy instruction and confidence judgments to improve metacognitive monitoring skills. *Metacognition and Learning*, *4*, 161-176.

## Implications for Effective Learners:

- Above all, help learners to learn to be strategic. This includes helping them to learn many strategies and be flexible in using them
- Also, strategies are only effective when learners know when, where, and why they should apply them
- Teach learners to make a habit of actively reflecting on their learning

# General Problem-Solving Model




# Identifying the Problem:

- People are not in the habit of problem finding
- Enough background knowledge?
- People tend to be impulsive and not reflect on the nature of the problem
- Well-Defined vs. Ill-Defined

## Well versus Ill-Defined

***Ill-Defined***

- Desired goal unclear
- Information missing
- Several possible solutions

***Well-Defined***

- Goal clearly stated
- All information present
- Only one correct solution

## Representing the Problem:

- Consider external representations to relieve demands upon working memory and organize information (e.g. pictures, diagrams, charts)
- Experts spend proportionately more time at this stage than novices

## Selecting Strategies:

***Algorithm***

- Exhaustive
- Solution guaranteed

***Heuristic***

- Rules-of-thumb
- Efficient
- Solution not guaranteed
- Examples
  - ***Trial & Error***
  - ***Means End Analysis***
  - ***Analogy***
  - ***Working Backwards***

## Implementing the Strategy:

- Experts utilize more strategies (strategy shifting), consider more solutions, and evaluate solutions at a deeper level
- Convergent vs. Divergent thinking

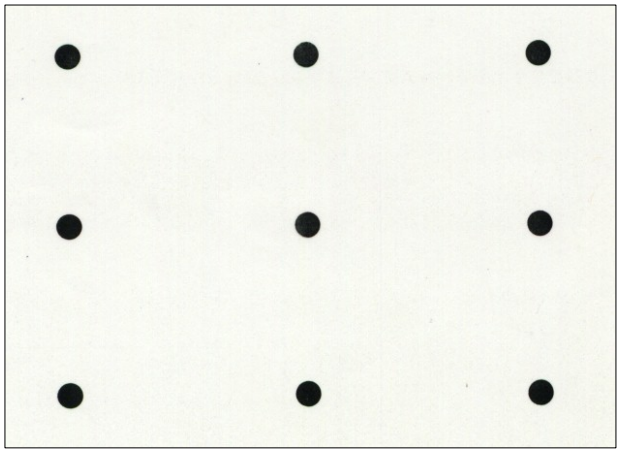
## *Convergent Thinking*

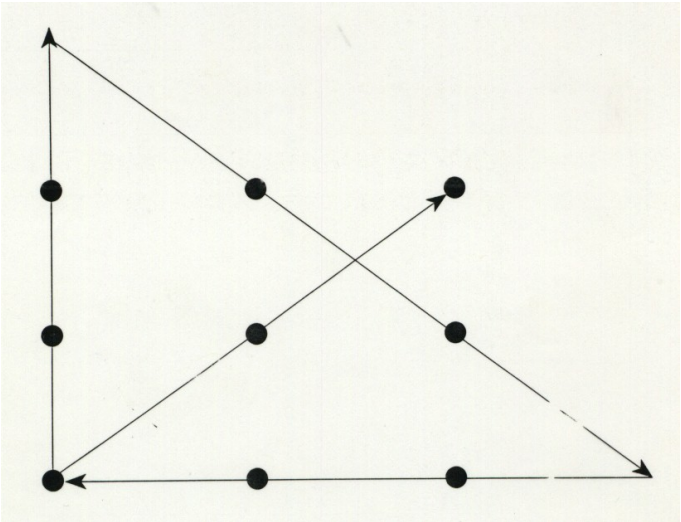
**Focus on one solution**

## *Divergent Thinking*

**Consider novel solutions**

## Nine Dot Problem





# What is Creativity?

*"Ability to produce work that is both novel and appropriate"*
(Sternberg & Lubart, 1996)

*"The capacity to perform mental work that leads to an outcome both novel and applicable."* (Pereira, 1999)

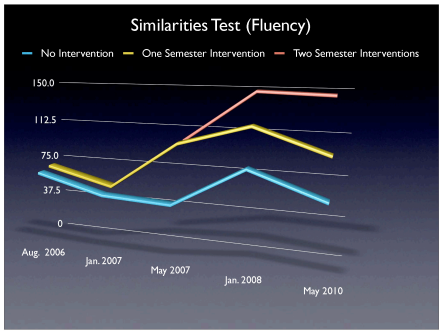
**NOVEL** -> original, unexpected

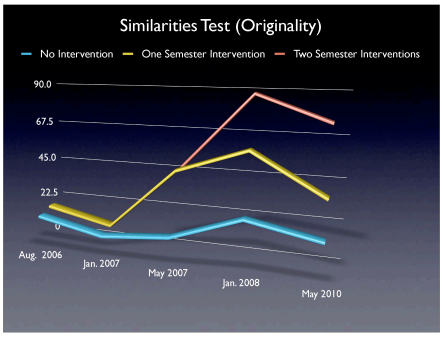
- => **Associative thinking – recombine existing knowledge with divergent approaches**

**PRODUCTIVE** -> appropriate, applicable, useful, meets task constraints, has a contribution

- => **Critical thinking – What you select out, focus on**

# Creativity & Metacognition




Hargrove, R. A., & Nietfeld, J. L. (2014). The impact of metacognitive instruction on creative problem solving. *Journal of Experimental Education*. DOI: 10.1080/00220973.2013.876604

# Fostering Creativity

- Show students that creativity is valued
- Focus on internal rewards
- Promote mastery of subject area
- Ask thought-provoking questions
- Encourage metacognitive strategies that support creative thinking
- Give students freedom, security to take risks

## Functional Fixedness

A condition that arises when we lose the ability to view familiar objects in a novel way

## Evaluating the Results:

- The chance to improve problem-solving skills rests at this stage and is very metacognitive in nature
- Teachers who are "reflective practitioners" spend more time at this stage
- The development of self-regulatory skills is dependent upon evaluation

***The Radiation Problem***

**Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue (Duncker, 1945)?**

*In solving this problem you may find that one of the stories you read before will give you a hint for a solution of this problem.*

TRANSFER

# Transfer of Learning

- Occurs when something learned at one time and place is applied in another setting
  - Transferring to another university
    - Schedule time with advisor
    - Knowing how to register for classes
    - Where to find information--library
- Most difficult challenge for teachers!
- People often don't realize the relevance of their prior knowledge in new situations
- Important to instill a "disposition for transfer" in your learners
- Need to reduce inert knowledge

## Factors Affecting Transfer

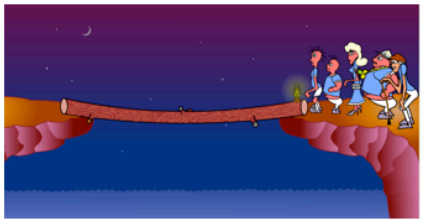
- Structured practice that promotes automated problem solving increases transfer
- Meaningful learning leads to greater transfer than rote learning
- Relate problem-solving skills in one domain to another by the use of analogy. Students should see material as context-free rather than context-bound
- Give numerous worked-out examples
- Similarity between two situations increases transfer
- Transfer is more likely when only a short amount of time has elapsed after students have studied a topic

## Applying problem solving . . .

In your groups try to solve the 2 problems on the following screen. In so doing, comment on:

- How the general problem solving model could help?
- What role does metacognition play?
- How would you encourage students to transfer their strategies to other problems?

***Family Bridge Problem***. Please help this family to cross to the other side of the bridge. Notice that: It is night, so you must have a lamp. Each person crosses the bridge at a different speed: 1 sec, 3 sec, 6 sec, 8 sec, and 12 seconds. The bridge can hold a maximum of 2 persons. A pair must walk together at the rate of the slower person. The lamp has only enough light for 30 seconds!



***Fun With Fuses***

**Assume you have a number of long fuses of which you only know that they burn for exactly one hour after you light them at one end. However, you don't know whether they burn with constant speed. Also assume that you have a lighter but no watch.**

**The Question: How can you measure exactly three quarters of an hour in time with these fuses?**
**Hint: Two fuses are sufficient to measure three quarters of an hour.**
**A second hint: A fuse can be lighted from both ends at the same time (which reduces its burning time significantly).**

## Implications for Effective Learners:

- **Effective learners are flexible problem solvers, they toggle between strategies, and think divergently/creatively**
- **Help learners develop skills in representing problems**
- **Teach general strategies (e.g. draw out the problem, take your time, consider many different strategies to solve the problem, utilize background knowledge)**
- **Teach learners strategies to cue themselves to consider background knowledge when solving a problem**

## Teaching Metacognitive Strategy Regulation

- Model strategies that cut across domains
- Encourage students to transfer strategies (eliminate inert knowledge)
- Demonstrate why some strategies are better than others
- Explain when and where a strategy will be used
- Use checklists to help monitor

## Effective learners . . .

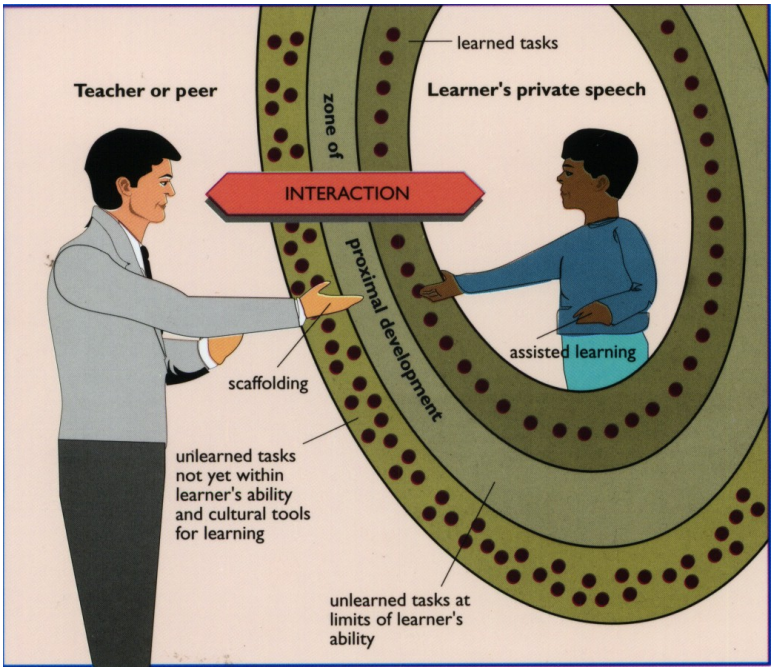
. . . learn through scaffolded apprenticeship.

# Vygotsky's Social Constructivism

## *Zone of Proximal Development*

*"the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers."*

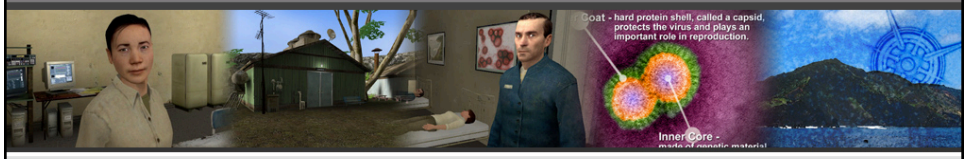
*Vygotsky, 1935*



# Research Team

- Interdisciplinary Coordination
  - Computer Science
  - Educational Psychology
  - Curriculum & Instruction
  - K-12 students and teachers
- Infrastructure
  - Computational: Game Technology
  - Personnel: Graphic Design & Animation

**Crystal Island – Outbreak**

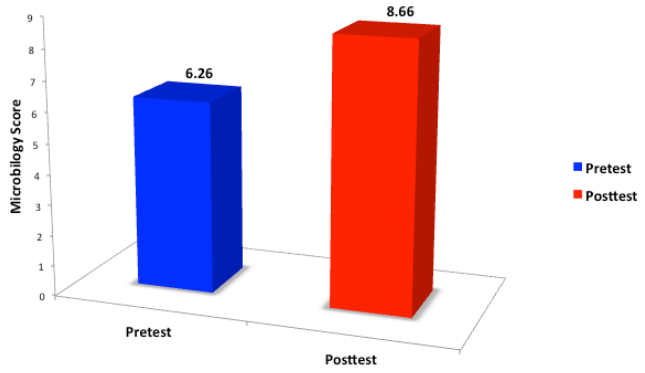



**Crystal Island – Uncharted Discovery**


# Crystal Island - Outbreak

# Results

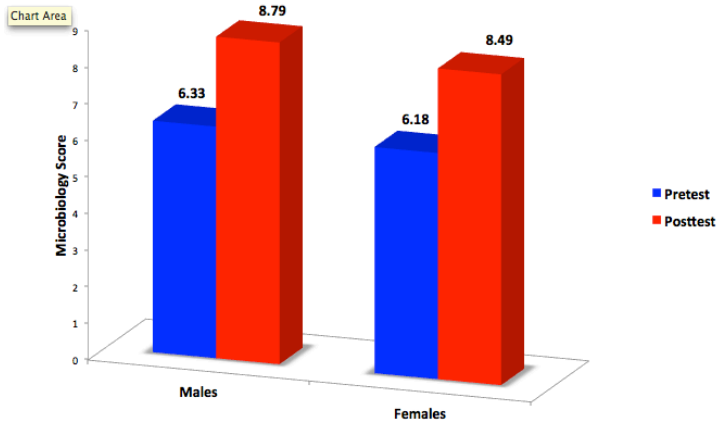
**What is the impact of playing CRYSTAL ISLAND on learning?**




**Significant increase in microbiology content scores**

# Results

**What is the impact of gender on performance in CRYSTAL ISLAND?**




**Both genders made significant increases in content knowledge but no differences between gender**

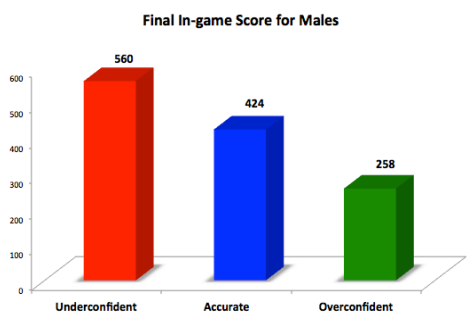
# Results

**What is the impact of gender on performance in CRYSTAL ISLAND?**

- **During gameplay, males completed significantly more goals than females although these group differences disappear when controlling for number of reported hours playing video games.**
- **Our findings suggest that males and females may be motivated to perform well in environments such as CRYSTAL ISLAND for different reasons and may regulate their performance differently to achieve similar outcomes.**
- **Predicting female performance was more elusive than male performance in our setting**

# Results

**The impact of overconfidence with males:**



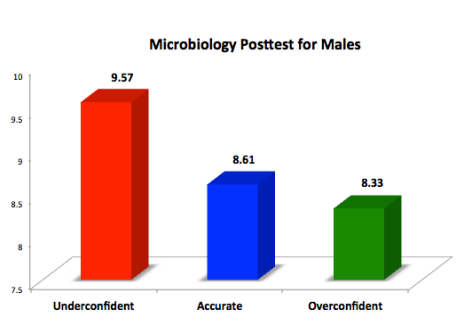



Table 1

*Differences in learning gains divided by diagnosis worksheet performance and prior knowledge differences*

| Measure | Low Worksheet Score $N = 59$ | | High Worksheet Score $N = 78$ | |
|---|---|---|---|---|
| | Low Prior Knowledge $N = 38$ | High Prior Knowledge $N = 21$ | Low Prior Knowledge $N = 32$ | High Prior Knowledge $N = 46$ |
| Microbiology Pre-Test | 4.50 (1.31)** | 7.86 (0.85)** | 5.12 (1.04)** | 8.13 (2.48)** |
| Microbiology Post-Test | 6.68 (2.39)** | 8.95 (2.78)** | 9.09 (2.82) | 10.04 (2.48) |
| Application-Level Content Pre-Test | 2.25 (1.20)** | 4.43 (1.21)** | 2.43 (1.04)** | 3.98 (1.14)** |
| Application-Level Content Post-Test | 3.42 (1.38)** | 4.62 (1.80)** | 4.17 (1.80) | 4.81 (1.35) |
| Fact-Level Content Pre-Test | 2.39 (1.32)** | 3.43 (0.87)** | 2.67 (0.99)** | 4.09 (1.06)** |
| Fact-Level Content Post-Test | 3.17 (1.65)* | 4.33 (2.00)* | 4.97 (1.45) | 5.21 (1.67) |

Note: ** - $p < .01$, * - $p < .05$

# Crystal Island – Uncharted Discovery

## Crystal Island: Uncharted Discovery

- Aligned with the NC 5th grade Standard Course of Study
  - Landform identification
  - Map skills (map interpretation, models)
  - Problem-solving skills
- Overall objective: shipwrecked crew must establish life on volcanic island
- Access to several resources
  - Experts– cartographer, geographer
  - Tablet– island map, IslandPedia, quest log, camera, problem-solving model

## Some things we know about problem solving in Crystal Island – Uncharted Discovery . . .

- Girls solve quests and learn content knowledge at similar rates to boys
- Ability to accurately predict performance (calibration) is a significant predictor of game play efficiency
- Time spent on "seductive" activities is negatively correlated with both game and content performance
- Problem-solving apps haven't helped in the short term studies

## Summary Recommendations from the Information Processing Model

- Overlearn to the point of **automaticity**
- Encourage **deeper processing**
- Help guide **selective attention**
- Remember that **meaning** drives learning & memory
- Develop not only knowledge but the ability to **monitor** one's learning
- **Strategies** rule!