Metacognition and Motivation: Advancing STEM Learning for ALL Students!

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Retired Asst. Vice Chancellor & Professor of Chemistry
Director Emerita, Center for Academic Success
Louisiana State University
Transforming STEM Education: Inquiry, Innovation, Inclusion, and Evidence will bring together... STEM faculty and academic leaders... to share innovations, evidence, and practical strategies for succeeding in the dual STEM challenges of:

- **Reversing the dramatic U.S. loss of needed talent in STEM disciplines**, using evidence-based practices that increase persistence and achievement for all students

- **Ensuring that all STEM graduates build**--from the outset of their studies--the **multi-disciplinary knowledge, research skills, and mindsets** needed to address the complex challenges to be faced in every sphere of society.
Desired outcomes

- We will understand why many STEM students do not know how to learn
- We will have concrete learning strategies that faculty can teach students to increase learning
- We will have more resources for our students
- We will view our students differently
- We will see positive changes in our students’ performance and self-perception
- We will understand how metacognition and increased motivation increase student success
Metacognition

The ability to:

- think about one’s own thinking
- be consciously aware of oneself as a problem solver
- monitor, plan, and control one’s mental processing (e.g. “Am I understanding this material, or just memorizing it?”)
- accurately judge one’s level of learning

Why haven’t most students developed metacognitive skills?
According to data from the entering class of 2011...*

- It wasn’t necessary in high school
  - 60.5% of 2011 (down from 63% in 2010) entering first year students spent less than six hours per week doing homework in 12th grade.
  - 49.7% of these students said they graduated from high school with an “A” average.*

- Students’ confidence level is high
  - 70.9 % believe their academic ability is above average or in the highest 10 percent among people their age

*2011 Higher Education Research Institute Study
Help students identify and close “the gap”

current behavior ➔ current grades

MIND THE GAP

productive behavior ➔ desired grades
Turn Students into Expert Learners:

Teach Them Metacognitive Learning Strategies!
Reflection Questions

• What’s the difference, if any, between *studying* and *learning*?

• For which task would you work harder?
  A. Make an A on the test
  B. Teach the material to the class
The Story of Two Students

- **Travis**, *junior psychology student*
  47, 52, **82, 86**  B in course

- **Dana**, *first year physics student*
  80, 54, **91, 97, 90 (final)**  A in course
Travis, junior psychology student
47, 52, 82, 86

Problem: Reading Comprehension

Solution: Preview text before reading*
Develop questions*
Read one paragraph at a time and paraphrase information

*Develop anticipatory set
WITH HOCKED GEMS FINANCING HIM/ OUR HERO BRAVELY DEFIED ALL SCORNFUL LAUGHTER/ THAT TRIED TO PREVENT HIS SCHEME/ YOUR EYES DECEIVE/ HE HAD SAID/ AN EGG/ NOT A TABLE/ CORRECTLY TYPifies THIS UNEXPLORED PLANET/ NOW THREE STURDY SISTERS SOUGHT PROOF/ FORGING ALONG SOMETIMES THROUGH CALM VASTNESS/ YET MORE OFTEN OVER TURBULENT PEAKS AND VALLEYS/ DAYS BECAME WEEKS/ AS MANY DOUBTERS SPREAD FEARFUL RUMORS ABOUT THE EDGE/ AT LAST/ FROM NOWHERE/ WELCOME WINGED CREATURES APPEARED/ SIGNIFYING MOMENTOUS SUCCESS

Anticipatory set CAN interfere!

Let’s look at the car on the next slide...
Dana, first year physics student
80, 54, 91, 97, 90 (final)

Problem: Memorizing formulas and using www.cramster.com

Solution: Solve problems with no external aids and test mastery of concepts
Why the Fast and Dramatic Increase?

It’s all about the *strategies*, and getting *them* to *engage their brains*!
Counting Vowels in 45 seconds

How accurate are you?

Count all the vowels in the words on the next slide.
Dollar Bill
Dice
Tricycle
Four-leaf Clover
Hand
Six-Pack
Seven-Up
Octopus
Cat Lives
Bowling Pins
Football Team
Dozen Eggs
Unlucky Friday
Valentine’s Day
Quarter Hour
How many *words* or *phrases* do you remember?
Let’s look at the words again...

What are they arranged according to?
Dollar Bill
Dice
Tricycle
Four-leaf Clover
Hand
Six-Pack
Seven-Up
Octopus
Cat Lives
Bowling Pins
Football Team
Dozen Eggs
Unlucky Friday
Valentine’s Day
Quarter Hour
NOW, how many words or phrases do you remember?
What were two major differences between the two attempts?

1. We knew what the task was

2. We knew how the information was organized
What we know about learning

• Active learning is more lasting than passive learning
  -- Passive learning is an oxymoron*

• Thinking about thinking is important
  – Metacognition**

• The level at which learning occurs is important
  – Bloom’s Taxonomy***

Bloom’s Taxonomy

Anderson & Krathwohl, 2001

Bloom’s Taxonomy

- **Remembering**: Retrieving, recognizing, and recalling relevant knowledge from long-term memory.
- **Understanding**: Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
- **Applying**: Carrying out or using a procedure through executing, or implementing.
- **Analyzing**: Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure.
- **Evaluating**: Making judgments based on criteria and standards through checking and critiquing.
- **Creating**: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

This pyramid depicts the different levels of thinking we use when learning. Notice how each level builds on the foundation that precedes it. It is required that we learn the lower levels before we can effectively use the skills above.

http://www.odu.edu/educ/llschult/blooms_taxonomy.htm
When we teach students about Bloom’s Taxonomy...

They GET it!
At what level of Bloom’s did you have to operate to make A’s or B’s in high school?

1. Knowledge  
2. Comprehension  
3. Application  
4. Analysis  
5. Synthesis  
6. Evaluation

<table>
<thead>
<tr>
<th>Level</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21%</td>
</tr>
<tr>
<td>2</td>
<td>35%</td>
</tr>
<tr>
<td>3</td>
<td>25%</td>
</tr>
<tr>
<td>4</td>
<td>13%</td>
</tr>
<tr>
<td>5</td>
<td>3%</td>
</tr>
<tr>
<td>6</td>
<td>3%</td>
</tr>
</tbody>
</table>
At what level of Bloom’s did you have to operate to make A’s or B’s in high school?

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

How students answered (2013)
At what level of Bloom’s do you think you’ll need to be to make an A in Chem 1201?

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation
How students answered (in 2013)

At what level of Bloom’s do you think you’ll need to be to make an A in Chem 1201?

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

<table>
<thead>
<tr>
<th>Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>6%</td>
<td>9%</td>
<td>23%</td>
<td>40%</td>
<td>11%</td>
<td>11%</td>
</tr>
</tbody>
</table>

1 2 3 4 5 6
How do we teach students to move higher on Bloom’s Taxonomy?

Teach them the Study Cycle*

*adapted from Frank Christ’s PLRS system
The Study Cycle

**Intense Study Sessions**

<table>
<thead>
<tr>
<th>Step</th>
<th>Task</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set a Goal</td>
<td>1-2 min</td>
</tr>
<tr>
<td>2</td>
<td>Study with Focus</td>
<td>30-50 min</td>
</tr>
<tr>
<td>3</td>
<td>Reward Yourself</td>
<td>10-15 min</td>
</tr>
<tr>
<td>4</td>
<td>Review</td>
<td>5 min</td>
</tr>
</tbody>
</table>

**Decide what you want to accomplish in your study session**

**Interact with material** - organize, concept map, summarize, process, re-read, fill-in notes, reflect, etc.

**Take a break** - call a friend, play a short game, get a snack

**Go over what you just studied**

**Preview**

**Preview before class** – Skim the chapter, note headings and boldface words, review summaries and chapter objectives, and come up with questions you’d like the lecture to answer for you.

**Attend**

**Attend class** – GO TO CLASS! Answer and ask questions and take meaningful notes.

**Review**

**Review after class** – As soon after class as possible, read notes, fill in gaps and note any questions.

**Study**

**Study** – Repetition is the key. Ask questions such as ‘why’, ‘how’, and ‘what if’.

- Intense Study Sessions* - 3-5 short study sessions per day
- Weekend Review – Read notes and material from the week to make connections

**Assess**

**Assess your Learning** – Periodically perform reality checks

- Am I using study methods that are effective?
- Do I understand the material enough to teach it to others?
Metacognitive Get Acquainted Activity*

• What do you believe is important to understand and learn in ________________________?
• What do you believe to be critical characteristics of successful students in ____________?
• How will you study and prepare for exams in ________________________________?

Two Valuable References


How Students Can Improve by Studying Themselves

Researchers at CUNY's Graduate Center push 'self-regulated learning'

Grazyna Niezgoda, a math instructor at New York City College of Technology, says most students eventually appreciate the new methods.
Starting from scratch: RIT program teaches first-year students how to learn

*Project seeks to retain deaf, hard-of-hearing and first-generation STEM majors*

Oct. 18, 2013
by Susan Gawlowicz
Follow Susan Gawlowicz on Twitter
Follow RITNEWS on Twitter

Starting college on the right foot—and in the right frame of mind—can make the difference between completing a bachelor’s degree and dropping out in the first or second year of school.

Rochester Institute of Technology is launching a $900,000 National Science Foundation-funded program to improve the retention of deaf, hard-of-hearing and first-generation undergraduates majoring in science, engineering and computer science. Between five and 10 percent of RIT’s students are deaf or hard of hearing. Many attend the National Technical Institute for the Deaf or receive support services—such as interpreting and notetaking—from NTID while enrolled in one of RIT’s other eight colleges.

RIT’s Project IMPRESS (Integrating Metacognitive Processes and Research to Ensure Student Success) seeks to teach students self-reflection and self-assessment skills—key components of metacognition, or thinking about how one thinks and learns.

“We know that all students—not just our target population—overestimate their understanding,” says Scott Franklin, professor in RIT’s School of Physics and Astronomy. “Helping students see reflection, assessment and metacognition as a fundamental part of how they learn can make a huge impact on their success.”
Help Students Develop the Right Mindset


Mindset* is Important!

- **Fixed Intelligence Mindset**
  Intelligence is static
  You have a certain amount of it

- **Growth Intelligence Mindset**
  Intelligence can be developed
  You can grow it with actions

New York: Random House Publishing
## Responses to *Many* Situations are Based on Mindset

<table>
<thead>
<tr>
<th></th>
<th>Fixed Intelligence Mindset Response</th>
<th>Growth Intelligence Mindset Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Challenges</strong></td>
<td>Avoid</td>
<td>Embrace</td>
</tr>
<tr>
<td><strong>Obstacles</strong></td>
<td>Give up easily</td>
<td>Persist</td>
</tr>
<tr>
<td><strong>Tasks requiring effort</strong></td>
<td>Fruitless to Try</td>
<td>Path to mastery</td>
</tr>
<tr>
<td><strong>Criticism</strong></td>
<td>Ignore it</td>
<td>Learn from it</td>
</tr>
<tr>
<td><strong>Success of Others</strong></td>
<td>Threatening</td>
<td>Inspirational</td>
</tr>
</tbody>
</table>
“…Personally, I am not so good at chemistry and unfortunately, at this point my grade for that class is reflecting exactly that. I am emailing you inquiring about a possibility of you tutoring me.”

April 6, 2011

“I made a 68, 50, (50), 87, 87, and a 97 on my final. I ended up earning a 90 (A) in the course, but I started with a 60 (D). I think what I did different was make sidenotes in each chapter and as I progressed onto the next chapter I was able to refer to these notes. I would say that in chemistry everything builds from the previous topic.

May 13, 2011

Semester GPA: 3.8
What happens when we **teach** metacognitive learning strategies, Bloom’s Taxonomy, and the Study Cycle **to an entire class**, not just individuals?
Performance in Gen Chem I in 2011
Based on One Learning Strategies Session

<table>
<thead>
<tr>
<th></th>
<th>Attended</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam 1 Avg.:</td>
<td>71.65%</td>
<td>70.45%</td>
</tr>
<tr>
<td>Exam 2 Avg.:</td>
<td>77.18%</td>
<td>68.90%</td>
</tr>
<tr>
<td>Final course Avg*:</td>
<td>81.60%</td>
<td>70.43%</td>
</tr>
</tbody>
</table>

Final Course Grade: B C

The one 50-min presentation on study and learning strategies resulted in an improvement of one full letter grade!
Metacognition: An Effective Tool to Promote Success in College Science Learning*
Ninfeng Zhao¹, Jeffrey Wardeska¹, Saundra McGuire², Elzbieta Cook²
¹Department of Chemistry, East Tennessee State University
²Department of Chemistry, Louisiana State University

*Accepted for publication April 2013
Motivation

“Motivation refers to the personal investment an individual has in reaching a desired state or outcome.”
(Ambrose et. al, 68)

“In the academy, the term ‘motivating’ means stimulating interest in a subject and, therefore, the desire to learn it.”
(Nilson, 57)
Three Important Levers that Influence Motivation

- **Value** – the importance of a goal (attainment, intrinsic, instrumental)
- **Supportive Nature of the Environment** – the instructor is approachable, support is available from peers and others
- **Efficacy Expectancies** – the belief that one is capable of identifying, organizing, initiating, and executing a course of action that will bring about a desired outcome

Ambrose et al., 80
Sharing Strategies that Have Worked for Others Can Be Very Motivational
Top 5 Reasons Folks Did Not Do Well on Test 1 in General Chemistry

1. Didn’t spend enough time on the material
2. Started the homework too late
3. Didn’t memorize the information I needed to memorize
4. Did not use the book
5. Assumed I understood information that I had read and re-read, but had not applied
Top 5 Reasons Folks Made an A on Test 1:

- 1. Did preview-review for every class
- 2. Did a little of the homework at a time
- 3. Used the book and did the suggested problems
- 4. Made flashcards of the information to be memorized
- 5. Practiced explaining the information to others
At the end of a 60 minute learning strategies presentation by the professor, students were given a survey to determine their self-assessment whether they were using or not using the strategies. The average scores of the different groups on the first two exams are shown below.

<table>
<thead>
<tr>
<th>Reported Use of Strategies</th>
<th>Exam 1</th>
<th>Exam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not use the strategies</td>
<td>58</td>
<td>54</td>
</tr>
<tr>
<td>Used metacognitive strategies</td>
<td>95</td>
<td>80</td>
</tr>
</tbody>
</table>
Changes Faculty Have Made that *Improved* Learning and Performance

- Provide learning strategies information to students after Test 1, and tell them about mindset
  
  *(Psychology Professor at Southern Crescent Technical College, 2013)*

- Increase the frequency of tests from three per semester to biweekly
  
  *(Mathematics Professor at Miles College, 2013)*

- Have students determine their learning style and write reflection on how they will use the information
  
  *(Entomology Professor at LSU, 2009)*

- Present one 50 minute session on metacognition, Bloom’s Taxonomy, and the Study Cycle
  
  *(Chemistry Professor at Middle Tennessee State University, 2012)*

- Teach students how to read
  
  *(Chemistry Professor at LSU, 2004)*
<table>
<thead>
<tr>
<th>Date</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/04</td>
<td>Failed</td>
<td></td>
</tr>
<tr>
<td>10/04</td>
<td>Failed</td>
<td></td>
</tr>
<tr>
<td>11/04</td>
<td>Failed</td>
<td></td>
</tr>
<tr>
<td>12/04</td>
<td>Failed</td>
<td></td>
</tr>
<tr>
<td>1/05</td>
<td>Passed</td>
<td>Began work with CAS and the Writing Center in October 2005</td>
</tr>
<tr>
<td>10/05</td>
<td>Passed</td>
<td></td>
</tr>
<tr>
<td>11/05</td>
<td>Failed</td>
<td></td>
</tr>
<tr>
<td>12/05</td>
<td>Passed best in group</td>
<td></td>
</tr>
<tr>
<td>1/06</td>
<td>Passed</td>
<td></td>
</tr>
<tr>
<td>2/06</td>
<td>Passed</td>
<td></td>
</tr>
<tr>
<td>3/05</td>
<td>Failed</td>
<td></td>
</tr>
<tr>
<td>4/06</td>
<td>Passed last one!</td>
<td></td>
</tr>
<tr>
<td>5/06</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
... and from the perspective of a faculty member who learned metacognitive strategies as a student

“...I am happy to report to you that many of my students are using the study cycle and all of the outcomes are positive. In summary, students who were failing all of their classes, including my course and in their final semester before being removed from the university are now the top students in their respective classes. I am so proud of these students. Many of the students stated to me that they will continue to use the study cycle.....”

October 15, 2010
Algernon Kelley, Xavier University Chemistry Instructor
From a Xavier University student to Dr. Kelley in Fall 2011

Oct. 17, 2011

Hello Dr. Kelley. ... I am struggling at Xavier and I REALLY want to succeed, but everything I've tried seems to end with a "decent" grade. I'm not the type of person that settles for decent. What you preached during the time you were in Dr. Privett's class last week is still ringing in my head. I really want to know how you were able to do really well even despite your circumstances growing up. I was hoping you could mentor me and guide me down the path that will help me realize my true potential while here at Xavier. Honestly I want to do what you did, but I seriously can't find a way how to. Can I please set up a meeting with you as soon as you’re available so I can learn how to get a handle grades and classes?

Oct. 24, 2011

Hey Dr. Kelley, I made an 84 on my chemistry exam (compared to the 56 on my first one) using your method for 2 days (without prior intense studying). Thanks for pointing me in the right direction. I’ll come by your office Friday and talk to you about the test.

Nov 3, 2011

Hey Dr. Kelley! I have increased my Bio exam grade from a 76% to a 91.5% using your system. Ever since I started your study cycle program, my grades have significantly improved. I have honestly gained a sense of hope and confidence here at Xavier. My family and I are really grateful that you have taken time to get me back on track.
Knowledge of Metacognition Greatly Increases URM Student Success

- They are less likely to have been cognitively challenged in high school
- They are less likely to be encouraged to stick with it
- They are more likely to experience the impact of a paradigm shift
LA-STEM SCHOLARS

Percentage of total Scholars Served by Ethnicity & Gender: 2003-2011

Six-Year Graduation Rates in STEM

<table>
<thead>
<tr>
<th></th>
<th>*LA-STEM Research Scholars Program</th>
<th>Highly Selective Institutions</th>
<th>Louisiana State University</th>
<th>Selective Institutions</th>
<th>Moderately Selective Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>92.3%</td>
<td>51.8%</td>
<td>33.8%</td>
<td>37.4%</td>
<td>25.3%</td>
</tr>
<tr>
<td>Male</td>
<td>94.9%</td>
<td>52.8%</td>
<td>38.1%</td>
<td>38.1%</td>
<td>25.7%</td>
</tr>
<tr>
<td>Female</td>
<td>90.2%</td>
<td>49.8%</td>
<td>28.2%</td>
<td>36.0%</td>
<td>24.7%</td>
</tr>
<tr>
<td>Black</td>
<td>92.3%</td>
<td>34.4%</td>
<td>28.4%</td>
<td>26.7%</td>
<td>12.2%</td>
</tr>
</tbody>
</table>

LSU Office of Strategic Initiatives
Teaching and Learning Strategies That Work

SCIENCE, VOL 325
4 SEPTEMBER 2009
www.sciencemag.org

ROALD HOFFMANN\textsuperscript{1*} AND SAUNDRA Y. MCGUIRE\textsuperscript{2}

\textsuperscript{1}Department of Chemistry and Chemical Biology, Cornell University, Baker Laboratory, Ithaca, NY 14853, USA.

\textsuperscript{2}Center for Academic Success and Department of Chemistry, Louisiana State University, Baton Rouge, LA 70803, USA.
MARGINALIA

Learning and Teaching Strategies

Roald Hoffmann and Saundra Y. McGuire
Conclusion

We can significantly increase learning by...

- teaching students how to learn
- making learning visible
- making the implicit explicit
- not judging student potential on initial performance
- encouraging students to persist in the face of initial failure
- encouraging the use of metacognitive tools
Special Note

Please visit the CAS website at www.cas.lsu.edu. We have on-line workshops that will introduce you and your students to effective metacognitive strategies. Please feel free to contact me at smcgui1@lsu.edu.

Have fun teaching your students powerful metacognitive strategies!

Saundra McGuire
Useful Websites

• www.cas.lsu.edu
• www.howtostudy.org
• www.vark-learn.com
• www.drearlbloch.com
• Searches on www.google.com
**Additional References**


[http://academic.pg.cc.md.us/~wpeirce/MCCCTR/metacognition.htm](http://academic.pg.cc.md.md.us/~wpeirce/MCCCTR/metacognition.htm)

*Excellent student reference*
Acknowledgments

- Sarah Baird & LSU Center for Academic Success
- Prof. Isiah Warner, Dr. Zakiya Wilson and the LSU Office of Strategic Initiatives
- Dr. Elzbieta Cook, LSU General Chem Instruct
- National College Learning Center Association
- Prof. Roald Hoffmann, mentor and collaborator
- All of the faculty who implemented these strategies and provided feedback
- All of the students who changed their attitudes and behaviors and showed me what was possible!