Developing Students’ Metacognitive Strategies: The Key to Resilience, Persistence, Inclusion, and Success
Southeast Regional PULSE Institute-II : June 2016

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By the end of our workshop you should be able to:

• discuss key principles of how learning works and the role of metacognition;
• offer a brief overview of metacognition and relate it to cognition, mindset, and intellectual development;
• describe how metacognition aids student and instructor learning & development;
• consider ways to scaffold metacognitive practice throughout a department.

What is Metacognition?

METACOGNITION: Awareness & knowledge about one’s own thinking & learning (Zimmerman, 2002).

THREE TYPES OF METACOGNITION

• Knowledge of strategies appropriate to tasks
• Knowledge of strategy effectiveness
• Knowledge of self (Pintrich, 2002)

METACOGNITION IS A COLLECTION OF MANY DIFFERENT SKILLS, including:
  a. knowing one’s own strengths & weaknesses
  b. identifying appropriate learning goals
  c. planning one’s approach to the learning task
  d. monitoring progress
  e. evaluating performance
  f. reflecting on what did & did not work (in order to adjust and improve)

Creating
Building something new through synthesis, integration, and imagination. Examples include performance or visualization of abstract concepts, proposing novel ways to test hypotheses, and integrating information from disparate sources to construct new knowledge. **Sample metacognitive activity:** Develop a group skit to model a difficult concept; then write a reflective essay on how the activity influenced learning.

Evaluating
Making value judgments about ideas, solutions, methods, and so forth, based on the use of either quantitative or qualitative criteria or standards. Examples include evaluating the appropriateness of a health therapy, critiquing the author(s) explanations of experimental results, or assessing the ethical implications of a particular course of action. **Sample metacognitive activity:** Work in teams to reflect upon and compare personal study practices and propose a list of best practices. If possible, students critique lists developed by freshmen, upper level undergraduates, and graduate students.

Analyzing
Breaking a topic or problem into its separate components, deducing their relationships, and understanding their pattern of organization. Examples include deducing unstated assumptions, detecting cause and effect relationships, and comparing and contrasting methods of inquiry. **Sample metacognitive activity:** Teams of students develop a concept map of a difficult concept; then teams compare maps and describe reasoning.

Applying
Taking a principle or process previously learned and applying it in a new situation without being told to do so. Examples include applying social science generalizations to specific social problems or applying scientific or mathematical principles to practical situations. **Sample metacognitive activity:** construct a table for data collection based on a given experimental design and appropriate statistical analysis of the data; then articulate to peers what steps you employed in working through.

Understanding
Comprehending any communication (text, lecture, article, graph, etc.) through expressing it in another form (own words, new configuration, extrapolation, etc.). **Sample metacognitive activity:** Provide your own summary of the key findings of a research article in 70 words or less; peers assess for plagiarism and accuracy.

Remembering
Recalling/recognizing specific information, including facts, terminology, conventions, criteria, methodology, principles and theories. **Sample metacognitive activity:** Develop flash cards to remember/define key terms; discuss benefits and limits of technique with peers.

Post-Exam Reflection

This activity is designed to give you a chance to reflect on your exam performance and, more importantly, on the effectiveness of your exam preparation. Please be candid in your responses. Your responses are being collected to improve teaching and learning in this course. They will have no impact on your grade, but you will receive credit for thoughtful reflection. Please enter responses into the grey text boxes below.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>After studying for this exam, how many points (out of 100) did you expect to earn?</td>
<td>______</td>
</tr>
<tr>
<td>After completing the exam, how many points (out of 100) did you think you had earned?</td>
<td>______</td>
</tr>
<tr>
<td>How many points did you receive?</td>
<td>______</td>
</tr>
<tr>
<td>Approximately, how many hours did you spend studying for this exam?</td>
<td>______</td>
</tr>
<tr>
<td>Did you study enough?</td>
<td>□ yes  □ no</td>
</tr>
<tr>
<td>Could you have studied “smarter”?</td>
<td>□ yes  □ no</td>
</tr>
<tr>
<td>What percentage of your test-preparation time was spent in each of these activities?</td>
<td>______</td>
</tr>
<tr>
<td>Reading textbook sections for the first time</td>
<td>______</td>
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<tr>
<td>Re-reading textbook sections</td>
<td>______</td>
</tr>
<tr>
<td>Answering end-of-section questions</td>
<td>______</td>
</tr>
<tr>
<td>Reviewing knowledge survey questions</td>
<td>______</td>
</tr>
<tr>
<td>Reviewing your own notes</td>
<td>______</td>
</tr>
<tr>
<td>Reviewing handouts</td>
<td>______</td>
</tr>
<tr>
<td>Discussing course materials and questions with classmates</td>
<td>______</td>
</tr>
<tr>
<td>Studying the relations among concepts and ideas</td>
<td>______</td>
</tr>
<tr>
<td>Carefully look over your exam and estimate the percentage of points you lost to each of the following:</td>
<td>______</td>
</tr>
<tr>
<td>From careless mistakes</td>
<td>______</td>
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<tr>
<td>From not being familiar with terms</td>
<td>______</td>
</tr>
<tr>
<td>From not knowing facts</td>
<td>______</td>
</tr>
<tr>
<td>From not understanding concepts</td>
<td>______</td>
</tr>
<tr>
<td>From not being able to apply concepts in new contexts</td>
<td>______</td>
</tr>
<tr>
<td>From not seeing connections between concepts or facts</td>
<td>______</td>
</tr>
<tr>
<td>From not recognizing that information or ideas were important</td>
<td>______</td>
</tr>
<tr>
<td>From other reasons (please specify):</td>
<td>______</td>
</tr>
<tr>
<td>Based on your responses to the questions above, describe at least three (3) things that you plan to do differently in preparing for the next exam. For instance, will you spend more time studying, change a specific study habit, or try a new one? Please describe.</td>
<td>1. ______</td>
</tr>
<tr>
<td></td>
<td>2. ______</td>
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<tr>
<td></td>
<td>3. ______</td>
</tr>
<tr>
<td>What can I do to help support your learning and your preparation for the next exam?</td>
<td>______</td>
</tr>
</tbody>
</table>

https://www.cmu.edu/teaching/designteach/teach/examwrappers/
Cognitive Skills (based on revised Bloom’s Taxonomy)

Remember:
- recall
- recognize
- list
- label
- match

Understand:
- define
- organize
- articulate
- give example
- describe
- paraphrase

Analyze:
- compare
- infer
- validate
- examine
- scrutinize
- deduce
- query
- recognize
- list
- identify
- organize

Create:
- plan
- invent
- produce
- construct
- dramatize
- propose

Evaluate:
- verify
- interpret
- critique
- judge
- assess
- recommend
- prioritize

Apply:
- use
- adapt
- predict
- hypothesize
- simulate
- practice
- teach
- solve
- illustrate
- carry out

This diagram is based on Anderson and Krathwohl's A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives and on Crowe et al., 2008 Biology in Bloom, CBE-Life Sci Edu, 7:368-381. Developed by Ellen Goldey, egoldey@fau.edu (as of Aug. 1, 2016).
I think that learning through application is very important especially in the field of science. Using application familiarizes students with real-life issues and therefore makes the information more relevant. One thing that was frustrating about this activity was trying to interpret the graphs correctly. I overcame this challenge by reading the articles and graph summaries as well as asking questions about the material.

**Speculate:** With several questions, our group had to form conjectures with the evidence provided. One example is our speculation that malaria could reemerge in the US based on a global distribution map of Anopheles mosquitoes.

**Interpret:** Our group explained the meaning and significance of several graphs and maps, such as mosquito population fluctuations, biome distribution, and climate change.

**Differentiate:** Several times our group was asked to ascertain what made two things dissimilar. In question one we had to differentiate between the countries Uganda and Kenya in regards to their vast differences in numbers of malaria cases.

This diagram (developed by Ellen Goldsby, Wofford College, goldsbyes@wofford.edu) is based on Anderson and Kazhoni’s A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives and G. C. W. et al., 2008 Biology In Bloom, CBE-Life Sci Educ, 7:389-381.
Perry's Scheme of Intellectual and Ethical Development

Perry (1981) claimed that college learners (and others) journey through nine positions of intellectual (and moral) development, which can be grouped according to the learner's attitude towards knowledge. Perry also claimed that few students develop beyond position 5 while in college (and a smaller fraction of people ever in their lives), and even advanced learners fluctuate among the levels.

Positions 1 – 2: Dualism/Received Knowledge. Learners at these levels tend to think in terms of dualistic conflicts: “us vs. them” and “right vs. wrong.”

- **Early Dualism**: A learner's task is to receive the solutions to conflicts from Authorities.
- **Late Dualism**: Some Authorities disagree, so a learner's task is to learn which Authority is good, and which is bad so that she/he can receive knowledge from a “good” Authority.

Positions 3 – 4: Multiplicity/Subjective Knowledge. Learners recognize the existence of uncertainty in the form of multiple perspectives and multiple Authorities.

- **Early Multiplicity**: There are a number of “good” Authorities and they sometimes disagree. A learner should listen to “inner voices” because external Authorities can’t be trusted.
- **Late Multiplicity**: Some problems are unsolvable, and everyone has a right to their own opinion. A learner’s task is to be “open minded” – it doesn't matter which (if any) solution you choose.

Positions 5 – 6: Relativism/Procedural Knowledge. Learners at these positions recognize that there are different ways of knowing/truth-seeking/reasoning and that different Authorities use different procedures (empathetic/reflective/imaginative vs. empirical/technical/systematic). A learner who reaches these levels begins to see herself/himself as a potential Authority, with an intellectual and ethical identity, in a relativistic world.

- **Contextual Relativism**: Various solutions may be reasonable, and a learner's task is to use the procedures in the appropriate context.
- **Pre-Commitment**: A learner’s task is to use these procedures because he/she recognizes the need to commit to a solution despite ambiguity.

Positions 7 – 9: Commitment/Constructed Knowledge. Learners recognize that knowledge is constructed through integration of prior knowledge and purposeful reflection.

- **Commitment**: A learner’s task is to construct knowledge, formulate solutions to complex problems, and act on them.
- **Challenges to Commitment**: A learner’s task is to identify the implications of their actions/commitment, explore issues of responsibility/culpability, and reformulate his/her solutions and actions in light of such challenges.
- **Post-Commitment**: A learner’s task is to embrace life’s intellectual and ethical struggles and see construction of knowledge as a continuous and ever-evolving activity.

See also:


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1 This handout was developed by Wofford College professors Ellen Goldey (Chair of Biology) and Byron R. McCane (Archeologist and Chair of Religion). Any errors of reinterpretation and oversimplification are our own, and we gratefully acknowledge the following website [http://www.cse.buffalo.edu/~rapaport/perry.positions.html](http://www.cse.buffalo.edu/~rapaport/perry.positions.html), which we used as a template for the above descriptions. Perry’s model has informed our teaching and our own learning. You are welcome to contact us with follow-up inquiries at goldeyes@wofford.edu or mccanebr@wofford.edu.
<table>
<thead>
<tr>
<th>Bloom's level</th>
<th>Individual activities</th>
<th>Group activities</th>
</tr>
</thead>
</table>
| Knowledge (LOCS) | - Practice labeling diagrams  
- List characteristics  
- Identify biological objects or components from flash cards  
- Quiz yourself with flash cards  
- Take a self-made quiz on vocabulary  
- Draw, classify, select, or match items  
- Write out the textbook definitions  | - Check a drawing that another student labeled  
- Create lists of concepts and processes that your peers can match  
- Place flash cards in a bag and take turns selecting one for which you must define a term  
- Do the above activities and have peers check your answers  | |
| Comprehension (LOCS) | - Describe a biological process in your own words without copying it from a book or another source  
- Provide examples of a process  
- Write a sentence using the word  
- Give examples of a process  | - Discuss content with peers  
- Take turns quizzing each other about definitions and have your peers check your answer  | |
| Application (LOCS/HOCS) | - Review each process you have learned and then ask yourself: What would happen if you increase or decrease a component in the system or what would happen if you alter the activity of a component in the system?  
- If possible, graph a biological process and create scenarios that change the shape or slope of the graph  | - Practice writing out answers to old exam questions on the board and have your peers check to make sure you don't have too much or too little information in your answer  
- Take turns teaching your peers a biological process while the group critiques the content  | |
| Analysis (HOCS) | - Analyze and interpret data in primary literature or a textbook without reading the author's interpretation and then compare the authors' interpretation with your own  
- Analyze a situation and then identify the assumptions and principles of the argument  
- Compare and contrast two ideas or concepts  
- Create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows  | - Work together to analyze and interpret data in primary literature or a textbook without reading the author's interpretation and defend your analysis to your peers  
- Work together to identify all of the concepts in a paper or textbook chapter, create individual maps linking the concepts together with arrows and words that relate the concepts, and then grade each other's concept maps  | |
| Synthesis (HOCS) | - Generate a hypothesis or design an experiment based on information you are studying  
- Create a model based on a given data set  
- Create summary sheets that show how facts and concepts relate to each other  
- Create questions at each level of Bloom's Taxonomy as a practice test and then take the test  | - Each student puts forward a hypothesis about biological process and designs an experiment to test it. Peers critique the hypotheses and experiments  
- Create a new model/summary sheet/concept map that integrates each group member's ideas.  | |
| Evaluation (HOCS) | - Provide a written assessment of the strengths and weaknesses of your peers' work or understanding of a given concept based on previously determined criteria  | - Provide a verbal assessment of the strengths and weaknesses of your peers' work or understanding of a given concept based on previously determined criteria and have your peers critique your assessment  | |

1 Students can use the individual and/or group study activities described in this table to practice their ability to think at each level of Bloom's Taxonomy.
Be Metacognitive about Teaching…

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Sample self-reflections to promote faculty metacognition about teaching</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th><strong>I taught the Why</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How is my thinking about teaching changing?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>How is my approach to teaching different from last time?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What evidence do I have that these changes are occurring?</strong></td>
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<tr>
<td><strong>How will I think about my students’ learning in this course?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>In what ways am I approaching teaching my goals for students in this course?</strong></td>
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<tr>
<td><strong>What did I think today’s class was about?</strong></td>
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<tr>
<td><strong>How did the class go?</strong></td>
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<tr>
<td><strong>What did I think about students already know?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What did I think about these students?</strong></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>By the end of this course, will I be able to:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Walk the course more effectively?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Support these connections to learning?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Make the course more enjoyable?</strong></td>
<td></td>
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<tr>
<td><strong>Improve the class session?</strong></td>
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<tr>
<td><strong>Broaden the scope of the course?</strong></td>
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</tr>
<tr>
<td><strong>Assess students more accurately?</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Overall course</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What were my goals for this class session?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What did I think I accomplished?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What did I think I failed?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What went well?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What could I do to improve my lesson planning?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>How do I think this activity promotes faculty metacognition about teaching?</strong></td>
<td></td>
</tr>
</tbody>
</table>
They Just Do Not Listen!

Last semester, when I taught Medical Anthropology, the students’ research presentations were all glitz and very little substance. So this time, because this project is worth 50 percent of their final grade, I tried to forewarn my students: “Do not be seduced by technology; focus on substantive anthropological arguments and create engaging presentations.” And yet, it happened again. Last Tuesday, student after student got up in front of the class with what they believed to be engaging presentations—fancy fonts in their PowerPoint slides, lots of pictures swishing on and off the screen, embedded video clips, and so on. It was clear they had spent hours perfecting the visuals. Unfortunately, although their presentations were visually stunning, the content was very weak. Some of the students had not done thorough research, and those who did tended merely to describe their findings rather than craft an argument. In other cases, students’ arguments were not supported by sufficient evidence, and most of the images they included were not even connected to the research findings. I thought I was clear in telling them what I wanted and did not want. What is it going to take to make them listen?

Professor Tanya Strait

Be Metacognitive about Your Curriculum ... 

WHERE ALONG THE RUBRIC IS YOUR DEPARTMENT IN TERMS OF ENCOURAGING STUDENT METACOGNITIVE PROCESSES?

CONSIDER HOW YOU AND YOUR COLLEAGUES CAN DESIGN YOUR CURRICULUM TO DEVELOP AND SCAFFOLD STUDENT METACOGNITIVE PROCESSES ...

What possible, beginning areas in the curriculum do you feel that metacognitive processes can be introduced? What specific metacognitive activities & processes might you and your colleagues focus upon? What types of assignments?

Where, in what specific courses, could they be nurtured and developed? What specific metacognitive activities & processes might you and your colleagues expand upon? In what types of assignments?

Where, in what specific advanced courses or activities, could they be exemplified? What specific metacognitive activities & processes might you and your colleagues focus upon? What types of assignments or activities?
Table 1: Desired learning outcomes for students in biology, whether majors or one-course visitors to the discipline. This table was first developed in 2008 by biologists at Wofford College and it continues to be a dynamic document.

**What should our students know, be able to do, and care about as a result of this course/program/major?**

<table>
<thead>
<tr>
<th>Canonical Knowledge (To Know)</th>
<th>Skills (To Do)</th>
<th>Dispositions¹ (To Care About)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core biological theories of natural world (e.g., evolution).</td>
<td>Develop hypotheses and experiments (and/or use computational methods) to test them and make informed predictions (in words and graphs) as to experimental outcomes.</td>
<td>Curious about biological phenomena. Seeks explanations through scientific inquiry.</td>
</tr>
<tr>
<td>Foundational content, including organism diversity, metabolism, reproduction and growth, DNA structure/function, behavioral and ecological interactions.</td>
<td>Employ accuracy, care, and precision in observation, data collection, record keeping, measurement, etc. Practice increasingly complex lab techniques.</td>
<td>Skeptical but open-minded about truth claims; seeks supporting empirical evidence.</td>
</tr>
<tr>
<td>Functional numeracy (e.g., orders of magnitude, interpret graphs, concentrations, molarity).</td>
<td>Manage time effectively, practice effective study skills, work well alone and in teams</td>
<td>Growing confidence in own learning ability with improving learning skills.</td>
</tr>
<tr>
<td>Biologists/scientists seek probable explanations based on empirical evidence.</td>
<td>Select and use appropriate statistical methods for data analysis. Readily employ quantitative reasoning.</td>
<td>Dedicated to honesty, ethical conduct &amp; integrity as behavioral norms.</td>
</tr>
<tr>
<td>The role of biology in a liberal education, in fulfilling the mission of the institution, in our democracy, and in the world.</td>
<td>Interpret results, which may be surprising, in ways that demonstrate ability to make judgments while also considering alternative explanations.</td>
<td>Perseverant despite obstacles inherent in scientific quests and life in general.</td>
</tr>
<tr>
<td>The power and limitations of science (and scientists). Role of cultural norms in influencing scientific practice.</td>
<td>Communicate effectively (oral, written, web, etc.). Paraphrase and cites others' ideas appropriately.</td>
<td>Heightened responsibility for applying knowledge to resolving problems (e.g., disease, climate change, biodiversity, wellness, etc.)</td>
</tr>
<tr>
<td>The dynamic nature of biology, new findings continuously remodel accepted interpretations</td>
<td>Reflect upon, review, and constructively critique own work and that of others. Regularly engage in metacognition.</td>
<td>Values self-reflection for maturation and cognitive development.</td>
</tr>
<tr>
<td>Research journals, conference proceedings, etc. are the venues for sharing new knowledge</td>
<td>Make meaning of complex issues in context. Be attuned to influence of cultural norms on self and others.</td>
<td>Appreciates and seeks to understand diversity of perspectives, backgrounds, etc. of peers/others.</td>
</tr>
<tr>
<td>Credentialing of a professional biologist; how one earns PhD, etc.</td>
<td>Think critically (use evidence, evaluate credibility, reveal bias in self and others).</td>
<td>Respects methodologies and scholarship of all academic disciplines, admits own ignorance, seeks expertise of others.</td>
</tr>
<tr>
<td>AAAS’ Vision and Change Core Concepts: e.g., information and energy flow/exchange/storage, grasp of systems biology.</td>
<td>Integrate and apply knowledge from other disciplines. Apply all knowledge to novel situations: predict/create/imagine/innovate.</td>
<td>Forms bonds to institution, teachers, and peers. Develops sense of belonging that is shared with other learners.</td>
</tr>
<tr>
<td>Understand mathematical models that explain/predict biological phenomena.</td>
<td>Construct/create models (i.e., mathematical/computational or physical) of biological phenomena while avoiding errors of reification.</td>
<td>Increased motivation (take action on issues, learn more than required, seek justice, etc.), including active exploration of intellectual identity; perhaps as a biologist.</td>
</tr>
</tbody>
</table>

¹“A goal of all science courses should be to instill in students the values, dispositions, and habits of mind that characterize working scientists….Science is the art of interrogating nature – that is, it is a system of inquiry that is predicated on a set of values and that requires mastery of systematic problem-solving techniques, the power of reason, and the art of abstraction.” AAAS, The Liberal Art of Science, 1990, p. 17.
Metacognition, Course, & Curricular Design

A list of resources compiled by Ellen Goldey & Michael Reder.
SERP Summer 2016    Wofford College


Note: Several biological concept inventories are available to assess your students’ knowledge and misconceptions (see http://bioliteracy.colorado.edu/ and several at https://saber-biologyeducationresearch.wikispaces.com/Concept+Assessments-Biology). See examples of exam wrappers: https://www.cmu.edu/teaching/design/teach/examwrappers/