iCognition

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Abstract. To what degree can technology be used to facilitate research on the value of metacognition? Here we consider how to implement metacognitive training in a course on atmospheric sciences using two web applications. One is used in-class and the other for homework. Early results are discussed.

I remember once finishing a lecture on the why particles are distributed in three modes in the atmosphere. I used an image, brilliantly developed years earlier by Prof. Kenneth Whitby of the University of Minnesota showing a plot of the tri-modal distribution of particle number versus particle size (Figure 1) as I felt it embodied the essence of what I was trying to convey that hour. To be sure I was pleased with my lecture, detailed yet full of examples and relevant examples working to describe how physical processes in the atmosphere would be expected to produce three distinct sizes of particles. The graph had served to end the lecture with the scientific major chord that would have made Beethoven proud.

I stood and turned to the class and asked for questions. There was a long silence, which I assumed to be a time of reflection, with the students absorbing the lesson and constructing their own understanding. Then, just before time was up a fellow in the front row raised his hand and asked, "I see the three mountains in the picture, but I don't understand which way the wind is blowing."

It is the only time in my 30 years of teaching that I swore at a student…

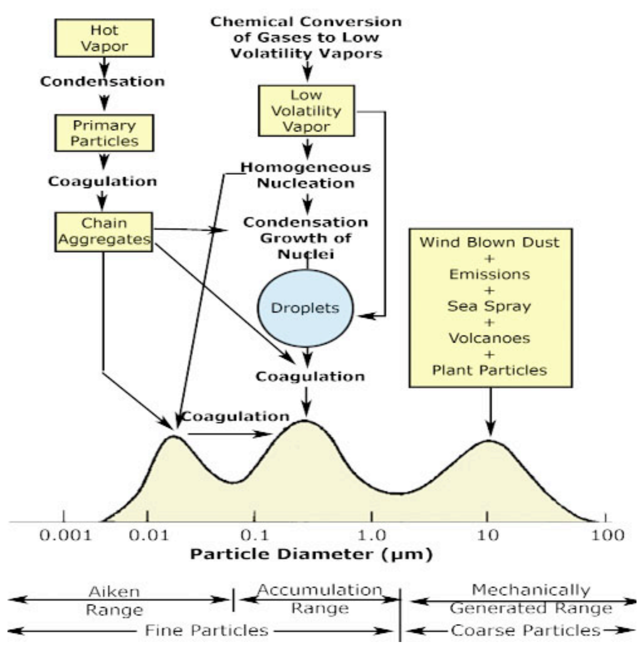

Figure 1. Frequency distribution of particles in the atmosphere by size as developed by Whitby (1978).

The relationship of this story to metacognition is embodied in that rapscallion's response. Students often think they understand what is being taught but it is not uncommon that that are wrong. Metacognition is, first, the process of students, independent of quizzes and tests, understanding what they understand. Second, once realizing their understanding is flawed it is the process of students independently making adjustments in their learning strategies to improve their learning in subsequent opportunities.

It is not something taught in any science class I ever took.

Metacognition can also happen with a wide range of granularity. On the scale of a semester, for example, many instructors design a first exam that is somewhat harder than the rest. This serves to get the attention of those who thought they understood the material and took meager effort to prepare for the exam. Having made that mistake once some will change their study strategies and devote more time and energy to the process by the second exam. Here a simple way to stimulate metacognition is to meet with those who perform poorly and ask them if they were surprised by their grade, why they think they did poorly, and how had they studied for the exam leading to questions about what strategies they will want to adopt to prepare for the next exam.

The literature is ripe with articles on metacognition, but scientists may find such literature obtuse and lacking in examples relevant to their discipline. So, at the risk of insulting the scholars of this field this article offers a short guide to metacognition. My goal is to give my opinion on why we, as geoscientists, should care about it; examples of how you might implement it in your classes and strategies for assessing whether it was worth the effort. My motivation for exploring this issue, I will admit, has not been entirely altruistic (i.e. to better the learning outcomes of my students) but more to explore how to build these principles into the web applications I am constructing for large classes. I offer these tools as one example for how to implement metacognitive principles in lecture and in homework assignments.

What is Metacognition?

As a scientist I do not feel qualified to define what metacognition is or isn't. Fortunately for me the topic has been well articulated by others, including on this site. In *How People Learn* (NRC, 2000) metacognition is identified as one of three core learning principles for the enterprise of teaching. They state

> "Integration of metacognitive instruction with discipline-based learning can enhance student achievement and develop in students the ability to learn independently. It should be consciously incorporated into curricula across disciplines and age levels."

Yet, despite its perceived importance it is possible that a broad spectrum of science instructors at colleges and universities are unfamiliar with how to implement metacognitive instruction in their courses. Moreover, even if motivated to use metacognition instruction, it remains a "fuzzy" concept (Wellman, 1983) with many authors offering variations on the basic definition.

Metacognition has been defined to consist of the knowledge and regulatory skills that are used to control one's cognition (Schraw, 2001). Schoenfeld (1987) summarized that metacognition encompasses three categories of students' intellectual behavior:

1. Their knowledge about their own thought processes (Is it accurate?)
2. Their self-regulation of knowledge (Do they track their learning actions?)
3. Their beliefs and intuitions (What beliefs/preconceptions do they bring to class that will shape their learning?)

Accepting that the integration of metacognitive instruction is an important and useful component of course design in higher education, instructors are still left to identify methods to achieve this goal in there own classes.

What's in Metacognition for Me?

Many students arrive in our classes with good study habits and a desire to learn. They have, at some point, constructed strategies for adapting their learning to new situations and disciplines. But other students, and particularly in the survey courses required of non-science majors, bring to class a preconceived view that science "doesn't come easily" to them and, save for protecting their precious GPA, they have little incentive to change that opinion. Some of these students complain that they are doing well in their other topics but science provides a mental block. This self-perception, coupled with their non-voluntary conscription in the science class offers them little hope for performing well in the course. These are the students for whom we earn our salaries.

Arguably we could ignore them and ignore their grousing about the requirement and the course (a popular decision as many of the instructors for these courses have likewise been conscripted into participating). But for those who are passionate about their discipline it is both inconceivable that students don't share their enthusiasm and an enigma that students do poorly on their exams. It is, in fact, confusing why some students cannot do well on the exams and quizzes. It is for these latter students that metacognitive skills can play an important role and, arguably, it is through the administration of metacognitive training that instructors may find the best hope for overcoming the preconceptions students carry into class.

A simple step in metacognitive training that I've employed is to require all students who do "poorly" (definitions are subjective) to meet with me after the first exam. In these individual meetings I try to learn about the student's history and how they perceive they are doing in their other classes and their attitudes about learning. I've used these opportunities to ask how they studied for the first exam and work with them to construct other strategies. As a result of this I began to compile a list of strategies that students

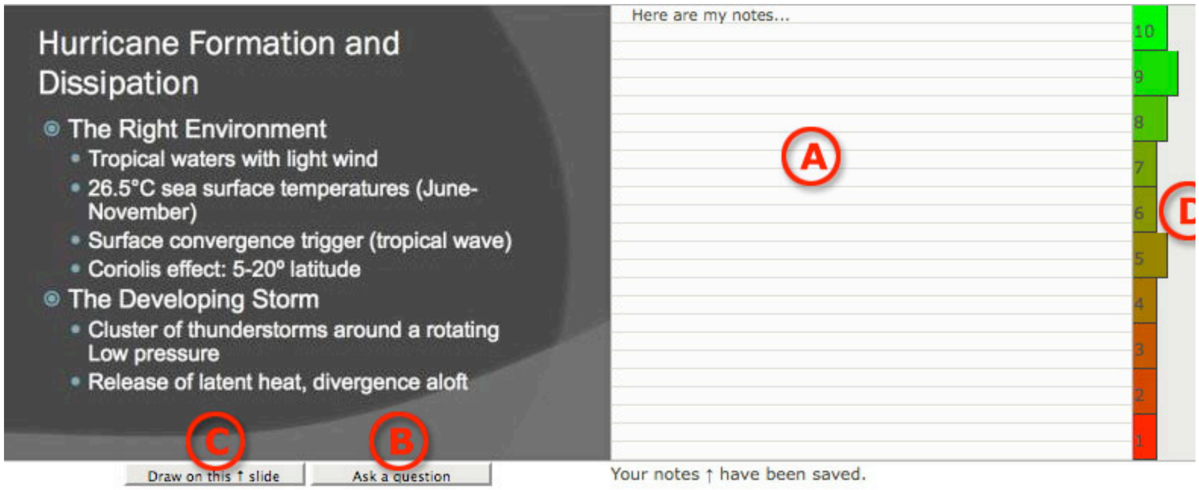

Figure 2. Screen shot from one pane of LectureTools showing (A) note-taking area, (B) question-submission button, (C) draw-on the instructor slide and (D) student self-assessment of "confidence" in understanding. [from http://www.lecturetools.org]

thought would be useful. On top of that I spent an excellent semester on sabbatical at the Carl Wieman Science Education Institute at the University of British Columbia in Vancouver where faculty and science educators meet weekly to discuss a weekly reading on topics germane to science education. Here articles drawn from the literature were discussed, some of which focused on the issue of metacognition.

My interest was to take the lessons learned from my own experiences and those gleaned from the literature and incorporate them in two web applications that I was developing for use in classes at the University of Michigan.

Using Web Tools to Study Metacognition

Over the past four years I have been designing, coding, and evaluating systems that use Internet devices to expand peer discourse in introductory science classes. Two systems have evolved, the first, 'LectureTools' (http://www.lecturetools.org), began as a framework to research new methods for expanding in-lecture discourse by engaging students in text-based, image-based and simulation based responder questions. The second, XamPREP (http://www.xamprep.com) was my attempt to rethink the design of on-line textbooks by making them more inquiry-based. Neither tool is presented as a solution to how to integrate metacognitive training into class, both do, however, represent a framework in which both new methods and approaches can be tested.

In-Class Tools

The original intention was to develop a web-based student response system (SRS). However, as students and instructors used (http://www.lecturetools.org 'LectureTools'] they offered ideas for how it could be made more useful and easier to use. The system evolved rapidly through ad hoc trials coupled with rapid prototyping.

Today 'LectureTools' has evolved to provide a range of student response options plus it allows students to take notes synchronized to lecture slides, draw on and save the instructor's lecture slides, pose clarifying questions that can be answered asynchronously during class or after class and self-assess their understanding during lecture (see Figure 2). The latter aspect ("D" in Figure 2) is an evolving effort to facilitate student introspection during lecture. While still a research tool the concept was that students should be able to indicate their self-assessed "confidence" with the material being presented. In principle this allows students to mark parts of the lecture where they are less self-confident and instantly get feedback on how the whole class is voting (the "confidence" bars update every few seconds). Moreover the instructor also receives this information in real-time and can use this information to revisit topics during lecture or subsequently.

Out-of-class Tools

One motivating reason I wanted to redesign the textbook was students freely admitted that a large majority rarely opened the book save for the week before an exam. This was especially true for students who had scored poorly on exams. My goal was to force reading more in concert with lecture and the mechanism I used to achieve this required a redesign of the textbook.

First, the textbook is delivered in an inquiry-based format where I can easily select about ten multiple choice questions before each lecture and assign them to be competed before lecture begins. As the student tries to answer these questions they are immediately directed to the place in the book where they can begin to find the answer. This model 1) forces students to consider concepts germane to lecture before lecture and 2) focuses their reading to the areas of the text that I consider particularly important. A hidden agenda is to provide a model for weaker students to instill more consistent and synchronized study habits.

At the same time I wanted the online textbook to be more than just a textbook online. I wanted it to take advantage of the communicative power of thee Internet by integrating tools for self-assessment and query. Figure 3a illustrates an initial screen in a pre-lecture quiz. Figure 3b illustrates the screen when the student gets the question correct. Notice it now offers both the opportunity t self assess their level of confidence in understanding the question and answer and a link to pose a follow-up question that is sent to a representative of the class (chosen by the instructor). Figure 3c shows the graph returned after entering a confidence factor in which the cumulative votes for the whole class are returned. These graphs are also available to the instructor who can review which questions caused the poorest confidence and can choose to use this feedback to guide lecture discussion.

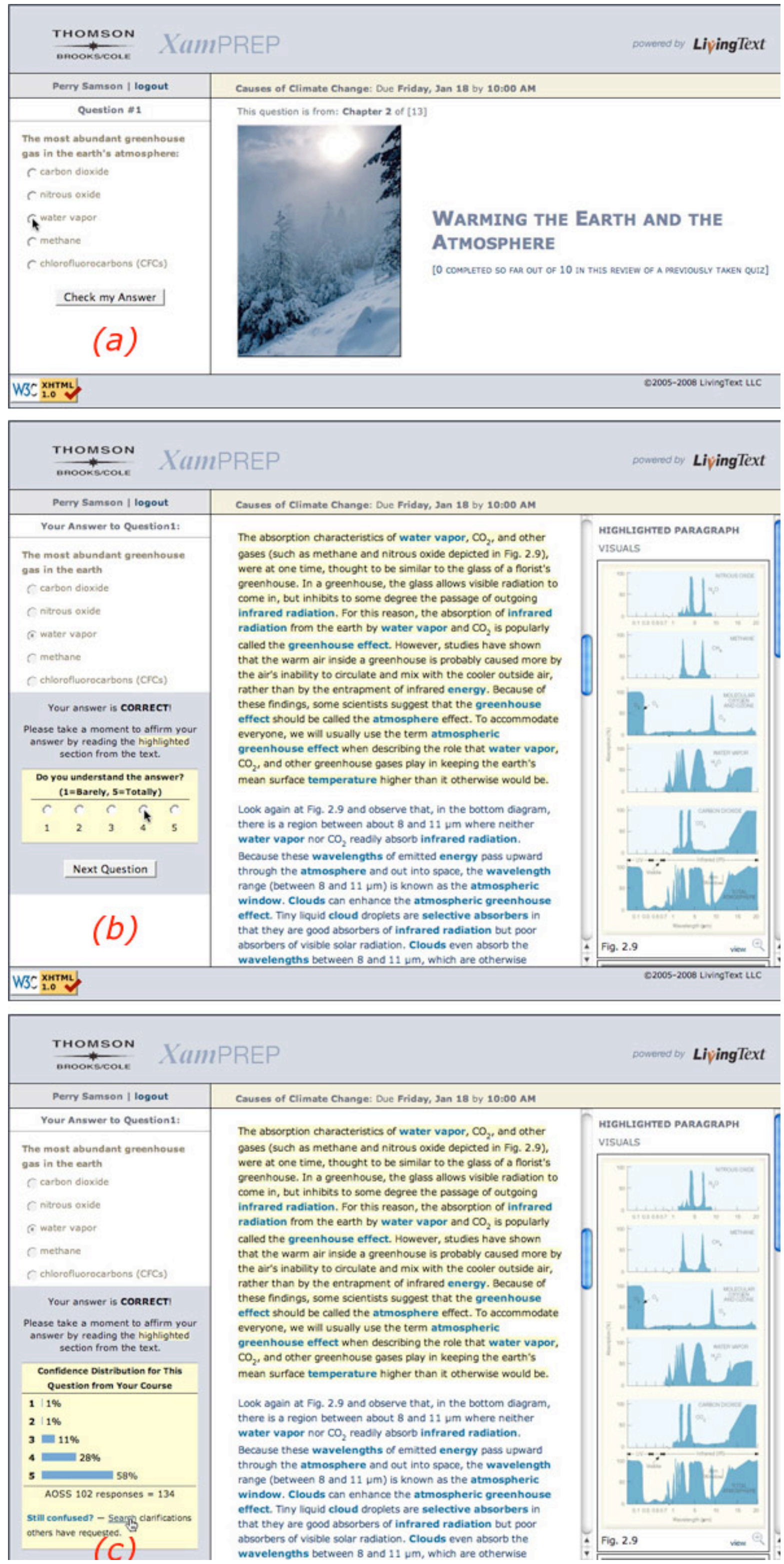

Figure 3. Screen shot from XamPREP showing (a) presentation of one of the questions in a pre-lecture quiz, (b) feedback when the student answers correctly, and (c) additional feedback when the student indicates their level of confidence in understanding the question and answer. [from http://www.xamprep.com]

Models for Implementing Metacognition

A model for how to implement metacognition is presented on the SERC website[1] based on the work of Lovett (2008). Restated, the examples offered are to consider building "wrappers" around lectures, homework and exams that will lead students to monitor and adapt their learning strategies. Focusing first on lectures it is suggested that instructors begin lecture by encouraging their students to think about the key points of the lecture as they listen and take notes. At the end of the lecture, ask the students to write what they think the three most important ideas of the lecture. After they hand those in, the instructor should reveal what they consider to be the three most important ideas from the lecture.

It has been suggested by Lovett (2008) and others that one model for teaching students to monitor their learning and to adapt their strategies to learning challenges is through use of "wrappers." In lecture, for example, it is beneficial to "wrap" the lecture - or a subset of the lecture - with a question before and after. One example would be to ask students to assess their ability to, say, read maps, then give them a challenge that requires map reading and ask them afterwards to assess their ability to perform the task assigned. Through this process of self-assessment, concept challenge, feedback and post-assessment students will often see that their level of understanding is less than they expected. Subsequent discussion can help the student rethink the concept and challenge the beliefs/preconceptions they brought to class.

Success has also been shown at reducing the granularity of assessment to the sub-lecture level. One alternative is to offer "mini-lectures" that are wrapped inside a concept question. Palinscar and Brown (1984) also propose the use of "reciprocal teaching" wherein students interact verbally to increase their understanding as part of the "wrapped" mini-lecture. This approach resonates well in science education where Mazur (1997) has introduced "peer instruction" to stimulate verbal interactions in science classes. Peer instruction has been demonstrated (Bair et al., 2007: Crouch and Mazur, 2001) to be effective in increasing student understanding.

The "mini-lecture" model (Figure 4) suggests the following steps:

1. Break lecture into smaller units and, as appropriate, pose a concept test first that asks both a concept question and/or queries the students to assess their understanding of the concept.
2. Once they have answered you ask them to defend/discuss their answer through discussion with others in the class.
3. At this point you may ask them to edit/repost their answers to questions from (1) and/or open a discussion with the class to answer questions that have arisen.

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[1] http://serc.carleton.edu /NAGTWorkshops/metacognition/teaching_metacognition.html

4. Optionally, at the end of this mini-lecture you may ask a follow-up metacognitive question like "Now that you have completed this segment, how quickly and easily do you think you can solve similar problems?"

The mini-lecture typically transitions into a new concept and the cycle is restarted. Clearly it would become onerous to all to ask metacognitive questions multiple times in a lecture so it is suggested that step (4) be offered only occasionally and most effectively on the more challenging concepts. We speculate, but have yet to assess, that introduction of these techniques earlier in the semester will help condition the students to critically assess their understanding throughout the semester.

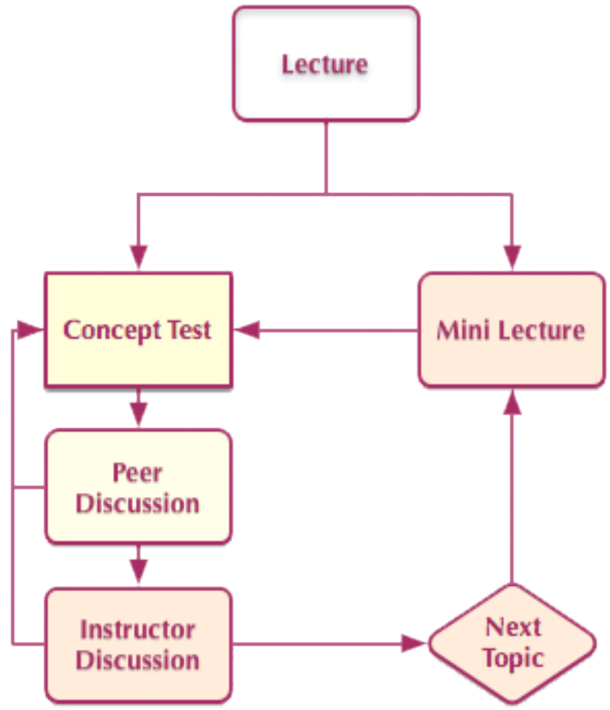

Figure 4. Model for Mini-Lectures based on Peer Instruction techniques (Mazur, 1997).

The "wrapper" for the mini-lecture will be to ask students to self-assess their understanding of the topic prior to the content quiz. This is followed by a concept challenge. As they answer each question they are asked to self-assess their confidence in their answer. The solution is posed and students are asked to assess how well they did and, if incorrect, where they believe their logic was flawed. The value of the technology here is to document answers and provide a reasonably easy mechanism to construct and deliver questions and surveys.

References

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