Teach STEM Students HOW to Learn: Metacognition is the Key!

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MISSION STATEMENT

To create a **transformative educational experience** for students focused on **deep disciplinary knowledge; problem solving; leadership, communication, and interpersonal skills; and personal health and well-being.**

To cultivate a transformative university community committed to (a) **attracting and retaining diverse, world-class talent**; (b) creating a collaborative environment open to the free exchange of ideas, where research, creativity, innovation, and entrepreneurship can flourish; and (c) **ensuring individuals can achieve their full potential**...
Carnegie Mellon University Retention and Graduation Rates

CMU Retention Rate is **98%**!
National Average is 71%
Pennsylvania Average is 78%

CMU Six-Year Graduation Rate is **88.3%**
National Average is 47.6%

Expected UTC Rate is **92.0%**

www.collegefactual.com/colleges/carnegie-mellon-university/academic-life/academic-life/academic-life/
How *Might* Carnegie Mellon Improve These Rates?

- Teach Students Metacognitive Learning Strategies To Improve Students’ Capability
- Help Students Develop the Right Mindset to Improve Their Confidence
- Motivate Students to Implement Effective Metacognitive Learning Strategies
Metacognition

The ability to:

- think about your own thinking
- be consciously aware of yourself as a problem solver
- monitor, plan, and control your mental processing (e.g. “Am I understanding this material, or just memorizing it?”)
- accurately judge your level of learning
- know what you know and what you don’t know

Power of Metacognitive Learning Strategies

Sydnie’s Story: Intro and emails

- First encounter on September 23, 2013
- Email on October 14, 2013
- Email on January 9, 2014
- Email on May 7, 2014
- Update on July 26, 2016  Cum GPA 3.5
- Email on February 7, 2017  Cum GPA 3.6
  Sem GPA 4.18
Effective Homework Strategy

• **Study material first**, before looking at the problems/questions

• **Work example problems** (without looking at the solutions) until you get to the answer

• **Check** to see if answer is correct

• If answer is not correct, **figure out where mistake was made**, without consulting solution

• **Work homework** problems/answer questions as if taking a test
The Story of Two More 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
A Reading Strategy that Works: SQ5R

- **Survey** (look at intro, summary, bold print, italicized words, etc.)
- **Question** (devise questions survey that you think the reading will answer)
- **Read** (one paragraph at a time)
- **Recite** (summarize in your own words)
- **Record or wRite** (annotate in margins)
- **Review** (summarize the information in your words)
- **Reflect** (other views, remaining questions)
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

* Developing an 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

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
Dana Lewis, MS in Medical Physics, 2015
Univ of Texas Graduate School
of Biomedical Sciences at Houston
Thesis research at UT MD Anderson Cancer Center

Practicing Medical Physicist as of 8/28/2016
when she completed her residency!
Faculty Must Help Some Students Make the Transition to College

Help students identify and close “the gap”

current behavior $\rightarrow$ current grades

MIND THE GAP

productive behavior $\rightarrow$ desired grades
Welcome

Academic Development is the place to go for help with your academic work. We offer peer tutoring, academic coaching in study skills, supplemental instruction and EXCEL collaborative learning groups for traditionally difficult courses. Our programs are available to all Carnegie Mellon University students and are designed to help both students who are having academic difficulties and those who just want to improve their academic performance. The peer tutoring, study skills, supplemental instruction and EXCEL components of Academic Development utilize group and individualized instruction to accommodate the diverse learning styles and skill levels of the student population.
How do you think most students would answer the following?

- What did most of your teachers in high school do the *day before the test*?
- What did they *do* during this activity?
- What grade would you have made on the test if you had gone to class *only* on the day before the test?
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
Why Is Such Fast and Dramatic Increase Possible?

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.
<table>
<thead>
<tr>
<th>Dollar Bill</th>
<th>Cat Lives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dice</td>
<td>Bowling Pins</td>
</tr>
<tr>
<td>Tricycle</td>
<td>Football Team</td>
</tr>
<tr>
<td>Four-leaf Clover</td>
<td>Dozen Eggs</td>
</tr>
<tr>
<td>Hand</td>
<td>Unlucky Friday</td>
</tr>
<tr>
<td>Six-Pack</td>
<td>Valentine’s Day</td>
</tr>
<tr>
<td>Seven-Up</td>
<td>Quarter Hour</td>
</tr>
<tr>
<td>Octopus</td>
<td></td>
</tr>
</tbody>
</table>
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

Creating
Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

Evaluating
Making judgments based on criteria and standards through checking and critiquing.

Analyzing
Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure.

Applying
Carrying out or using a procedure through executing, or implementing.

Understanding
Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.

Remembering
Retrieving, recognizing, and recalling relevant knowledge from long-term memory.

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

They GET it!
How do you think students answered?

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

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating
How do you think students answered?

At what level of Bloom’s do you think you’ll need to operate to make A’s in college courses?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating
At what level of Bloom’s did you have to operate to make A’s or B’s in high school?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating

How students answered (2013)
How students answered (in 2013)

At what level of Bloom’s do you think you’ll need to operate to make A’s in college?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating
At what level of Bloom’s did you have to operate to make A’s and B’s in high school?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating

How students answered (2014)
At what level of Bloom’s do you think you’ll need to operate to make A’s in college?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating

How students answered (in 2014)
At what level of Bloom’s did you have to operate to make A’s and B’s in high school?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating

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**How students answered (2017)**

- **Remembering**: 38%
- **Understanding**: 22%
- **Applying**: 22%
- **Analyzing**: 13%
- **Evaluating**: 6%
- **Creating**: 0%
At what level of Bloom’s do you think you’ll need to operate to make A’s in college?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating
At what level of Bloom’s do you think you’ll need to operate to make A’s and B’s in high school?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating

How students answered (in 2018)
At what level of Bloom’s do you think you’ll need to operate to make A’s in college?

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating

How students answered (in 2018)
How do we teach students to move higher on Bloom’s Taxonomy?

Teach them the Study Cycle*  

*adapted from Frank Christ’s PLRS system
1. Set a Goal (1-2 min) - Decide what you want to accomplish in your study session
2. Study with Focus (30-50 min) - Interact with material: organize, concept map, summarize, process, re-read, fill-in notes, reflect, etc.
3. Reward Yourself (10-15 min) - Take a break: call a friend, play a short game, get a snack
4. Review (5 min) - Go over what you just studied

*Intense Study Sessions

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

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

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 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?

Center for Academic Success
B-31 Coates Hall • 225.578.2872 • www.cas.lsu.edu
The intense study sessions helped me most. I actually got A+ on 3 out of 4 of my finals using that method of studying. It’s important to use it everyday before finals week, and I think it would really benefit students during finals week.
Why is using the textbook so important?
An activity will demonstrate this

- What word comes to mind when you see c_t?
- Would this word have come to your mind if we lived in a culture that had no cats and you’d never seen the word?
- Our brains automatically fill in missing information if we’re very familiar with the content (txt msgs)
- Does your brain have the info to fill in what’s missing in graduate courses?
- Will the test be written from what YOUR brain or the professor’s brain sees in the notes?
Email from a Spring 2011 Chemistry 1201 Student

“...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>
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</table>

**Final Course Grade:** B C

The one 50-min presentation on study and learning strategies was followed by an improvement of one full letter grade.

Performance in Gen Chem 1202 Sp 2013 Based on One Learning Strategies Session

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<tr>
<th></th>
<th>Attended</th>
<th>Absent</th>
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</thead>
<tbody>
<tr>
<td>Exam 1 Avg:</td>
<td>71.33%</td>
<td>69.27%</td>
</tr>
<tr>
<td>Homework Total:</td>
<td>169.8</td>
<td>119.1</td>
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<tr>
<td>Final course Avg*:</td>
<td><strong>82.36%</strong></td>
<td><strong>67.71%</strong></td>
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<tr>
<td><strong>Final Course Grade:</strong></td>
<td><strong>B</strong></td>
<td><strong>D</strong></td>
</tr>
</tbody>
</table>

The 50-min presentation on study and learning strategies was followed by an improvement of two letter grades
Performance in Gen Chem 1202 Sp 2015 Based on One Learning Strategies Session

<table>
<thead>
<tr>
<th></th>
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<th>Absent</th>
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</thead>
<tbody>
<tr>
<td>Exam 1, 2, 3 Avg:</td>
<td>68.14%</td>
<td>69.67%</td>
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<td>Exam 4 Avg:</td>
<td>83.45%</td>
<td>75.91%</td>
</tr>
<tr>
<td>Final Exam Avg:</td>
<td>80.98%</td>
<td>75.24%</td>
</tr>
<tr>
<td>Final course Avg*:</td>
<td>84.90%</td>
<td>78.83%</td>
</tr>
</tbody>
</table>

**Final Course Grade:** B     C

The 50-min presentation on study and learning strategies after exam 3 was followed by an improvement of one letter grade
Metacognition: An Effective Tool to Promote Success in College Science Learning*

Ningfeng Zhao¹, Jeffrey Wardeska¹, Saundra McGuire², Elzbieta Cook²

¹Department of Chemistry, East Tennessee State University
²Department of Chemistry, Louisiana State University

*March/April 2014 issue of JCST, Vol. 43, No. 4, pages 48-54
Professor Ningfeng Zhao’s Exam Averages

Intervention:
One fifty minute learning strategies session after Exam 1

## Professor Nina Stein’s Exam Averages in Organic Chemistry

<table>
<thead>
<tr>
<th>EXAM</th>
<th>AVERAGE</th>
<th>AVERAGE</th>
<th>AVERAGE*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Fall 2013</td>
<td>Fall 2014</td>
</tr>
<tr>
<td>1</td>
<td>69.25</td>
<td>70.06</td>
<td>77.42</td>
</tr>
<tr>
<td>2</td>
<td>79.40</td>
<td>73.33</td>
<td>86.17</td>
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<tr>
<td>3</td>
<td>70.35</td>
<td>73.38</td>
<td>85.12</td>
</tr>
<tr>
<td>final</td>
<td>66.00</td>
<td>63.06</td>
<td>82.17</td>
</tr>
</tbody>
</table>

*The semester I did the study skills workshop

**Intervention:** One twenty minute learning strategies session after Exam 1

Nina Stein, University of Connecticut, personal communication, April 4, 2015
Three Common Demands from Students in Large Lecture Classes*

- **Provide Presentation Slides Before Lecture**
  - *Helps with notetaking and cuing prior knowledge*

- **Make Practice Tests Available**
  - *Helps students “train their brains to make the kinds of mental maneuvers we expect of them*
  - *Helps with notetaking and cuing prior knowledge*
  - *Having them write a question engages them in higher order thinking and promotes their metacognitive abilities*

- **Implement More Active Learning or More Teaching**
  - *Research supports the value of active learning, but some students don’t like it. Explaining its value helps.*

Hodges, Linda C, *National Teaching and Learning Forum*, Volume 25, Number 5, September 2016, as reprinted in February 26, 2017 “Tomorrow’s ProfessorSM eNewsletter, sponsored by the Stanford Center for Teaching and Learning and provided by Rick Reis.
<table>
<thead>
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<th>Date</th>
<th>Result</th>
<th>Date</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/04</td>
<td>Failed</td>
<td>10/05</td>
<td>Passed</td>
</tr>
<tr>
<td>10/04</td>
<td>Failed</td>
<td>11/05</td>
<td>Failed</td>
</tr>
<tr>
<td>11/04</td>
<td>Failed</td>
<td>12/05</td>
<td>Passed best in group</td>
</tr>
<tr>
<td>12/04</td>
<td>Failed</td>
<td>1/06</td>
<td>Passed</td>
</tr>
<tr>
<td>1/05</td>
<td>Passed</td>
<td>2/06</td>
<td>Passed</td>
</tr>
<tr>
<td>2/05</td>
<td>Failed</td>
<td>3/06</td>
<td>Failed</td>
</tr>
<tr>
<td>3/05</td>
<td>Failed</td>
<td>4/06</td>
<td>Passed last one!</td>
</tr>
<tr>
<td>4/05</td>
<td>Failed</td>
<td>5/06</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Began work with CAS and the Writing Center in October 2005
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.
Conclusion

We can significantly increase learning by...

- teaching students how to learn
- making learning visible
- not judging student potential on initial performance
- encouraging students to persist in the face of initial failure
- encouraging the use of metacognitive tools for deep and integrative learning
Useful Websites

- [www.cas.lsu.edu](http://www.cas.lsu.edu)
- [www.howtostudy.org](http://www.howtostudy.org)
- [www.vark-learn.com](http://www.vark-learn.com)
- [www.drearlbloch.com](http://www.drearlbloch.com)
Additional References


http://academic.pg.cc.md.us/~wpeirce/MCCCTR/metacognition.htm

*Excellent student reference*
Just out in January...
A Book for Students