Promoting Student Metacognition

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Feature
Approaches to Biology Teaching and Learning

Promoting Student Metacognition

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> Learning how to learn cannot be left to students. It must be taught. (Gall *et al.*, 1990)

Imagine yourself as the instructor of an introductory undergraduate biology course. Two students from your course independently visit your office the week after the first exam. Both students are biology majors. Both regularly attend class and submit their assignments on time. Both appear to be eager, dedicated, and genuine students who want to learn biology. During each of their office hours visits, you ask them to share how they prepared for the first exam. Their stories are strikingly different (inspired by Ertmer and Newby, 1996).

During office hours, Josephina expresses that she was happy the exam was on a Monday, because she had a lot of time to prepare the previous weekend. She shares that she started studying after work on Saturday evening and did not go out with friends that night. When queried, she also shares that she reread all of the assigned textbook material and made flashcards of the bold words in the text. She feels that she should have done well on the test, because she studied all Saturday night and all day on Sunday. She feels that she did everything she could do to prepare. That said, she is worried about what her grade will be, and she wants you to know that she studied really hard, so she should get a good grade on the exam.

Later in the week, Maya visits your office. When asked how she prepared for the first exam, she explains that she has regularly reviewed the PowerPoint slides each evening after class since the beginning of the term 4 weeks ago. She also read the assigned textbook pages weekly, but expresses that she spent most of her time comparing the ideas in the PowerPoint slides with the information in the textbook to see how they were similar and different. She found several places in which things seemed not to agree, which confused her. She kept a running list of these confusions each week. When you ask what she did with these confusions, she shares that she brought them to her weekly study group with peers from her course lab section. There, she says, she got most of her questions answered and lots of her confusions cleared up. She has come to office hours to ask you about a couple of things that she did not figure out before the exam that she thinks she probably missed. She is not too worried about her score on the exam, because most of the material related to problems and concepts that she felt had been thinking about a lot.

So, what is different about Josephina and Maya? No doubt many things, including their educational histories, their personalities, and more. However, one key difference in their approach to their studies is evident from their stories. They appear to be strikingly different in knowing how to learn, being able to monitor their own understanding, being reflective about what they understand and do not understand, and being able to strategize about how to resolve their confusions. They are different in their ability to use metacognitive approaches in their learning.

INTRODUCING METACOGNITION

The importance of metacognition in the process of learning is an old idea that can be traced from Socrates' questioning methods to Dewey's twentieth-century stance that we learn more from reflecting on our experiences than from the actual experiences themselves (Dewey, 1933). What is more recent is the coining of the term "metacognition" and the emergence of a metacognition research field in the last four decades. Credited to developmental psychologist John Flavell in a publication from the 1970s, metacognition is used in different disciplines in different ways, and a common, succinct definition appears to be elusive in the literature. Below is an excerpt from Flavell's original writing, as well as several additional definitions and conceptualizations from different sources:

> Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact. (Flavell, 1976)

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> Metacognition: awareness or analysis of one's own learning or thinking processes. (Merriam-Webster, 2012)

> Metacognition also includes self-regulation—the ability to orchestrate one's learning: to plan, monitor success, and correct errors when appropriate—all necessary for effective intentional learning... Metacognition also refers to the ability to reflect on one's own performance. (National Research Council, 2000)

> Students learn to monitor and direct their own progress, asking questions such as "What am I doing now?," "Is it getting me anywhere?," "What else could I be doing instead?" This general metacognitive level helps students avoid persevering in unproductive approaches... (Perkins and Salomon, 1989)

These multiple perspectives on what metacognition might entail—which expand on Flavell's original definition to include an emphasis on planning, monitoring, and evaluating one's own learning processes—are likely related to the relative youth of the metacognition research field and the associated growing pains of an emerging discipline (Flavell, 1979; Schraw, 1998). Delineation of distinct aspects of metacognition, development of tools for measuring these aspects, and strategies for teaching them to students are all active areas of inquiry among researchers across several social science disciplines (Zohar, 2009; Schraw *et al.*, 2006). In addition, there are complex overlaps between metacognition research and other research arenas focused on self-regulated learning (an individual's ability to take control of his or her learning; Schraw *et al.*, 2006) and self-efficacy (an individual's conceptualization of his or her own competency; Bandura, 1977). Because the goal of this feature is to translate ideas from other disciplines that may have immediate, practical relevance for biology education, I will leave these intriguing overlaps and areas of active inquiry for the exploration of interested readers.

So, let us reconsider Josephina and Maya. Their stories are likely familiar to anyone who has taught college biology even for a short period of time. And the reactions from faculty to these two kinds of students might be briefly summarized as exasperation with Josephina and elation with Maya. Faculty are often perplexed by students like Josephina, who do not seem to have mastered learning how to learn, and some faculty will assert that it is their job to "teach biology, not study strategies." Yet metacognition, which represents more than just study skills, has been linked to improving thinking skills and promoting conceptual change in younger students (Nickerson *et al.*, 1985; White and Gunstone, 1989; Georghiades, 2000). Additionally, there is evidence that improved metacognition is associated with promoting young students' overall academic success (Adey and Shayer, 1993; Kuhn and Pearsall, 1998). Evidence indicates that individuals with poor metacognitive skills perform less well academically than peers (Kruger, 1999; Dunning *et al.*, 2003). But there remains much to be learned about the influence of metacognition on learning, especially among college-age students and within particular disciplinary contexts (e.g., biology vs. physics vs. music theory). So, how can we as biology educators use what is currently known about metacognition to our and our students' advantage to support biology teaching and learning? What could integrating student metacognition into a college biology course look like? And how might active learning look different with more emphasis on metacognition?

USING METACOGNITION TO HELP STUDENTS LEARN TO THINK LIKE BIOLOGISTS

> To make an individual metacognitively aware is to ensure that the individual has learned how to learn. (Garner, 1988)

With the recent publication of the 2011 American Association for the Advancement of Science (AAAS) report, *Vision and Change for Undergraduate Biology Education*, and the 2012 President's Council of Advisors on Science and Technology (PCAST) report, *Engage to Excel*, considerable attention is being paid to transforming the learning experiences of undergraduate students in the sciences (AAAS, 2011; PCAST, 2012). An example of our collective aspirations as a biology education community for what we want students to be able to do at the conclusion of their undergraduate biology education is stated as follows in *Vision and Change*:

> Biology in the 21st century requires that undergraduates learn how to integrate concepts across levels of organization and complexity and to synthesize and analyze information that connects conceptual domains.

This aspiration can be approximated by the assertion that we want undergraduate learning experiences to help students learn to think like biologists. Promoting student metacognition—teaching students to think about how they are thinking about biology and how they approach learning about biology—would seem to be a useful strategy in striving to reach these kinds of goals for students (NRC, 2000; D'Avanzo, 2003; Crowe *et al.*, 2008). Below, I describe potential approaches to increasing attention to metacognition in undergraduate biology classrooms, including: 1) explicitly teaching students metacognitive strategies, and 2) more generally building a classroom culture grounded in metacognitive strategies by modifying what we are already doing.

EXPLICITLY TEACHING STUDENTS METACOGNITIVE STRATEGIES IN BIOLOGY COURSES

> There is a need to teach for metacognitive knowledge explicitly...we are continually surprised at the number of students who come to college having very little metacognitive knowledge; knowledge about different strategies, different cognitive tasks, and particularly, accurate knowledge about themselves. (Pintrich, 2002)

Teaching students to use metacognition to understand how they are thinking about biology provides an important step on the path to thinking like a biologist (AAAS, 2011). In the context of undergraduate biology teaching, this need not take much time, and it is an effort that is in the service of learners and learning, as well as teachers and teaching. Table 1 provides examples of self-questions that metacognitive undergraduate biology learners might ask in the process of planning, monitoring, and evaluating their learning in the context of a single class session, a homework assignment, an

Table 1. Sample self-questions to promote student metacognition about learning[a]

Activity	Planning	Monitoring	Evaluating
Class session	• What are the goals of the class session going to be? • What do I already know about this topic? • How could I best prepare for the class session? • Where should I sit and what should I be doing (or not doing) to best support my learning during class? • What questions do I already have about this topic that I want to find out more about?	• What insights am I having as I experience this class session? What confusions? • What questions are arising for me during the class session? Am I writing them down somewhere? • Do I find this interesting? Why or why not? How could I make this material personally relevant? • Can I distinguish important information from details? If not, how will I figure this out?	• What was today's class session about? • What did I hear today that is in conflict with my prior understanding? • How did the ideas of today's class session relate to previous class sessions? • What do I need to actively go and do now to get my questions answered and my confusions clarified? • What did I find most interesting about class today?
Active-learning task and/or homework assignment	• What is the instructor's goal in having me do this task? • What are all the things I need to do to successfully accomplish this task? • What resources do I need to complete the task? How will I make sure I have them? • How much time do I need to complete the task? • If I have done something like this before, how could I do a better job this time?	• What strategies am I using that are working well or not working well to help me learn? • What other resources could I be using to complete this task? What action should I take to get these? • What is most challenging for me about this task? Most confusing? • What could I do differently midassignment to address these challenges and confusions?	• To what extent did I successfully accomplish the goals of the task? • To what extent did I use resources available to me? • If I were the instructor, what would I identify as strengths of my work and flaws in my work? • When I do an assignment or task like this again, what do I want to remember to do differently? What worked well for me that I should use next time?
Quiz or exam	• What strategies will I use to study (e.g., study groups, problem sets, evaluating text figures, challenging myself with practice quizzes, and/or going to office hours and review sessions)? • How much time do I plan on studying? Over what period of time and for how long each time I sit down do I need to study? • Which aspects of the course material should I spend more or less time on, based on my current understanding?	• To what extent am I being systematic in my studying of all the material for the exam? • To what extent am I taking advantage of all the learning supports available to me? • Am I struggling with my motivation to study? If so, do I remember why I am taking this course? • Which of my confusions have I clarified? How was I able to get them clarified? • Which confusions remain and how am I going to get them clarified?	• What about my exam preparation worked well that I should remember to do next time? • What did not work so well that I should not do next time or that I should change? • What questions did I not answer correctly? Why? How did my answer compare with the suggested correct answer? • What questions did I not answer correctly? Why? What confusions do I have that I still need to clarify?
Overall course	• Why is it important to learn the material in this course? • How does success in this course relate to my career goals? • How am I going to actively monitor my learning in this course? • What do I most want to learn in this course? • What do I want to be able to do by the end of this course?	• In what ways is the teaching in this course supportive of my learning? How could I maximize this? • In what ways is the teaching in this course not supportive of my learning? How could I compensate for or change this? • How interested am I in this course? How confident am I in my learning? What could I do to increase my interest and confidence?	• What will I still remember 5 yr from now that I learned in this course? • What advice would I give a friend about how to learn the most in this course? • If I were to teach this course, how would I change it? • What have I learned about how I learn in this course that I could use in my future biology/science courses? In my career?

[a]Inspired by Ertmer and Newby (1996), Schraw (1998), and Coutinho (2007).

exam, or an entire course. While this collection of questions by no means represents the entire landscape of what metacognition could involve, it does provide starting points for faculty who wish to talk with students explicitly about metacognitive strategies. These questions can be shared directly with students and/or embedded into particular assignments. Several examples of how these student self-questions can be explicitly used in teaching a biology course are considered below.

Preassessments—Encouraging Students to Examine Their Current Thinking

The importance of instructors knowing what students are thinking about a topic prior to trying to teach them something new has been written about extensively. However, preassessment can also be helpful for the learner and is a wonderful opportunity for promoting metacognition among students. "What do I already know about this topic that could guide my learning?" is an example of a self-question that it at the core of most preassessments used by instructors. It takes no more than a few simple statements by an instructor to transform an existing preassessment prompt—be it a homework assignment, an index card, or a clicker question—into a metacognitive activity for students, directing them not only to complete the task as part of the course, but also to be metacognitive in doing so and to use the information given on the preassessment to help them begin thoughtful planning of how they might approach learning this new idea.

The Muddiest Point—Giving Students Practice in Identifying Confusions

One long-standing, active-learning strategy that has been used across many disciplines in classrooms of any size is the Muddiest Point (Angelo and Cross, 1993). Usually done as an in-class, quick-write on an index card, students are asked to write for a brief period of time—1, 3, or 5 min, usually at the end of a class session—to address the self-question "What was most confusing to me about the material being explored in class today?" Similar to preassessments, the Muddiest Point is incredibly useful to instructors in gauging what was challenging for or unclear to students. However, the oft-missed opportunity is for this activity to explicitly charge students to identify what they are confused about and then to embrace, work on, and wrestle with that confusion as they participate in the learning activities of the course. For many students, it is an unusual experience for an instructor to invite them to share confusions aloud in a science classroom, in which the conversation is often limited to students who are offering the scientifically most accurate answer. Students who are confused risk scorn by raising a question or revealing confusion, unless instructors explicitly invite the sharing of confusions and create a safe learning environment in which to do so. Regular use of the Muddiest Point in classrooms, which requires only a few minutes, sets a tone that confusion is a part of learning and that articulating confusions is not done solely to inform the instructor, but also to inform students themselves; students can use identified confusions to drive their independent learning or to generate dialogue in review sessions.

Retrospective Postassessments—Pushing Students to Recognize Conceptual Change

Cognitive psychologists and science education researchers conceptualize learning as a student-centered activity in which students change their ideas about a topic (Posner *et al.*, 1982). This view implies that students will not really learn new information if they do not go through a metacognitive realization that requires them to examine how they thought about the topic before and how they are thinking differently about that topic now; this is similar to Dewey's assertion that reflection on an experience is the key step in learning (Dewey, 1933). A simple tool for explicitly charging students to think about how their ideas are (or are not) changing is a retrospective postassessment. As its moniker implies, this tool is a postassessment and occurs after learning may have taken place. It is retrospective, in that students are asked to recall how they were thinking about the topic prior to course learning activities and compare that with how they are now thinking about the same topic afterward. As an example, students might be asked to complete the phrase: "Before this course, I thought evolution was. . . Now I think that evolution is. . ." Alternatively, they may be asked to write about three ways in which their thinking about a given topic has changed over a given period of time. Either of these explicit approaches to teaching metacognition is a mechanism of training students to self-question, "How is my thinking changing (or not changing) over time?"

Reflective Journals—Providing a Forum in Which Students Monitor Their Own Thinking

In the case of Josephina, one of the metacognitive strategies that she simply does not seem to possess is to be analytical about what did or did not work well for her in studying for the last exam, and to then use that information in preparing for future exams. Instructors can assign something as simple as a low-stakes, low-points writing assignment after a first exam, asking students to reflect and write a brief letter to their future selves covering: "What about my exam preparation worked well that I should remember to do next time? What did not work so well that I should not do next time or that I should change?" If an instructor assigns such writing, either in conjunction with an exam or as part of a specific reflective writing assignment, he or she is explicitly giving students a strategy for developing metacognitive approaches, as well as practice using that approach in the context of their disciplinary course. To extend this, instructors can also assign a reread of this writing before the next exam and a second writing assignment on how well students followed their own advice to themselves. In addition, students can be asked to share their strategies with fellow students and to identify at least two new exam preparation strategies used by their peers. If such writing about their metacognitive, thinking, and learning strategies is done regularly, students can create a reflective/biologist journal and can be rewarded with some form of credit, as for other course activities.

BUILDING A BIOLOGY CLASSROOM CULTURE GROUNDED IN METACOGNITION

> Making the discussion of metacognitive knowledge part of the everyday discourse of the classroom helps foster a language for students to talk about their own cognition and learning. (Pintrich, 2002)

While using specific individual assignments to teach students metacognitive strategies is one explicit approach, there are more subtle ways that metacognition can be integrated into the fabric of any course and become part of the everyday language of both teacher and students. This is particularly useful in helping students to become aware of when it is appropriate to apply their own metacognitive strategies—for

Table 2. Sample prompts for integrating metacognition into course activities

Pair discussion after a clicker question	Active-learning tasks and/or homework assignments (e.g., case studies, concept maps, problem sets)	Preparation for quizzes or exams
Share how you thought about what the question was asking. Share the process you used to arrive at an answer you wanted to choose. What was your main reason for choosing your answer, and what were the main reasons you did not choose each of the other answers? How did your ideas compare with your neighbor's ideas? What was most confusing to you about this question? How confident are you in your answer? Why? What else would you need to know to increase your confidence?	Pose three questions that you had about the concepts you explored in your assignment that you still cannot answer. Describe at least two ideas related to this assignment that you found confusing. "I learned a lot in doing this assignment." To what extent do you agree? disagree? How was the way you approached completing this assignment different compared with the last time we had an assignment like this? What advice would you give yourself based on what you know now if you were starting this assignment all over again?	How do you plan on preparing for the upcoming exam? Why? What resources are available to support you? How will you make sure to use these? How does your strategy for exam preparation compare with at least three colleagues in your lab section? (Go ask them!) What concepts have you found most confusing so far? What concepts have been most clear? Given that, how should you spend your study time in preparing for the exam? Based on your performance on the first exam, write a letter to yourself with advice about preparing for the next exam.

example, identifying confusions—that they may have learned through previous assignments. The point at which students have both learned metacognitive strategies *and* have become aware of when to apply these strategies is hypothetically the point at which they have matured into lifelong learners within their disciplines. Below are several starting points for thinking about how the language and habit of metacognition could become part of everyday classroom culture. In addition, Table 2 provides some sample prompts that can be used to add a metacognitive aspect to learning activities that may already be in use in your teaching, such as pair discussions after clicker questions, a variety of types of homework assignments, and the ever-present exams and quizzes. Simply adding one additional question or using some of the language in the table in making the assignment can demonstrate to students the value you as an instructor place on their efforts to develop metacognitive habits of mind as a biology student. Below are four general ways that instructors might build a classroom culture that promotes metacognition and conveys that culture to students.

Give Students License to Identify Confusions within the Classroom Culture

While most faculty welcome questions from students in or out of class, it is generally not in the culture of college science courses for students to share their confusions; rather, there is a focus on right answers and on being scientifically correct (Tobias, 1990; Steele and Aronson, 1995; Seymour and Hewitt, 1997). Simply giving students permission to be confused is one way to provide the impetus for students to be metacognitive and to ask themselves what they do not understand. Sometimes all that is required is for an instructor to explicitly share with students that an upcoming topic has proved confusing to students in the past and that confusion is to be expected. Even slight alterations in the verbal directions for course activities could serve to give students the license to share and display what is confusing to them, as opposed to hiding it. For example, during in-class pair discussion of a clicker question, the direction to not only compare chosen answers with a colleague but also to pose one question that relates to something you found confusing about the question could immediately increase the willingness and comfort level of students to discuss confusion, which demands them to be metacognitive during the activity.

Integrating Reflection into Credited Course Work

Integrating reflection into any course can be achieved by a relatively simple tweaking of existing course assignments. In addition to having students respond to homework questions or solve problems, instructors need only add one or more questions that push students to consider their own thinking (see Table 1). These questions can be as simple as "What was most challenging to you about this assignment?" to "What questions arose during your work on this assignment that you had not considered before?" The instructor's decision to make these kinds of questions part of an assignment—and part of the grading scheme for the assignment—can prompt students to bring a more metacognitive stance to their everyday coursework. Similarly, for assignments that involve diagramming or concept mapping, instructors can encourage (or require) students to indicate in their work what questions arose and which concepts they found most confusing. In this more subtle approach, what changes is not the assignment itself, but the nature of the assignment.

Metacognitive Modeling by the Instructor for Students

As a professional, practicing biologist, it can be almost impossible to remember a time when you did *not* think biologically, to remember the nature of your own biological confusions as a student, and to be able to offer up self-reflective examples of your own transitions in thinking for your students. As researchers, we think metacognitively all the time, reflecting on our current understanding of our research system, what the burning questions are, and how our thinking has changed over the years with new data. Showing students explicitly how you, as a biologist, think procedurally in solving a problem—how you start, how you decide what to do first and then next, how you check your work, how you know when you are done—is one example of metacognitive modeling. A teaching colleague of mine shared that he was perplexed as to why students were unable to make accurate predictions about the proportions of different phenotypes in the offspring from a specific cross, as required in response to a homework question. But when he asked all of the students to do a problem in class one day, he noticed that only a minority of them were drawing a Punnett square. When he asked several students why they did not have pencil and paper out, they said they thought they should just be able to do it mentally. My colleague then went to the stage and proceeded to metacognitively present how he thinks through a problem similar to their homework question. His first step—always, even as a practiced biologist—is to get out a pencil and a piece of paper and to translate the problem into a Punnett square! Showing students how we think about a biology concept, or how biologists more generally have thought about a concept over the history of biology, illustrates how the entire field of biology has changed its collective understanding. For example, what biologists think about how plants grow and build mass has undergone multiple revisions over time. In addition, our collective understanding of how genetic information is transferred from parent to offspring across all species is ripe for analysis of how "thinking like a biologist" looked different in Mendel's time versus the modern era.

ON INSTRUCTOR METACOGNITION AND BIOLOGY TEACHING

We began this exploration of metacognition by considering two contrasting students—Josephina and Maya. Now, imagine that you have the opportunity to talk to two of your biology faculty colleagues about their approaches to teaching. Both are research-active, full professors in biology. Both regularly teach introductory courses for biology majors. Both appear to be genuinely eager to help their students succeed in their biology courses. In your conversation with each of them, you begin by asking them about how their teaching is going this semester. In addition, you ask each of them how they prepare for class each week. Their stories are strikingly different.

Kara expresses dissatisfaction with the students in her upper-division biology course. She thinks that the students are getting worse every year, even though she works harder and harder to bring them more cutting-edge research in the field. She shares that she has committed to updating all of her PowerPoint lectures this semester, even though she already has tenure, and has often stayed up very late the night before to make sure that her slides are really clear. When queried about how she gets insights into how students are thinking, she shares that she has added an additional exam between the mid-term and the final to motivate students to keep up with the reading. She is also very frustrated that no students come to her office hours. She feels like she is doing everything she can to help students understand the material, but they do not seem to be willing to work as hard in a course as she did when she was an undergraduate. She is worried about her student evaluation scores, which have declined over the years, and she thinks it is not fair to be evaluated by students who do not seem to care about their learning.

In contrast, another faculty colleague, Aerial, seeks your input on a new series of clicker questions she has developed as the basis of a classroom activity she is trying out with her students the next day. From prior experience, she knows that few students are able to connect the ideas of photosynthesis with those of climate change, and she wants to start her new unit on transformation of matter and energy with an assessment question that will really get students thinking about their prior ideas. She has changed this unit of her course each time she has taught it over the last several years, based on all the information she has collected from students about their ideas on the topic. She is aware that the more she knows about how students are thinking, the more ideas she has about new things to try in her teaching. She also shares that many of the homework writing assignments students have already submitted before the midnight deadline show that they have identified exactly the confusions she wants to alert them to tomorrow! When you ask her if she is concerned about how students will react to her new clicker-based classroom activity, she is not too worried. She regularly shares with students her own rationale for why she has developed a particular learning activity for them and gets their feedback on it through an index card or homework assignments so that she will have insights for the next time she teaches the same activity.

So, what is different about Kara and Aerial? No doubt many things, but one key difference is their ability as faculty members to be metacognitive about their *teaching*. Similar to the contrast between Josephina and Maya's abilities to be metacognitive about their *learning*, there is a difference in the extent to which each of these faculty members is *thinking about how they think* about their teaching. While instructors no doubt bring a deeply metacognitive approach to their field of scientific research, cultivating a metacognitive lens toward one's teaching does not appear to automatically or easily transfer. However, developing a metacognitive stance toward one's own teaching—thinking about how you think about teaching—can be a wonderfully natural entry point into iteratively changing one's own teaching practice. Self-analysis about one's own ideas about teaching could include: What assumptions do I hold about students? To what extent do I have evidence for those assumptions? Why do I make the instructional decisions that I make? What do I know about teaching? What would I like to learn? What am I confused about? These analyses can also become more specific to particular granularities, ranging from an individual class session to the scope of an entire course. Table 3 provides some starting points in the form of sample self-questions for faculty that may aid them in becoming more metacognitive about their teaching.

Postscript 1: Using Metacognition to Make the Most of Active Learning—Learning from History

As stated above, attention to improving undergraduate biology education is high at present, and active-learning strategies are a central approach among suggested changes (AAAS, 2011). However, what different instructors mean by active learning and what active learning actually looks like in a different classrooms has not been well documented or investigated (Ebert-May *et al*., 2011; Tanner, 2011). Metacognition is not generally central, or even included, in discussions and articles about active learning. In fact, the term "active learning" is prominent and often used in the *Vision and Change for*

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

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

Undergraduate Biology Education report, whereas "metacognition" does not make an appearance (AAAS, 2011). One possible difference in the effectiveness of active-learning pedagogies in the hands of different instructors may lie in the extent to which these instructors consider student metacognition when they implement active-learning strategies.

During the 1980s, K–12 science education experienced a period of intense focus on hands-on learning, which might be considered parallel to the recent rise in emphasis on active learning in undergraduate biology education. However, there was a general dissatisfaction, with reports that K–12 students were doing a lot of activities but not necessarily very much thinking. The hands-on era in K–12 science education was followed a shift in both the language and emphasis in policy documents to minds-on and inquiry-based learning in the 1990s (National Research Council, 1996). One aspect of this shift in emphasis in K–12 science education reform was an increased emphasis on student metacognition, students thinking about what they were thinking while they were doing, as opposed to just doing hands-on, active things without the thinking. As such, attention to student metacognition may be especially salient at this moment in the history of the undergraduate biology education revolution. To avoid repeating the trajectory of K–12 science education reform, explicit attention to integrating metacognition into undergraduate biology classrooms could help keep a focus on the *learning* part of active learning.

Postscript 2: On Thinking about Your Thinking about This Article...

Why, in the first place, did you choose to read this feature? Was it the title? The term "metacognition"? What did you already know or think about metacognition before reading this feature? How, if at all, have your ideas changed? What in this article was most intriguing to you? What are you thinking about in terms of how you might use those ideas? What in the article was most confusing? How do you plan to follow up on that to clarify your ideas and learn more? Will you? Why or why not? As you read, what, if anything, came to mind that you already do with your students that may promote their use of metacognitive strategies? Are you thinking about how explicit you are with your students about the thinking strategies and processes that you yourself use as a practicing biologist? What is the most important thought you had in reading this article? Did it even have anything to do with metacognition?

REFERENCES

Adey P, Shayer M (1993). An exploration of long-term far-transfer effects following an extended intervention program in the high school science curriculum. Cogn Instr *11*, 1–29.

American Association for the Advancement of Science (2011). Vision and Change: A Call to Action, Final Report. Washington, DC: AAAS. http://visionandchange.org/finalreport.

Angelo T, Cross K (1993) Classroom Assessment Techniques: A Handbook for College Teachers, 2nd ed., San Francisco, CA: Jossey-Bass.

Bandura A (1977). Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev *84*, 191–215.

Coutinho SA (2007). The relationship between goals, metacognition, and academic success. Educate *7*, 39–47.

Crowe A, Dirks C, Wenderoth MP (2008). Biology in Bloom: implementing Bloom's Taxonomy to enhance student learning in biology. CBE Life Sci Educ *7*, 368–381.

D'Avanzo C (2003). Application of research on learning to college teaching: ecological examples. BioSciences *53*, 1121–1128.

Dewey J (1933). How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process, Boston: Heath.

Dunning D, Johnson K, Ehrlinger J, Kruger J (2003). Why people fail to recognize their own incompetence. Curr Directions Psychol Sci *12*, 83–87.

Ebert-May D, Derting TL, Hodder J, Momsen JL, Long TM, Jardeleza SE (2011). What we say is not what we do: effective evaluation of faculty professional development programs. BioScience *61*, 550–558.

Ertmer PA, Newby TJ (1996). The expert learner: strategic, self-regulated, and reflective. Instr Sci *24*, 1–24.

Flavell JH (1979). Metacognition and cognitive monitoring: a new area of psychological inquiry. Am Psychol *34*, 906–911.

Gall MD, Gall JP, Jacobsen DR, Bullock TL (1990). Tools for Learning: A Guide to Teaching Study Skills, Alexandria, VA: Association for Supervision and Curriculum Development.

Garner R (1988). Metacognition and Reading Comprehension, Norwood, NJ: Ablex.

Georghiades G (2000). Beyond conceptual change learning in science education: focus on transfer, durability, and metacognition. Educ Res *42*, 119–139.

Kruger J, Dunning D (1999). Unskilled and unaware of it: how differences in recognizing one's own incompetence lead to inflated self-assessments. J Personality Soc Psychol 77, 1121–1134.

Kuhn D, Pearsall S (1998). Relations between metastrategic knowledge and strategic performance. Cogn Dev *13*, 227–247.

Merriam-Webster (2012). www.merriam-webster.com/dictionary/metacognition (accessed 14 March 2012).

National Research Council (NRC) (1996). National Science Education Standards, Washington, DC: National Academies Press.

NRC (2000). How People Learn: Brain, Mind, Experience, and School, Washington, DC: National Academies Press.

Nickerson RS, Perkins DN, Smith EE (1985) The Teaching of Thinking, Hillsdale, NJ: Lawrence Erlbaum.

Perkins DN, Salomon G (1989). Are cognitive skills context-bound? Educ Res *18*, 16–25.

Pintrich P (2002). The role of metacognitive knowledge in learning, teaching, and assessing. Theory Pract *41*, 219–226.

Posner GJ, Strike KA, Hewson PW, Gertzog WA (1982). Accommodation of a scientific conception: towards a theory of conceptual change. Sci Educ *66*, 211–227.

President's Council of Advisors on Science and Technology (2012). Report to the President—Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. www.whitehouse.gov/administration/eop/ostp/pcast (accessed 13 March 2012).

Schraw G (1998). Promoting general metacognition awareness. Instr Sci *26*, 113–125.

Schraw G, Crippen K, Hartley K (2006). Promoting self-regulation in science education: metacognition as part of a broader perspective on learning. Res Sci Educ *36*, 111–139.

Seymour E, Hewitt NM (1997). Talking About Leaving: Why Undergraduates Leave the Sciences, Boulder, CO: Westview.

Steele CM, Aronson J (1995). Stereotype threat and the intellectual test performance of African Americans. J Pers Soc Psychol *69*, 797–811.

Tanner KD (2011). Reconsidering "what works." CBE Life Sci Educ *10*, 329–333.

Tobias S (1990). They're not dumb. They're different. A new tier of talent for science. Change *22*, 11–30.

White RT, Gunstone RF (1989). Metalearning and conceptual change. Int J Sci Educ *11*, 577–586.

Zohar (2009). Paving a clear path in a thick forest: a conceptual analysis of a metacognitive component. Metacognition Learning *4*, 177–195.