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

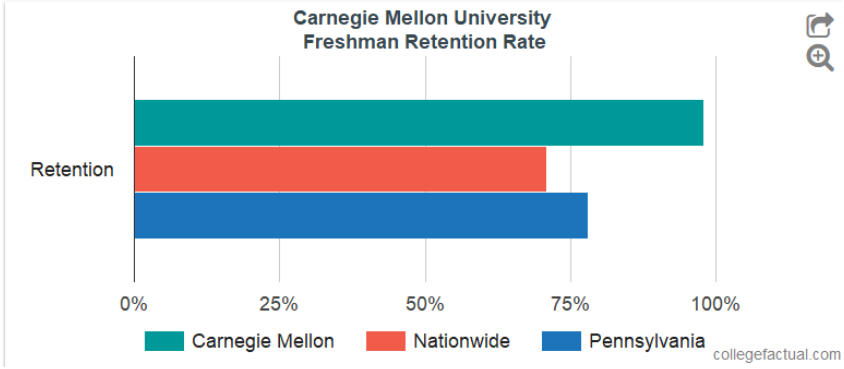
Carnegie Mellon Freshmen Retention Rate Rankings

Nationwide Ranking (89 out of 2,225)

worse — better

Pennsylvania Ranking (4 out of 136)

worse — better



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

Nationwide Rankings for First-Time / Full-time Graduation Rates at Carnegie Mellon

Four Year Graduation Rate Ranking (144 out of 2,136)

worse — better

Six Year Graduation Rate Ranking (157 out of 3,836)

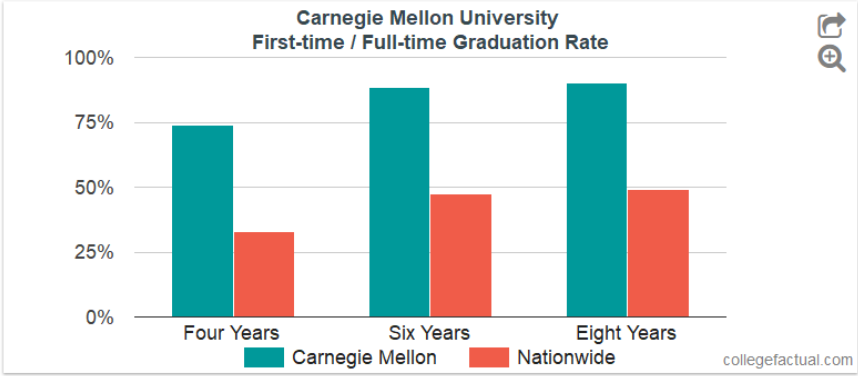
worse — better

Eight Year Graduation Rate Ranking (145 out of 3,835)

worse — better

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/graduation-and-retention/

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

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), The nature of intelligence (pp.231-236). Hillsdale, NJ: Erlbaum

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

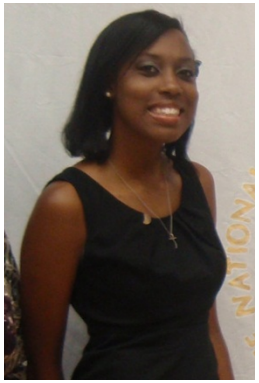
First Voyage of Christopher Columbus

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

Dooling, J.D. and Lachman, R. Effects of Comprehension on Retention of Prose, *Journal of Experimental Psychology,* (1971), Vol. 88, No. 2, 216-222

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* → ***current grades***

productive *behavior* → ***desired grades***

A VERY Valuable Partner

Carnegie Mellon University

Search

Academic Development

The Learning Zone

The Learning Zone ACADEMIC DEVELOPMENT

About | Academic Coaching | EXCEL Groups | Peer Tutoring | Supplemental Instruction | Student Jobs | Give Now | Resources

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.

Schedules

- Walk-in Tutoring Schedule
- SI Schedule
- Workshops

Resources

- Fast Facts
- I'm a CMU student and I need advice on...

for Grad Students

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*?

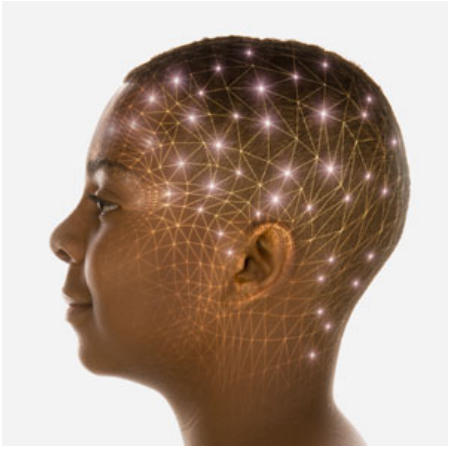
- For which task would you work harder?

  A. Make an A on the test

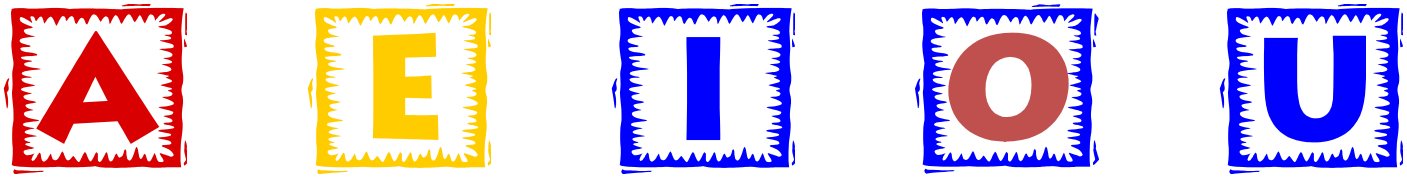
  B. Teach the material to the class

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.

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

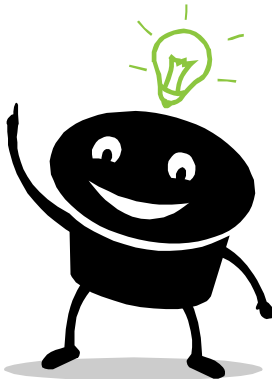
Cat Lives
Bowling Pins
Football Team
Dozen Eggs
Unlucky Friday
Valentine’s Day
Quarter Hour

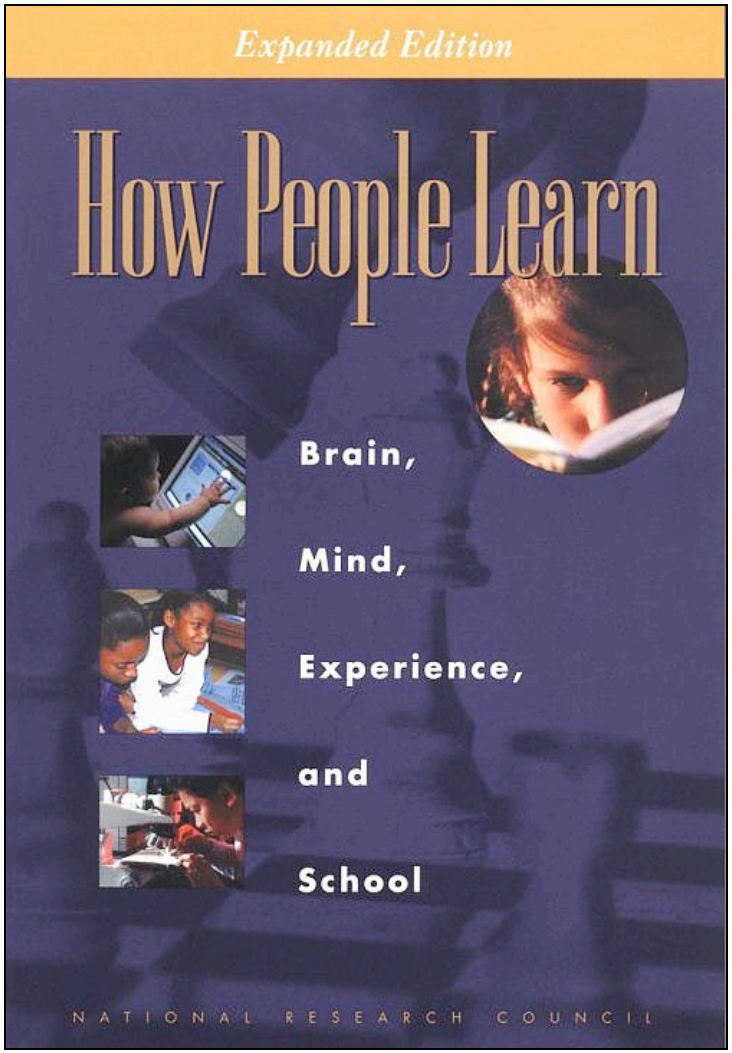
NOW, how many words or phrases do you remember?

What were two major *differences* between the two attempts?

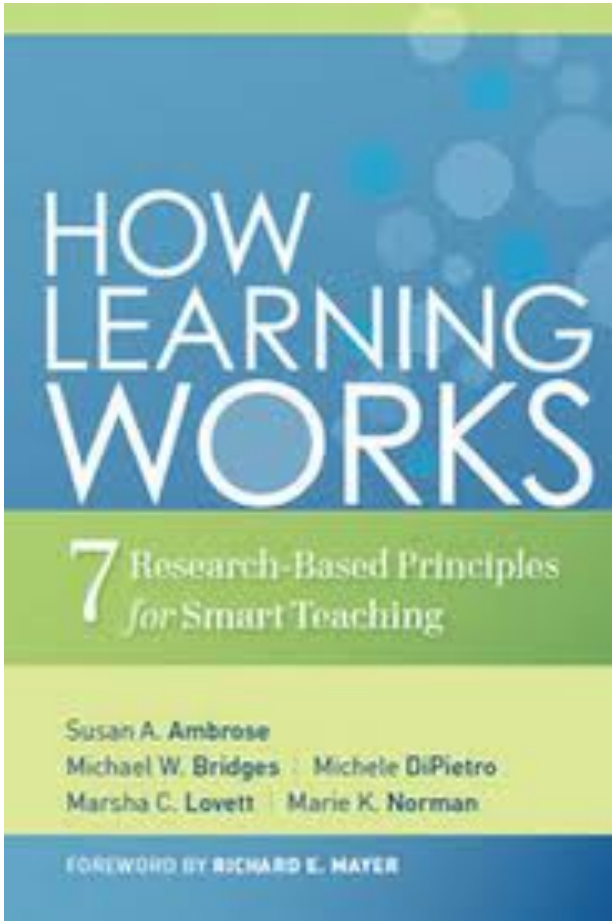
1. We knew what the task was

2. We knew how the information was organized





Bransford, J.D., Brown, A.L., Cocking, R.R. (Eds.), 2000. *How people learn: Brain, Mind, Experience, and School.* Washington, DC: National Academy Press.



Ambrose, S.A., Bridges, M.W., DiPietro, M., Lovett, M.C., Norman, M.K. (2010) *How Learning Works: Seven Research-Based Principles for Smart Teaching*. San Francisco, CA: Jossey Bass.

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***

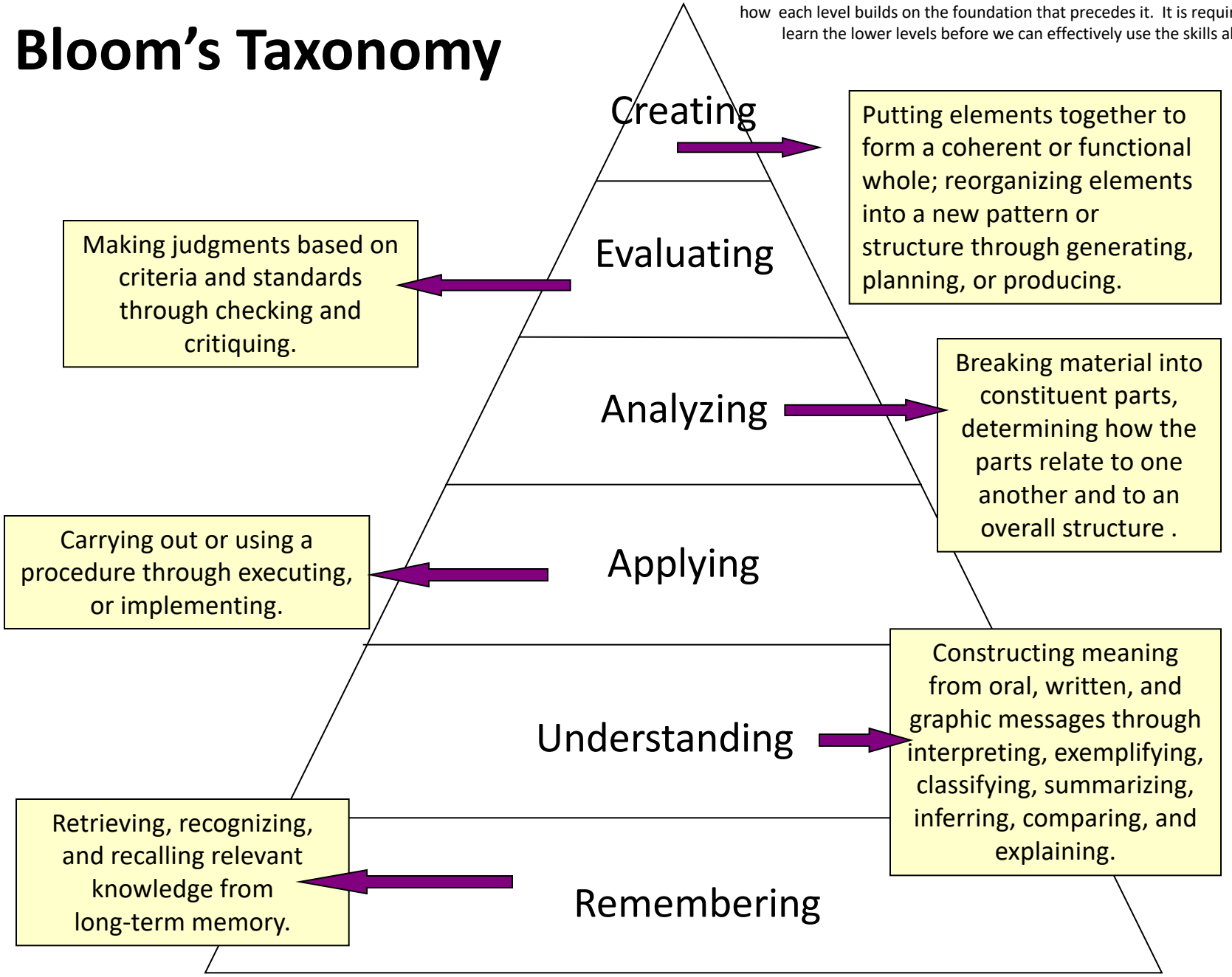
*Cross, Patricia, "Opening Windows on Learning" League for Innovation in the Community College, June 1998, p. 21.

** Flavell, John, "Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry." *American Psychologist*, Vol 34(10), Oct 1979, 906-911.

*** Bloom Benjamin. S. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain.* New York: David McKay Co Inc.

Bloom's Taxonomy

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!

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?

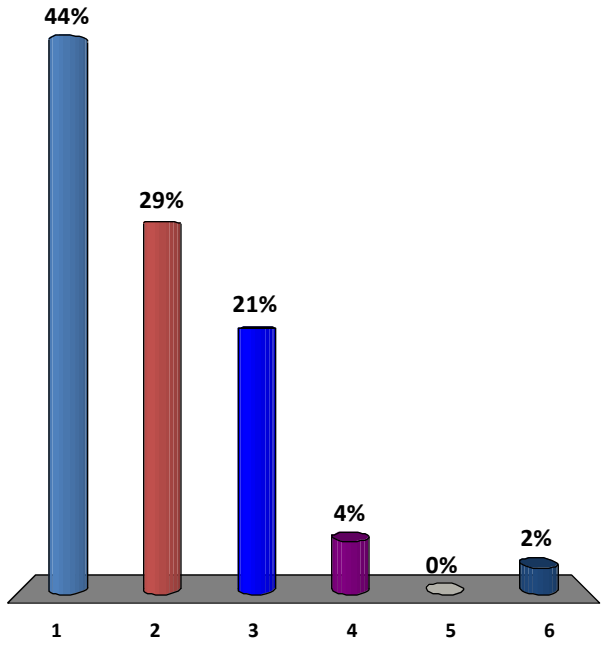
At what level of Bloom's do you think you'll need to operate to make A's in college courses?

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

How students answered (2013)

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 (in 2013)

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

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2. Understanding
3. Applying
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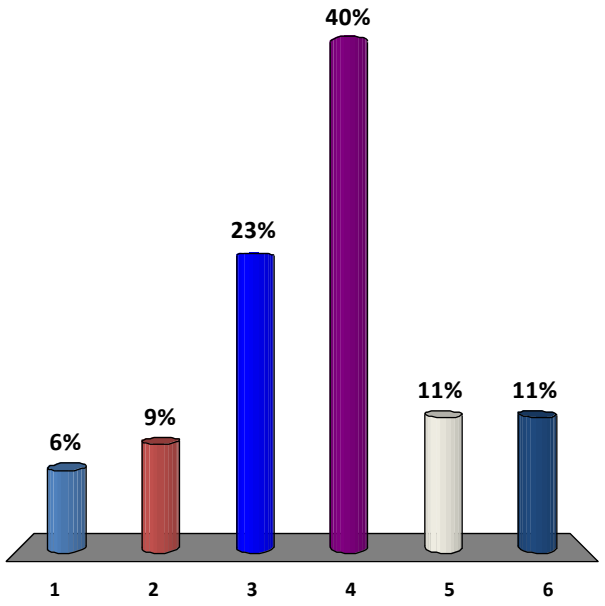
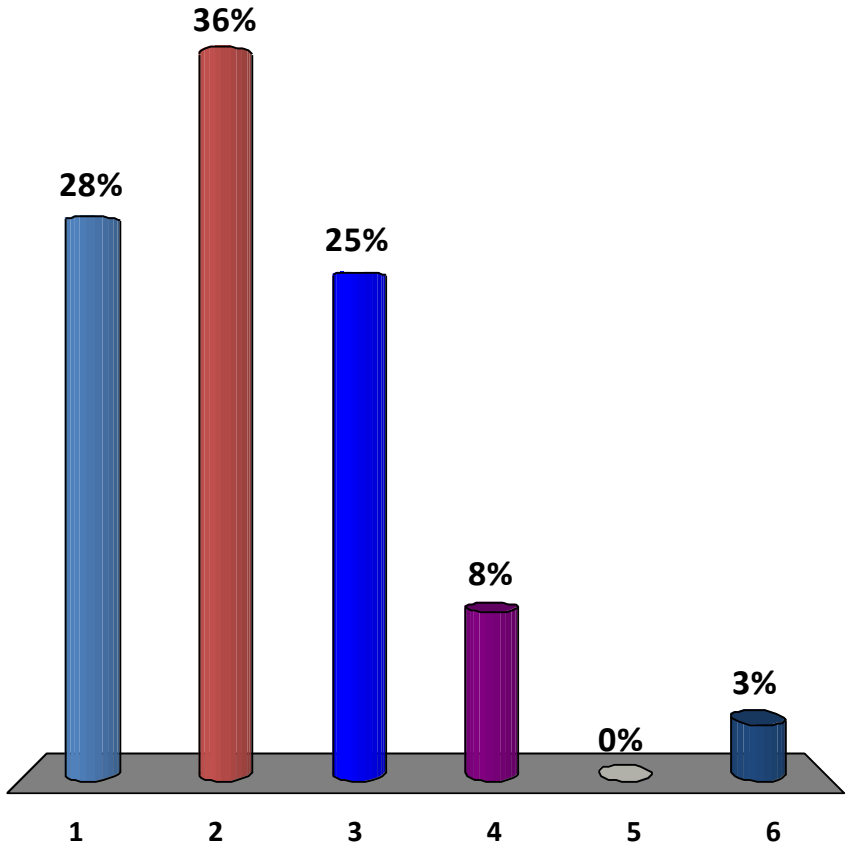
6. Creating



How students answered (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



How students answered (in 2014)

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

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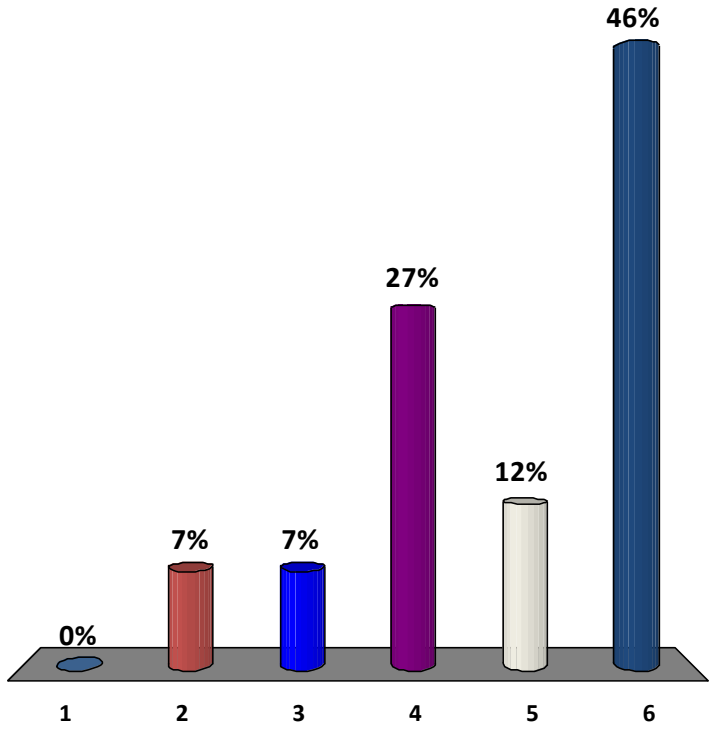
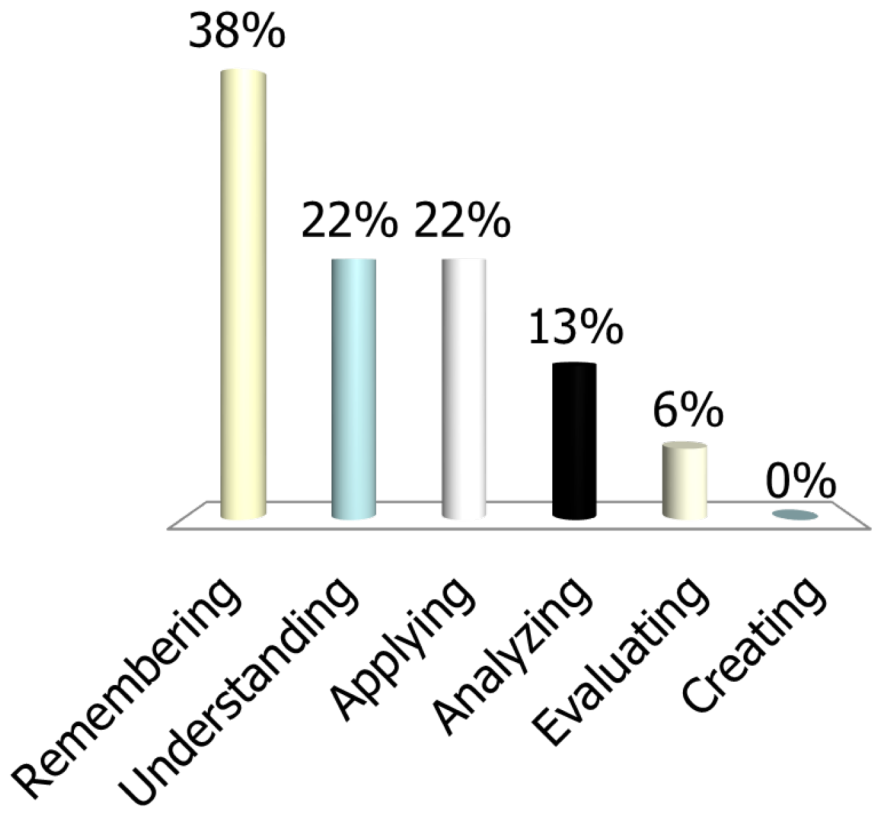


How students answered (2017)

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

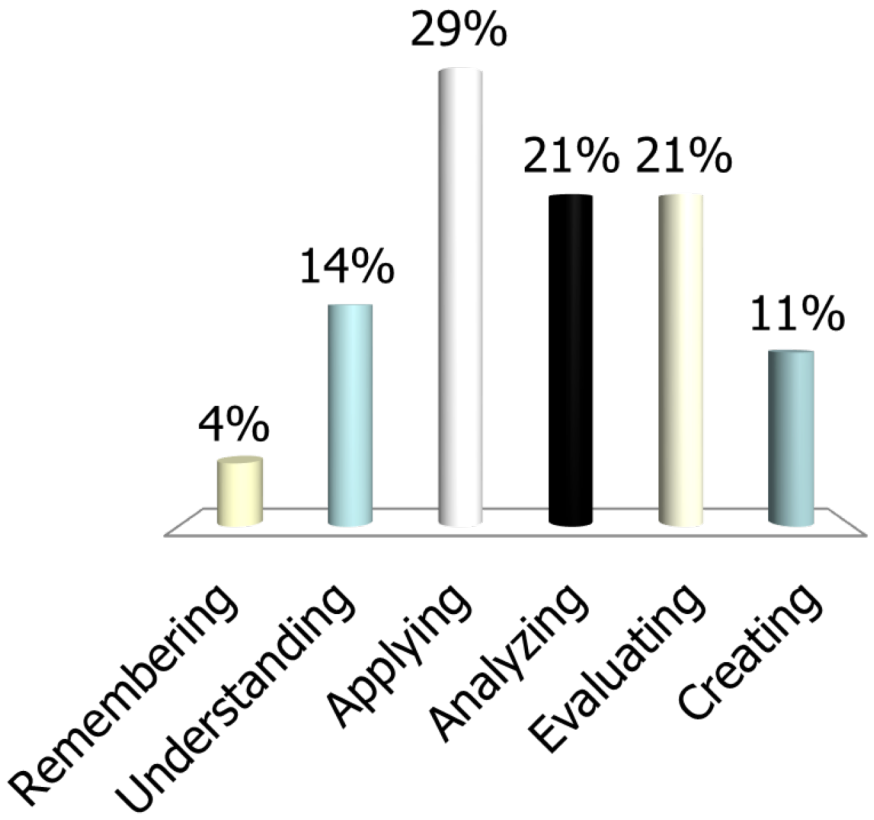
1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating



How students answered (in 2017)

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

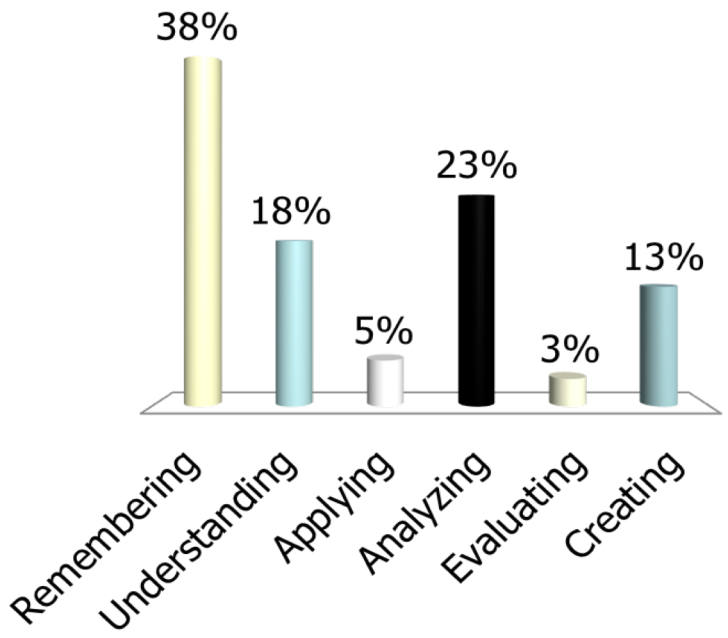
1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating



How students answered (in 2018)

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
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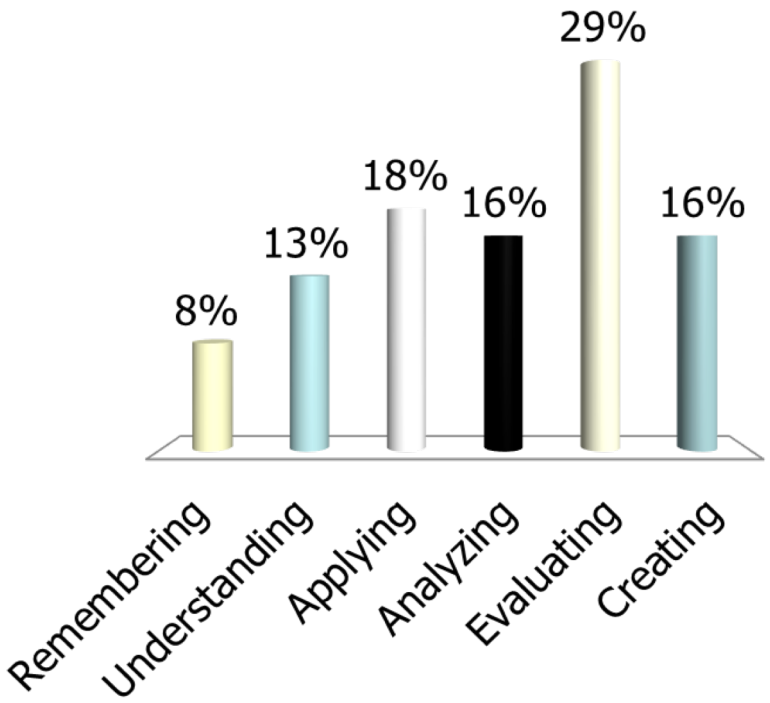
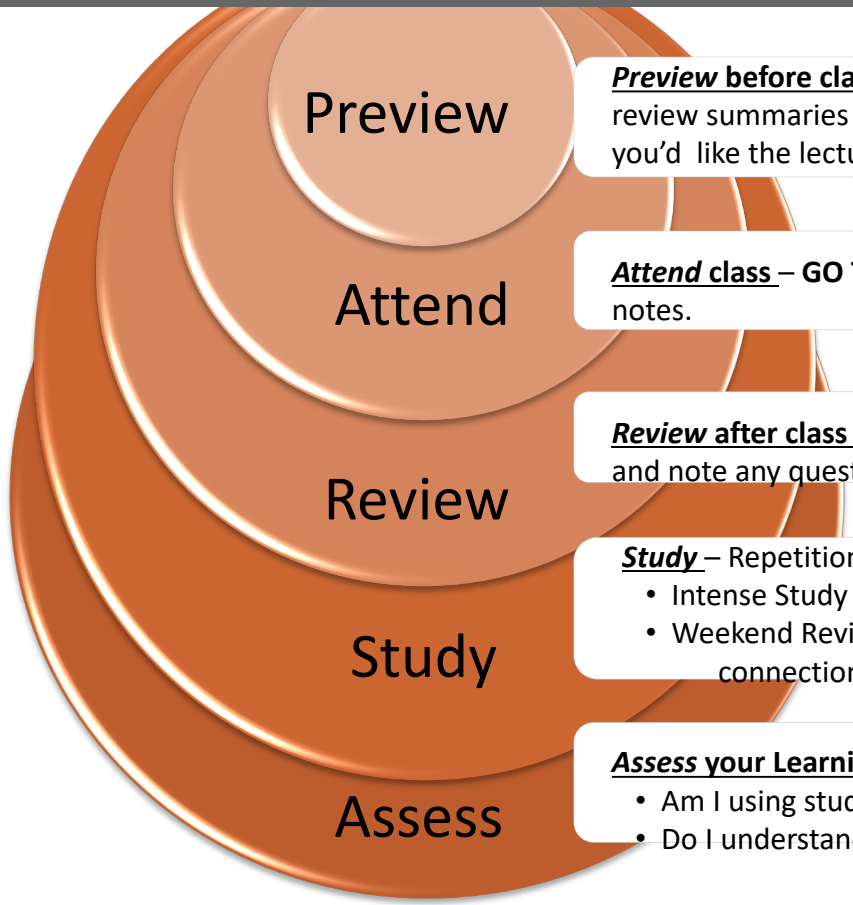


How do we teach students to move *higher* on Bloom's Taxonomy?

Teach them the Study Cycle*

adapted from Frank Christ's PLRS system

The Study Cycle



***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?

*Intense Study Sessions

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**

Brea Manuel, BS in Chemistry, 2018
Entering PhD Program at Emory University on Full Fellowship in Fall 2018

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*

	Attended	Absent
Exam 1 Avg:	71.65%	70.45%
Exam 2 Avg:	77.18%	68.90%
Final course Avg*:	81.60%	70.43%
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

***Cook, E.; Kennedy, E.; McGuire, S. Y. *J. Chem. Educ.*, 2013, 90 (8), 961–967**

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

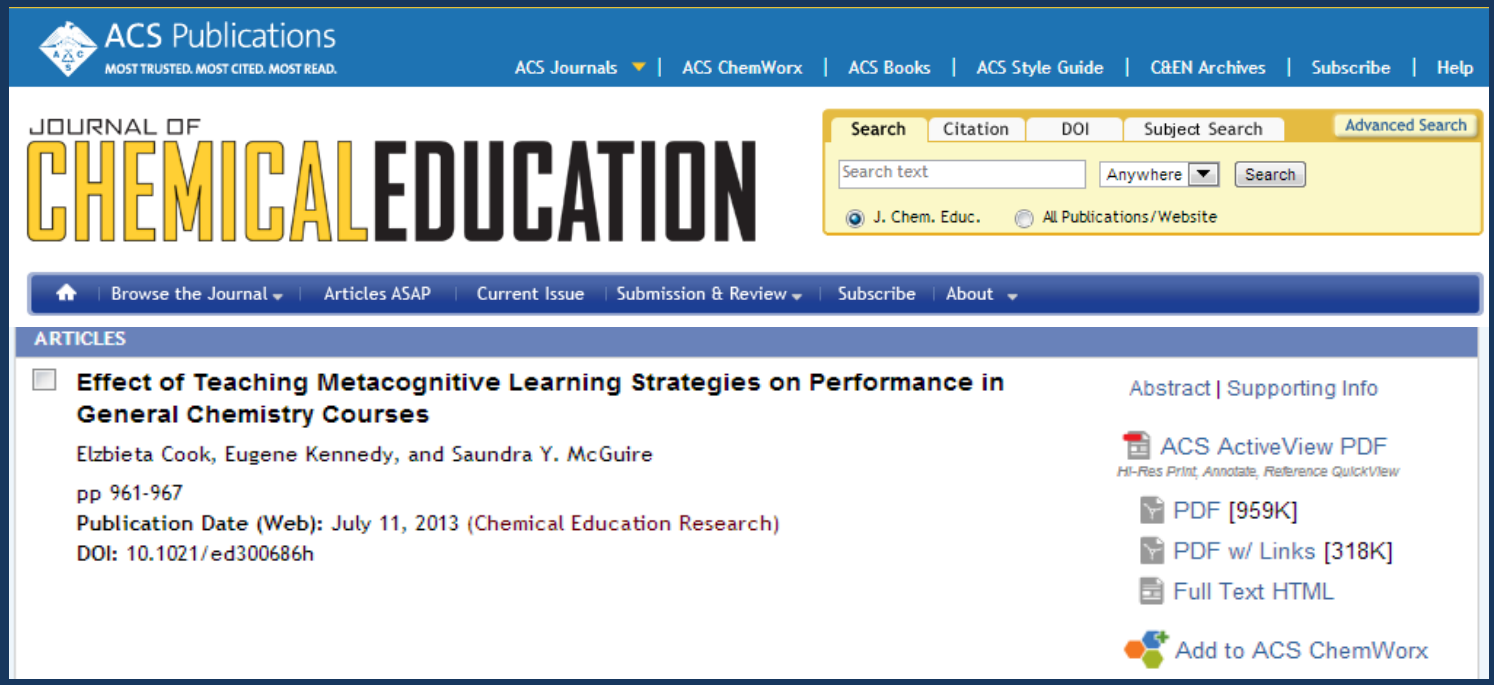
	Attended	Absent
Exam 1 Avg:	71.33%	69.27%
Homework Total:	169.8	119.1
Final course Avg*:	82.36%	67.71%
Final Course Grade:	**B**	**D**

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

	Attended	Absent
Exam 1, 2, 3 Avg:	68.14%	69.67%
Exam 4 Avg:	83.45%	75.91%
Final Exam Avg:	80.98%	75.24%
Final course Avg*:	84.90%	78.83%
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



Journal of College Science Teaching

Metacognition: An Effective Tool to Promote Success in College Science Learning*

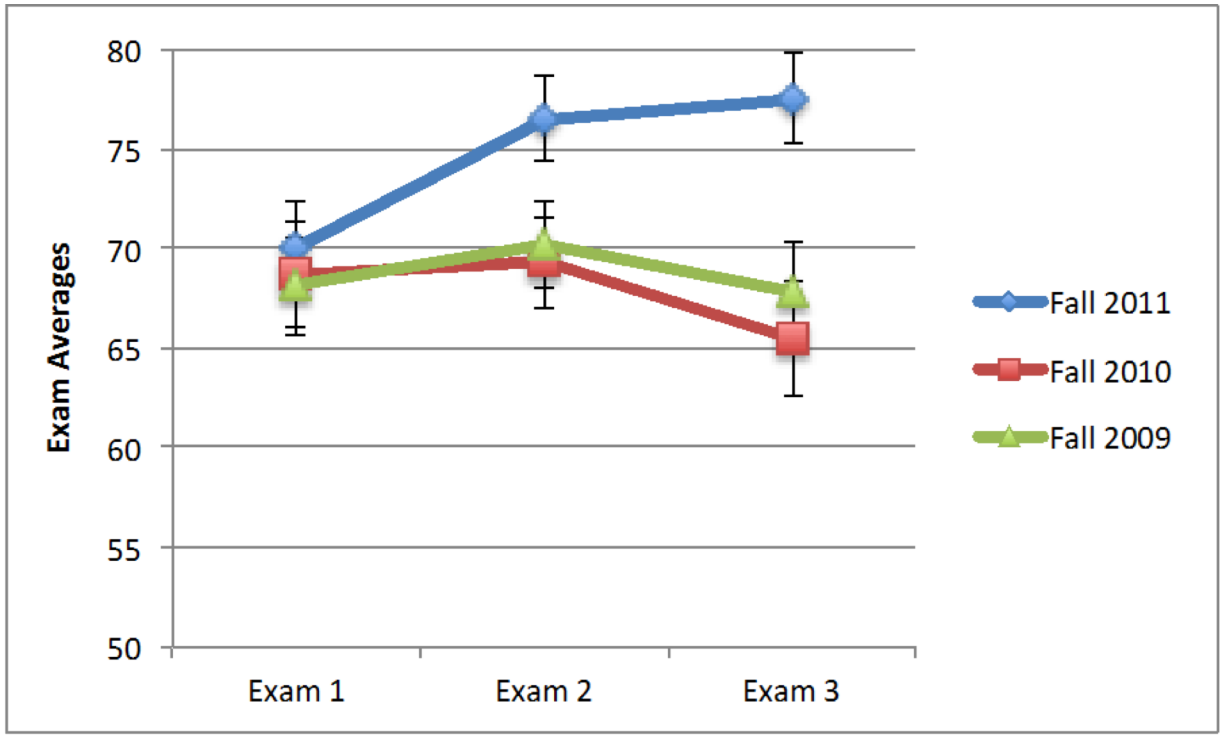
Ningfeng Zhao[1], Jeffrey Wardeska[1], Saundra McGuire[2], Elzbieta Cook[2]

[1]Department of Chemistry, East Tennessee State University

[2]Department 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

Zhao, N., Wardeska, J. G., McGuire, S. Y., & Cook, E. (2014). Metacognition: An effective tool to promote success in college science learning. *Journal of College Science Teaching, 43*(4), 48–54.

Professor Nina Stein's Exam Averages in Organic Chemistry

EXAM	AVERAGE	AVERAGE	AVERAGE*
	Fall 2012	Fall 2013	Fall 2014
1	69.25	70.06	77.42
2	79.40	73.33	86.17
3	70.35	73.38	85.12
final	**66.00**	**63.06**	**82.17**
			***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 Professor℠ eNewsletter, sponsored by the Stanford Center for Teaching and Learning and provided by Rick Reis.

LSU Analytical Chemistry Graduate Student's Cumulative Exam Record

2004 – 2005			2005 – 2006	
9/04	Failed		10/05	Passed
10/04	Failed		11/05	Failed
11/04	Failed	Began work with CAS and the Writing Center in October 2005	12/05	Passed best in group
12/04	Failed		1/06	Passed
1/05	Passed		2/06	Passed
2/05	Failed		3/06	Failed
3/05	Failed		4/06	Passed last one!
4/05	Failed		5/06	N/A

Dr. Algernon Kelley, December 2009

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.**

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
- www.howtostudy.org
- www.vark-learn.com
- www.drearlbloch.com

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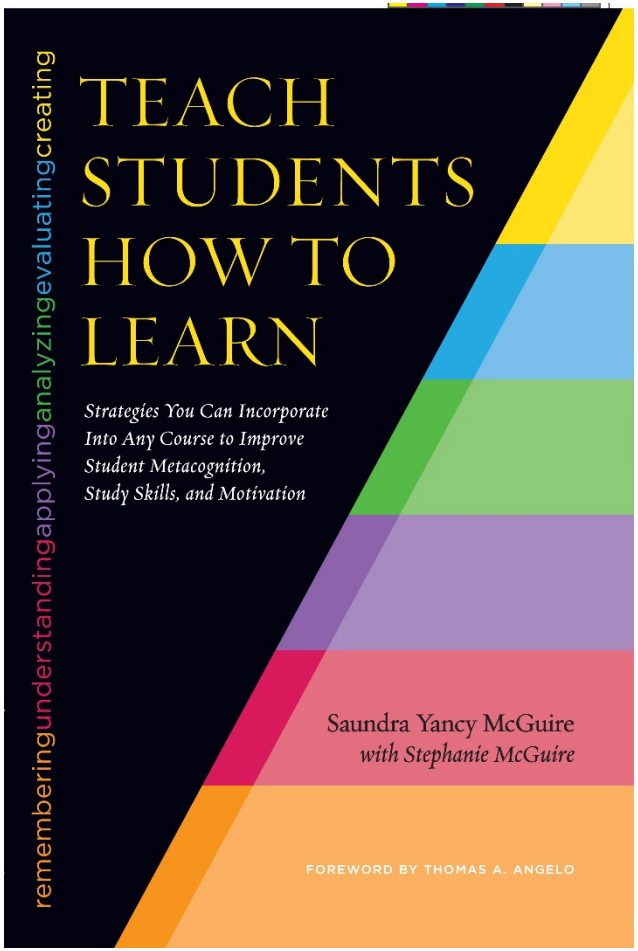
  http://academic.pg.cc.md.us/~wpeirce/MCCCTR/metacognition.htm

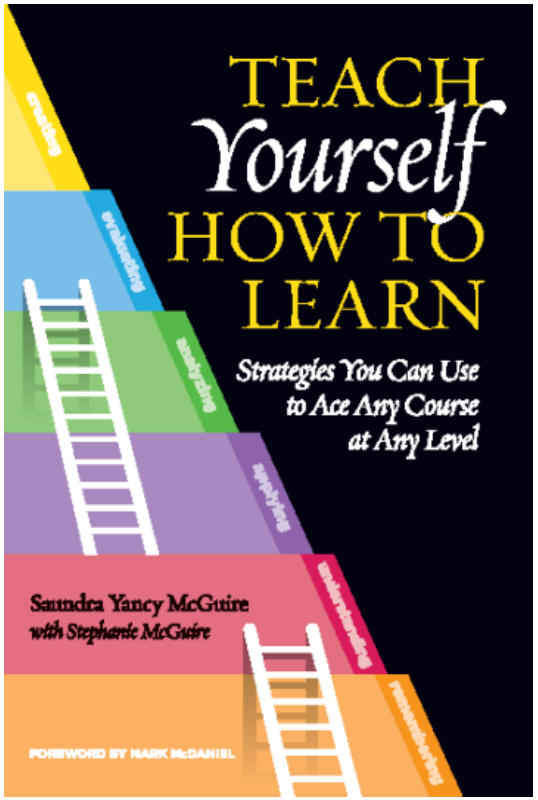
*Excellent student reference

A Recent Reference



***McGuire, S.Y. (2015). Teach Students How to Learn: Strategies You Can Incorporate into Any Course to Improve Student Metacognition, Study Skills, and Motivation*. Sterling, VA: Stylus**

Just out in January…
A Book for Students



McGuire, S.Y. (2018). Teach Yourself How to Learn: Strategies You Can Use to Ace Any Course at Any Level. Sterling, VA: Stylus