Developing Students’ Metacognitive Strategies: The Key to Resilience, Persistence, Inclusion, and Success

Michael Reder, Connecticut College & Ellen Goldey, Wofford College (Florida Atlantic University)
By the end of our workshop you should be able to:

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

Awareness and knowledge about own thinking/learning.

Metacognition is developed through ongoing cycle of practice, feedback, and reflection.

Where metacognition fits into *How Learning Works*

1. Prior knowledge can help or hinder learning
2. How students organize knowledge influences how they learn and apply knowledge
3. Motivation generates, directs, and sustains what students do to learn.
4. Mastery is achieved through integration and application
5. Goal-directed practice and targeted feedback combines for ongoing cycle of learning
6. Students’ level of development interacts with social, emotional, and intellectual climate to impact learning
7. To become self-directed and self-regulatory, students must become **metacognitive** and self-aware

Develop a concept map

Use the seven principles to create a simple concept map of “How Learning Works”

Add appropriate linkages, such as action verbs

Image Credit: Jean-Louis Zimmermann
Three Types of Metacognitive Knowledge

• Knowledge of strategies appropriate to tasks
  – How might I most effectively learn or do “X”?  
    e.g., annotating, answering prompts, doing problems?

## Novice problem solvers

<table>
<thead>
<tr>
<th>Elapsed Time (mins)</th>
<th>0</th>
<th>2</th>
<th>4</th>
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<th>12</th>
<th>14</th>
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<td>Read</td>
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## Expert problem solvers

| Elapsed Time (mins) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|--------------------|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
| Read               |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Analyze            |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Explore            |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Plan               |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Implement          |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Verify             |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

*Schoenfeld (1987)*
Three Types of Metacognitive Knowledge

• Knowledge of strategies appropriate to tasks
  – How might I most effectively learn or do “X”? e.g., annotating, answering prompts, doing problems?

• Knowledge of strategy effectiveness
  – What worked; what didn’t? What can I do better/differently to improve? e.g., exam wrappers

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>Score</th>
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</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>
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<tr>
<td>How many points did you receive?</td>
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<tr>
<td>Approximately, how many hours did you spend studying for this exam?</td>
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<tr>
<td>Did you study enough?</td>
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<tr>
<td>Could you have studied “smarter”?</td>
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<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>
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<tr>
<td>Re-reading textbook sections</td>
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<tr>
<td>Answering end-of-section questions</td>
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<tr>
<td>Reviewing knowledge survey questions</td>
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<tr>
<td>Reviewing your own notes</td>
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<tr>
<td>Reviewing handouts</td>
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<tr>
<td>Discussing course materials and questions with classmates</td>
<td></td>
</tr>
<tr>
<td>Studying the relations among concepts and ideas</td>
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<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>
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<tr>
<td>From not being familiar with terms</td>
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<tr>
<td>From not knowing facts</td>
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<tr>
<td>From not understanding concepts</td>
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<tr>
<td>From not being able to apply concepts in new contexts</td>
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<tr>
<td>From not seeing connections between concepts or facts</td>
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<tr>
<td>From not recognizing that information or ideas were important</td>
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</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>
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</tr>
<tr>
<td>1.</td>
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<td>2.</td>
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<tr>
<td>3.</td>
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</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>

See other examples at: https://www.cmu.edu/teaching/designteach/teach/examwrappers/
Three Types of Metacognitive Knowledge

• Knowledge of strategies appropriate to tasks
  – How might I most effectively learn or do “X”?  
    e.g., annotating, answering prompts, doing problems?

• Knowledge of strategy effectiveness
  – What can I do better/differently to improve?  
    e.g., exam wrappers

• Knowledge of self
  – What motivates me to learn? Do I take responsibility for my learning?  
    How can I use my strengths to address my weaknesses? Do I avoid a challenge? Am I willing to change my strategies to improve my learning?

Metacognitive knowledge of self affected by:

- Prior learning and misconceptions
- Mindset
- Practice in, and awareness of, all cognitive domains
- Stage of intellectual development
- Motivation to change/stretch/learn
Metacognitive knowledge of self affected by:

- Prior learning and misconceptions
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- Practice in, and awareness of, all cognitive domains
- Stage of intellectual development
- Motivation to change/stretch/learn
Accurate self-awareness

Study wasn’t necessary in high school

60% of first year students spent less than six hours per week doing homework in 12th grade.

50% graduated high school with an “A” average.

Students’ confidence level is often high

at least until they take their first college test.

Early failure can cause attrition

Instructor intervention and support is most critical when embarrassment and sadness peak.

Lack of resilience is linked to mindset.

Statistics from 2011 Higher Education Research Institute Study
Metacognitive knowledge of self affected by:

- Prior learning and misconceptions
- Mindset
- Practice in, and awareness of, all cognitive domains
- Stage of intellectual development
- Motivation to change/stretch/learn
Fixed
Intelligence is static; you have a fixed amount of it

Growth
Intelligence can be developed; you can grow it
Carol Dweck, Stanford University, author of *Mindset*

*When you hear “children,” think “freshmen”*

handout of Holmes graphic
Metacognitive knowledge of self affected by:

– Prior learning and misconceptions
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– Stage of intellectual development
– Motivation to change/stretch/learn
Level and awareness of cognition

How do your students get practice working at higher cognitive levels? How might you help them be more aware of the cognitive level of their tasks?

Revised taxonomy from Anderson, L.W., Krathwohl, D.R. (Eds) (2001)
One example with first-year students

Cognitive Skills
(based on revised Bloom's Taxonomy)

Remember
- name
- define
- recall
- recognize
- list
- label

Understand
- classify
- explain
- give example
- summarize
- organize

Analyze
- compare
- contrast
- deconstruct
- infer
- predict
- map

Evaluate
- defend
- conclude
- prioritize
- assess
- justify
- interpret

Apply
- use
- practice
- revise
- adapt
- hypothesize

Create
- invent
- construct
- devise
- speculate
- imagine
- design
- integrate

Higher order cognitive skills (HOCS) are shown in darker green, lower cognitive skills (LOCS) are more yellow.
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.

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

This diagram (developed by Ellen Goldey, Wofford College, goldeyae@wofford.edu) 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 Educ, 7:389-381.
see Crowe et al., Biology in Bloom, for other great examples:

<table>
<thead>
<tr>
<th>Bloom’s level</th>
<th>Individual activities</th>
<th>Group activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge (LOCS)</td>
<td>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, 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</td>
<td>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, Discuss content with peers, Take turns quizzing each other about definitions and have your peers check your answer</td>
</tr>
<tr>
<td>Comprehension (LOCS)</td>
<td>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</td>
<td>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</td>
</tr>
<tr>
<td>Application (LOCS/HOCS)</td>
<td>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</td>
<td>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, 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.</td>
</tr>
<tr>
<td>Analysis (HOCS)</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>Synthesis (HOCS)</td>
<td>Provide a written assessment of the strengths and weaknesses of your peers’ work or understanding of a given concept based on previously determined criteria</td>
<td>Provide a verbal assessment of the strengths and weaknesses of your peers’ work or understanding of a given concept based on previously described criteria and have your peers critique your assessment</td>
</tr>
<tr>
<td>Evaluation (HOCS)</td>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>
Metacognitive knowledge of self affected by:

- Prior learning and misconceptions
- Mindset
- Practice in, and awareness of, all cognitive domains
- Stage of intellectual development
- Motivation to change/stretch/learn
Perry Scheme of Intellectual and Ethical Development:

Perry Position:

- Dualism (Good vs. Bad)

View of Knowledge:

- Knowledge is Received (from Authorities)

The position of many incoming students; must get good teacher to be successful (bad teacher is to blame for lack of success)


Knefelkamp and Cornfeld, 1979, Combining Student Stage and Style in the Design of Learning Environments.
Perry Scheme of Intellectual and Ethical Development:

**Perry Position:**
- Dualism
- Multiplicity (there are multiple perspectives and all have value; be open-minded)

Knefelkamp & Cornfield: Learning Environments

**View of Knowledge:**
- Knowledge is Received
- Knowledge is Subjective (anyone can be right about anything)

People at this next stage often do not discern among points of view or validity of information.
Perry Scheme of Intellectual and Ethical Development:

Perry Position:
- Dualism
- Multiplicity
- Relativism (weigh various reasonable options)

Knefelkamp & Cornfield: Learning Environments

View of Knowledge:
- Knowledge is Received
- Knowledge is Subjective
- Knowledge is Procedural (depends upon procedures and context)

Students at this level begin to imagine becoming an expert in something.
Perry Scheme of Intellectual and Ethical Development:

Perry Position:
- Dualism
- Multiplicity
- Relativism
- Commitment (actions based on integration of knowledge and self reflection)

Knefelkamp & Cornfield: Learning Environments

View of Knowledge:
- Knowledge is Received
- Knowledge is Subjective
- Knowledge is Procedural
- Knowledge is Constructed (ongoing quest in face of ambiguity and human error)

Very few students – and few people – ever get to this position.
Metacognitive knowledge of self affected by:

– Prior learning and misconceptions
– Mindset
– Practice in, and awareness of, all cognitive domains
– Stage of intellectual development
– Motivation to change/stretch/learn
Getting Meta on Motivation

• What impacts student motivation?
  – emotions
  – relevance of course content and skills to self/world
  – connectedness to peers/instructor/department/institution
## Being more metacognitive about teaching

Table 3. Sample self-questions to promote faculty metacognition about teaching

<table>
<thead>
<tr>
<th>Activity</th>
<th>Planning</th>
<th>Monitoring</th>
<th>Evaluating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class session</td>
<td>• What are my goals for this class session? How did I arrive at these goals?</td>
<td>• What do I notice about how students are behaving during this class session? Why do I think this is happening?</td>
<td>• How do I think today’s class session went? Why do I think that?  What evidence do I have?</td>
</tr>
<tr>
<td></td>
<td>• What do I think students already know about this topic? What evidence do I have for my thinking?</td>
<td>• What language or active-learning strategies am I using that appear to be facilitating learning? impeding learning?</td>
<td>• How did the ideas of today’s class session relate to previous class sessions? To what extent do I think students saw those connections?</td>
</tr>
<tr>
<td></td>
<td>• How could I make this material personally relevant for my students? Why do I think this?</td>
<td>• How is the pace of the class going? What could I do right now to improve the class session?</td>
<td>• How will I think about how today’s class session went influence my preparations for next time?</td>
</tr>
<tr>
<td></td>
<td>• What mistakes did I make last time I taught this and how can I not repeat these?</td>
<td>• In what ways am I effectively reaching my goals for students through my teaching? How could I expand on these successful strategies?</td>
<td>• What evidence do I have that students in my course learned what I think they learned?</td>
</tr>
<tr>
<td>Overall course</td>
<td>• Why do I think it’s important for students pursuing a variety of careers to learn the ideas in my course? What are my assumptions?</td>
<td>• In what ways is my approach to teaching in this course not helping students learn? How could I change my teaching strategies to address this?</td>
<td>• What advice would I give to students next year about how to learn the most in this course?</td>
</tr>
<tr>
<td></td>
<td>• How does success in this course relate to my students’ career goals? How might I reveal these connections to them?</td>
<td>• How is my approach to teaching this course different from last time I taught it? Why?</td>
<td>• If I were to teach this course again, how would I change it? Why? What might keep me from making these changes?</td>
</tr>
<tr>
<td></td>
<td>• What do I want students to be able to do by the end of this course? Still be able to do 5 yr later?</td>
<td>• How is my thinking about teaching changing?</td>
<td>• How is my thinking about teaching changing?</td>
</tr>
</tbody>
</table>

Practicing what we preach: how can we be more metacognitive about our teaching?

Do you recognize yourself (or colleagues) in Professor Strait?

Drawing on the lessons in this workshop, discuss with others how you might advise Professor Strait.

What knowledge, skills and dispositions to we want for our students?

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.

<table>
<thead>
<tr>
<th>Canonical Knowledge (To Know)</th>
<th>Skills (To Do)</th>
<th>Dispositions (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>
</tbody>
</table>

"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.
How might you plan for a more metacognitive department?

- 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?