Metacognition: The Key to Improving STEM Outcomes Assessment Results

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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

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

Why is metacognition the key to improving STEM outcomes assessment results?

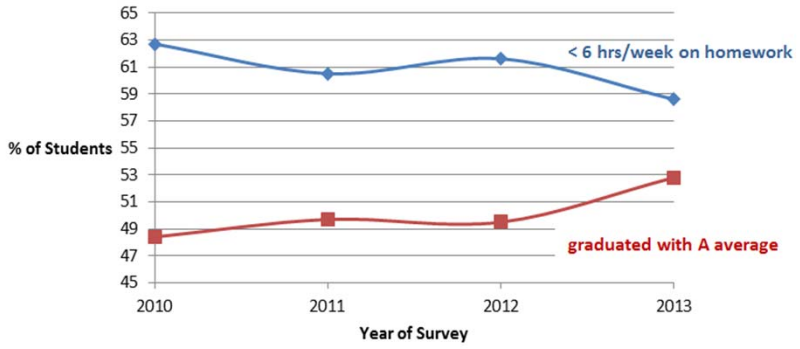
- It is the key to teaching students *how* to learn by providing effective strategies
- Students are intrigued by the simple strategies and motivated to use them
- When students develop metacognitive skills they increase their learning

Why haven't most students developed metacognitive skills?

It wasn't necessary in high school

Data from UCLA Higher Education Research Insitute (HERI)
First Year Student Survey - 2010 - 2013

	% who spent < 6 hours/wk on homework	% who graduated from HS with an A average
2010	62.7	48.4
2011	60.5	49.7
2012	61.6	49.5
2013	58.6	52.8



http://www.heri.ucla.edu/

2013 SAT® Report on College & Career Readiness

EXECUTIVE SUMMARY

The College Board's *2013 SAT® Report on College & Career Readiness* reveals that fewer than half of all SAT takers in the class of 2013 graduated from high school academically prepared for the rigors of college-level course work. This number has remained virtually

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?

STEM Faculty Must *Help Students Make the Transition to College*

Help students identify and **close "the gap"**

current *behavior* → ***current grades***

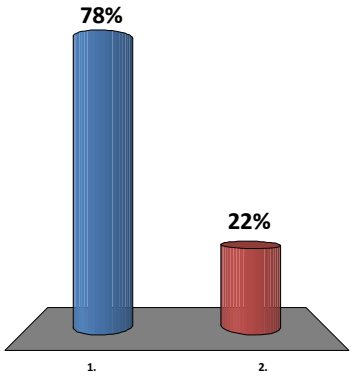
productive *behavior* → ***desired grades***

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

Which mode have you been in so far?*

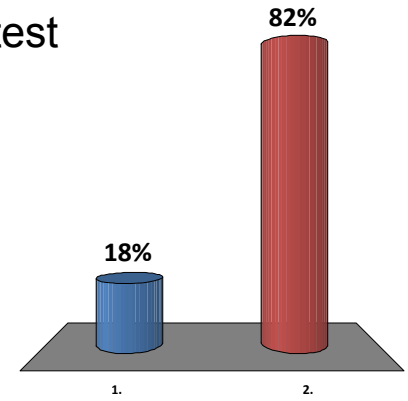
1. Study mode
2. Learn mode



*Fall 2014 Honors General Chemistry students

For which task would you work harder?*

1. Make an A on the test
2. Teach the material



*Fall 2014 Honors General Chemistry students

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

Before and After Test Scores

- Robert, freshman chemistry student
  42, 100, 100, 100 A in course
- Michael, senior pre-med organic student
  30, 28, 80, 91 B in course
- Miriam, freshman calculus student
  37.5, 83, 93 B in course
- Ifeanyi, sophomore thermodynamics student
  67, 54, 68, 95 B in course
- Terrence, junior Bio Engineering student
  GPA 1.67 cum, 3.54 (F 03), 3.8 (S 04)

More Before and After

Chemistry 2001

	Class Average	Student 1	Student 2	Student 3	Student 4
Test 1	76	65	67	70	83
Test 2	52	67	65	46	55
Test 3	72	61	68	68	65
Final	**78**	**107**	**88**	**88**	**90**

Date of Final Exam:	**December 14, 2005**
Meeting with Student No. 1:	**December 12, 2005**
Meeting with Student Nos. 2 & 4:	**December 2, 2005**
Meeting with Student No. 3:	**December 8, 2005**

The final was worth 100 points with a 10 bonus question.

Why Can Students Make Such a Fast and Dramatic Increase?

It's all about the ***strategies***!

Counting Vowels in 45 seconds

How accurate are you?

Count 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* from the list do you remember?

Let's look at the words again…

What are they arranged according to?

Dollar Bill	Cat Lives
Dice	Bowling Pins
Tricycle	Football Team
Four-leaf Clover	Dozen Eggs
Hand	Unlucky Friday
Six-Pack	Valentine's Day
Seven-Up	Quarter Hour
Octopus	

NOW, how many *words* or *phrases* from the list do you remember?

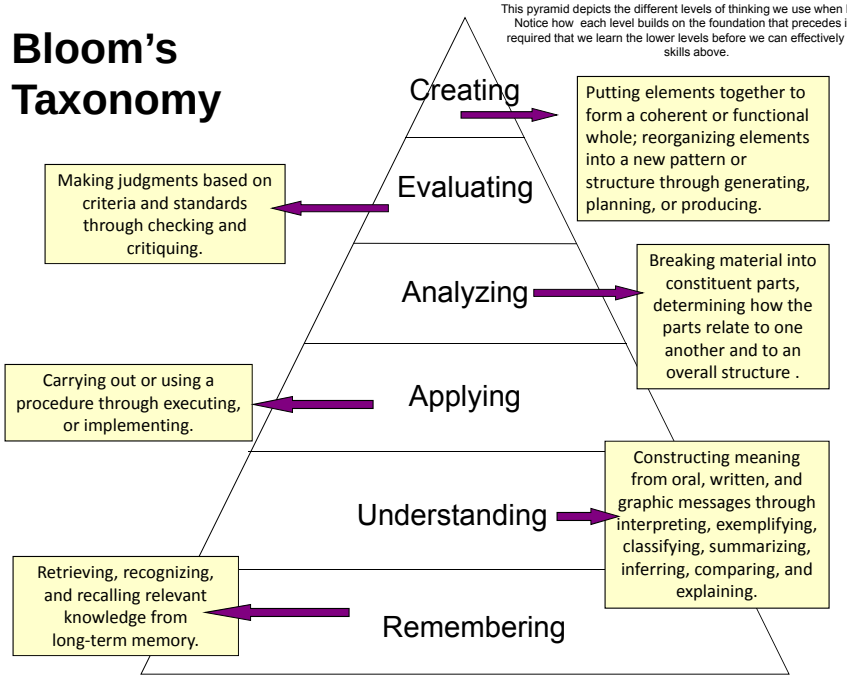
What were two major *differences* between the 1st and 2nd attempts?

1. We knew what the task was

2. We knew how the information was organized

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·

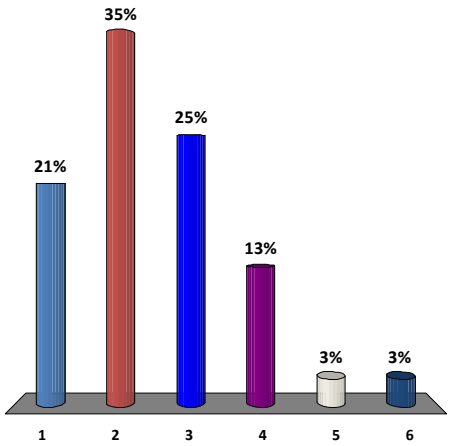
When we teach students about Bloom's Taxonomy…

They GET it!

How students answered (2008)

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 (2014)

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

1. Remembering
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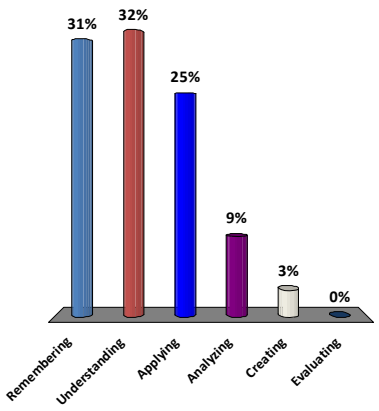
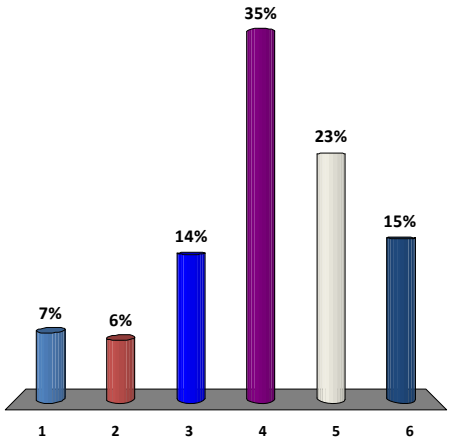


How students answered (in 2008)

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

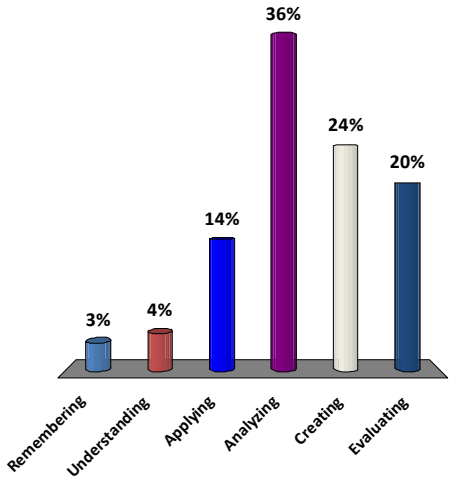
1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating



How students answered (in 2014)

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

A. Remembering
B. Understanding
C. Applying
D. Analyzing
E. Creating
F. Evaluating

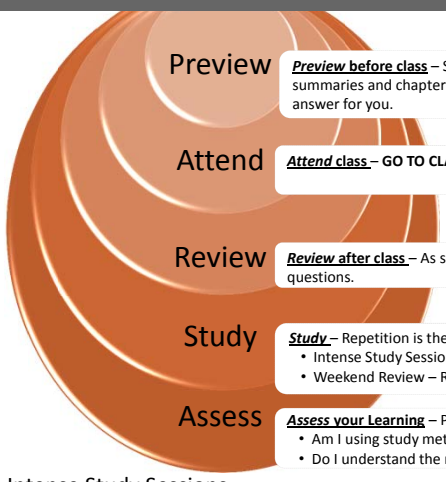


How do we teach students to move higher on Bloom's Taxonomy?

Teach them the Study Cycle*

**adapted from Frank Christ's PLRS system*

The Study Cycle



Preview – ***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?

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**– go for a short walk,, get a snack, relax
4	**Review**	5 min	**Go over what you just studied**

LSU

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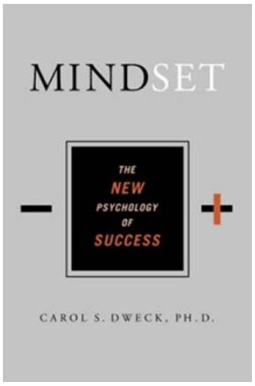
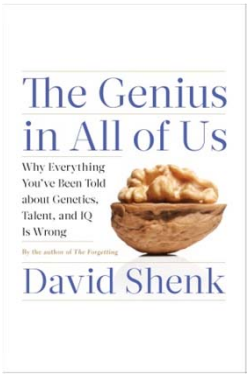
Help Students Develop the Right Mindset



Dweck, Carol, 2006. *Mindset: The New Psychology of Success.* New York: Random House Publishing



Shenk, David, 2010. *The Genius in All of Us: Why Everything You've Been Told About Genetics, Talent, and IQ Is Wrong. New York: Doubleday*

Mindset about Intelligence* Controls Growth!

- **Fixed Mindset**
  - Intelligence is static
  - You have a certain amount of it
- **Growth Mindset**
  - Intelligence can be developed
  - You can grow it with actions

Dweck, Carol (2006) *Mindset: The New Psychology of Success.* New York: Random House Publishing

Responses to *Many* Situations are Based on Mindset

	Fixed Mindset Response	Growth Mindset Response
Challenges	*Avoid*	*Embrace*
Obstacles	*Give up easily*	*Persist*
Tasks requiring effort	*Fruitless to Try*	*Path to mastery*
Criticism	*Ignore it*	*Learn from it*
Success of Others	*Threatening*	*Inspirational*

Email from a Spring 2011 General Chemistry 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

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 resulted in 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 resulted in an improvement of *two* letter grades!

Journal of College Science Teaching

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

Ninfeng 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

*Accepted for publication April 2013

Changes Faculty Have Made that *Improved* Learning and Performance

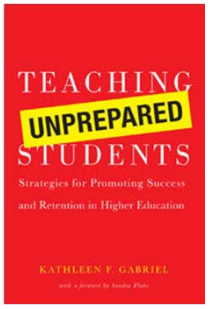
- **Provide learning strategies information to students after Test 1, and tell them about mindset**
  (Psychology Professor at Southern Crescent Technical College, 2013)
- **Increase the frequency of tests from three per semester to biweekly** *(Mathematics Professor at Miles College, 2013)*
- **Have 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 East Tennessee State University, 2012)*
- **Teach students how to read** *(Chemistry Professor at LSU, 2004)*

Metacognitive Get Acquainted Activity*

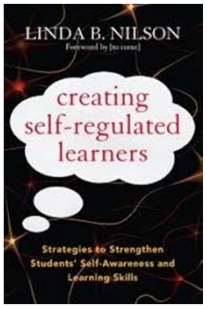
- What do you believe is important to understand and learn in _____?
- What do you believe to be critical characteristics of successful students in _____?
- How will you study and prepare for exams in _____?

***Simpson, M. & Rush, L. (2012) in *Teaching Study Strategies in Developmental Education*, Hodges, Simpson, Stahl eds. New York: Bedford/St. Martin's**

Two Valuable References



Gabriel, Kathleen F. (2008) *Teaching Unprepared Students.* Sterling, VA: Stylus Publishing



Nilson, Linda. (2013) *Creating Self-regulated Learners* Sterling, VA: Stylus Publishing

Email from ENG Professor at New Mexico State Univ.

Received on 10/22/2013

At the end of a 60 minute learning strategies presentation by the professor, students were given a survey to determine their self-assessment of whether they were using or not using the strategies. The average scores of the different groups on the first two exams are shown below.

Reported Use of Strategies	Exam 1	Exam 2
Did not use the strategies	58	54
Used metacognitive strategies	95	80

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.**

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

We *can* significantly increase achievement of student learning outcomes by…

- teaching students *how* to learn
- making learning *visible*
- making the implicit *explicit*
- *not judging* student potential on initial performance
- encouraging the use of *metacognitive tools*
- partnering with the *campus learning center!*

Special Note

Please visit the LSU Center for Academic Success website at www.cas.lsu.edu. We have on-line workshops that will introduce you and your students to effective metacognitive strategies.

Have fun teaching your students and faculty powerful metacognitive strategies that will lead to increased academic success!

Saundra McGuire
smcgui1@lsu.edu

Useful Websites

- www.cas.lsu.edu
- www.howtostudy.org
- www.vark-learn.com
- www.drearlbloch.com
- Searches on www.google.com

Additional References

- Bruer, John T. , 2000. *Schools For Thought: A Science of Learning in the Classroom. MIT Press.*
- Bransford, J.D., Brown, A.L., Cocking, R.R. (Eds.), 2000. *How people learn: Brain, Mind, Experience, and School.* Washington, DC: National Academy Press.
- Christ, F. L., 1997. *Seven Steps to Better Management of Your Study Time*. Clearwater, FL: H & H Publishing
- Cromley, Jennifer, 2000. *Learning to Think, Learning to Learn: What the Science of Thinking and Learning Has to Offer Adult Education*. Washington, DC: National Institute for Literacy.
- Ellis, David, 2006. *Becoming a Master Student*.* New York: Houghton-Mifflin.
- Hoffman, Roald and Saundra Y. McGuire. (2010). Learning and Teaching Strategies. *American Scientist ,* vol. 98, pp. 378-382.
- Nilson, Linda, 2004. *Teaching at Its Best: A Research-Based Resource for College Instructors.* Bolton, MA: Anker Publishing Company.
- Pierce, William, 2004. Metacognition: Study Strategies, Monitoring, and Motivation. *http://academic.pg.cc.md.us/~wpeirce/MCCCTR/metacognition.htm*

*Excellent student reference

Teaching Metacognitive Learning Strategies to Individuals or Groups: A Procedure that Works!

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Most students who enter colleges and universities have not developed effective learning strategies. Many have achieved success in high school by memorizing information for tests that have not required them to demonstrate critical thinking skills. After they fail their first test in college, students are at a loss as to why the strategies that worked so well up to this point are now failing them. They often begin to doubt their ability to succeed, and many drop out of classes, or even leave the institution without achieving the success of which they are capable. These students sometimes seek assistance from a faculty member or advisor, but often are told to "study harder" or to "focus on learning *concepts*" or to "do more homework problems. However, these suggestions do not help students who do not know how to interpret "study harder" or "focus on concepts". These students need explicit instruction and very specific strategies.

In conjunction with my colleagues at the Center for Academic Success at Louisiana State University (www.cas.lsu.edu) I have developed a method to teach these strategies to students in both **individual** and **group sessions**. This method is discussed in detail below. [Note: Variations of this process have been replicated and used effectively at other institutions across the country.]

Individual Learning Consultations with Students

When a student comes in for an individual consultation, it is most often because they have experienced academic difficulty, or they are concerned about their ability to succeed. Therefore, the first thing that I do is try to make the student feel comfortable being in an otherwise embarrassing situation in which they are confronting their failure (or potential failure).

Building the Relationship: To make the student feel comfortable, I ask them to tell me about where they are from, their high school academic experience, their academic interests, their extracurricular activities, etc. Asking for this information allows the student to discuss their prior success, while I assure them that they can be as successful in college as they were in high school. (When I am working with a graduate or professional school student, the message is that they can be as successful as they were in undergraduate school.)

Creating Hope: I then show students some "before and after" test scores of students with whom CAS has worked in the past. (See Summer Scholars presentation). Seeing that other students who made test scores in the 30's and 40's before hearing the strategies increased their scores to the 80's and 90's after learning the strategies, definitely arouses the interest of the student. This is the point at which students tend to become much more mentally engaged in the discussion. For the first time, they see evidence that their low scores will not necessarily doom them to failing the course.

Building Confidence: Next I will do the Count the Vowels exercise to actively demonstrate to the student how s/he can miserably fail on a task one minute, and then perform at an A or B level minutes later if they understand the task and have strategies to learn it. Students are even more motivated after the Count the Vowels exercise. I then proceed to help them develop effective learning strategies.

Guiding Analytic Reflection: The first reflection question I then ask is "What's the difference between studying and learning?". The most common answer I get is something like "Studying is just memorizing information for a test or a quiz" but learning is really "understanding and mastering the information so that it will not be forgotten soon as the test. I then ask if, up to this point, the student has been in "study" mode or "learning" mode. Every student I have asked to date has indicated "study mode". I then enthusiastically respond "YES! That's the reason you haven't done as well as you can. In this session we're going to learn to stay in 'learn mode'."

Introducing New Ideas: The next step is to introduce students to the concept of metacognition and to Bloom's Taxonomy as a hierarchy of learning levels. Almost none of them have heard of metacognition or seen Bloom's Taxonomy before, but they embrace it enthusiastically. Some even say "I wish I had known THIS in high school!"

I then ask "Up to this point, what's the highest level you've had to operate to make As' and B's in high school (or in undergraduate school)? The typical response is either Knowledge or Comprehension. And then I ask "What the LOWEST level you have to operate HERE in college to make and A or a B? Most say either application or analysis, with a few suggesting higher levels. Again, I reassure the student that we now know exactly what the problem is! They've been studying at the lower two levels, so they've got to "kick it up a few notches"! And I am quick to follow with "Boy, do we have a strategy for a accomplishing that!" I then introduce the Study Cycle*, which involves previewing the information to be covered in class, attending class, reviewing class material immediately (or as soon as possible) after class, engaging in "intense study sessions" to thoroughly learn the information, and assessing their learning strategies.

After learning about Bloom's Taxonomy and the Study Cycle, the student appears to be overjoyed that s/he not only knows what the problem is, s/he knows how to fix it!" The confidence level is visibly increasing.

There are several additional specific learning strategies we discuss at this point.

1. A READING COMPREHENSION STRATEGY involving: previewing the material, developing questions to be answered during the reading, reading on paragraph at a time and paraphrasing he paragraph.
2. A HOMEWORK PROBLEM STRATEGY that involves working all problems without using an example as a guide.

   *Adapted from Frank L. Christ's Preview-Learn-Review-Study Learning Cycle
3. A CONCEPT MASTERY STRATEGY involving "teaching the material" as a way of testing for complete understanding, and to discover when understanding is less than originally thought

   To help the student understand the value of "teaching the material" as a learning strategy, I ask the student the following reflection question:

   "For which task would you study harder: If you had to take a test on three chapters and make an A on the test? Or if you had to teach the material to the class?" Students immediately say "Teach the material!" And when I ask why they would study harder if they had to teach the material, they invariably say: "You have to really *know* the material if you have to teach it!" When I ask if, to this point, they have been in "make an A on the test mode", or in "teach the material mode", students say "make an A on the test mode". They see how preparing to teach the material results in a deeper understanding of the material.

Building Motivation to Change: I usually end the session with two final questions, each designed to get information about whether the student will implement the strategies we have talked about.

The first question is: "On a scale of 1 – 10, how different are the strategies we have talked about from the ones you have been using up to this point? (1 is not at all; 10 is as different as day and night) If the student gives a number between 8 and 10, I know that the student recognizes that there is a difference between what s/he has been doing and the strategies that we have been discussing during the session. Although I know that the strategies are different, if the student doesn't recognize this, s/he won't do anything different.

The second question is: "On a scale of 1 to 10, how motivated are you to start using the strategies? (1 is not at all; 10 is "I can't wait to start them today!") Again, I am happy with a number between 8 and 10.

I then reinforce the idea that the student's performance will depend on use of the strategies, not on how smart s/he is, and leave the student with the added confidence that s/he *can* be successful. I ask students to email me to let me know how they are doing, and I let them know that I'll be available for future meetings.

A Group Session for Students in a Particular Course

The process described above for use in one-on-one consulting situations with individual students can also be used by teachers with a group of students in a specific course. I have done this with students in my own chemistry courses; other teachers have done it with their courses.

What I often do is offer one special, 50-minute session that students in the course can opt to attend. This session lasts approximately one hour and typically is scheduled after the first or second exam in the course. The purpose of the session is to help the class as a whole improve its performance. I then proceed to ask the class the same types of reflection questions I ask in individual sessions. Additionally, I provide examples of questions from past exams to show them how using the learning strategies is crucial to success. After presenting strategies, I challenge the class to improve its performance, and have the students indicate in writing what strategy they are willing to implement. Data collected in selected general chemistry classes in which this session was provided show that the students who attended the session improved their performance whereas those who were absent experienced a decrease in performance on subsequent examinations.

References

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

Christ, F. L., 1997. *Seven Steps to Better Management of Your Study Time*. Clearwater, FL: H & H Publishing.

Dweck, Carol, 2006. *Mindset: The New Psychology of Success.* New York: Random House Publishing.

Ellis, David, 2011. *Becoming a Master Student, 14th edition.* Boston: Wadsworth.

Pierce, William, 2004. Metacognition: Study Strategies, Monitoring, and Motivation. *http://academic.pg.cc.md.us/~wpeirce/MCCCTR/metacognition.htm*

Shenk, David, 2010. *The Genius in All of Us: Why Everything You've Been Told About Genetics, Talent, and IQ Is Wrong.* New York: Doubleday.

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