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Features

Approaches in Cell Biology Teaching

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Why should students learn science? How should students learn science? How do we know when they learn science? Helping future teachers to find answers to these questions is a goal that appears in the mission statements of science pedagogy courses around the world. Once out of the college classroom and into our own, however, it becomes clear that finding the answers is a lifelong and not just a semester's journey. Our goal in this regular feature of *Cell Biology Education* is to provide insights that come from educators at various stages and from various perspectives along the journey. To inform decisions about science teaching and learning and classroom practice, we present philosophies and research findings that underlie the practical tips that we offer.

The online format of *Cell Biology Education* invites a reader response. We encourage you to contact us: 1) to ask questions about what you have read; 2) to tell us about specific examples of when you have tried an approach highlighted in the column, and whether it did or did not work; or 3) to share additional tips or resources that would be useful to others. We begin each new feature by sharing some of these comments, with your permission, of course. Please include your name, institution, and e-mail on all correspondence. We look forward to hearing insights and stories from you.

ANSWERS WORTH WAITING FOR: "ONE SECOND IS HARDLY ENOUGH"*

In teaching students of any age, on any topic, questions are a teacher's best friend. Questions provide insight into what students already know about a topic, determining beginning points for teaching. Questions reveal misconceptions and misunderstandings that must be addressed to move student thinking forward. Questions challenge students' thinking, leading them to insights and discoveries of their own. Perhaps most important, questions are often an instructor's only tool in checking for understanding during an explanation of organelles to middle-grade students or during a lecture on the machinery of protein translation to undergraduates.

Questions play such an important pedagogical role that student teachers are encouraged to ask them from the moment they first set foot in a classroom. The anecdote below from a student teacher (quoted from an article about reflective practice in teaching) points out just how hard it is, however, to put into practice such a seemingly simple act: asking a question. As he was encouraged to do in his pedagogy courses, the apprentice teacher telling the story opened his first class by posing a provocative question. And then he waited . . .

> I paused for the expected barrage of excited responses. I waited and waited. Anyone? Longer and longer. Help? It felt like an hour. A week. A year. Would the wait be worth it? A . . . yes? Finally from the back of the class! (Loughran, 2002, p. 37)

Most of us, no matter how long we have been teaching, can vividly recall such an excruciating moment of silence, which seemingly stretched on into years, as we waited for students to respond to our question. Teachers of all levels attempting to increase wait time in their own teaching practice describe it as "uncomfortable," "awkward," or even "painful," at first. Is it worth the wait? Mary Budd Rowe's ground-breaking papers introducing the concept of "wait time," are also enduring, having influenced teachers at all levels of education for the last 30 years (Rowe, 1969, 1974, 1978, 1987), and suggest that the answer to this question is a resounding, "Yes!"

Working with an audio-recorder and a chart-plotter as her primary scientific tools, Rowe examined hundreds of elementary-school classrooms asking the question, "How long do teachers wait after asking a question of their class, before receiving an answer or speaking again themselves?" Surprising to many, including the teachers themselves, Rowe found that on average, teachers waited only 1.5 s after their question for a student response (Rowe, 1974). If no student response came in that time period, teachers either asked a follow-up question or answered the question themselves. Rowe coined the term "wait time," more recently referred to as "deliberate silence" or "think time" (Stahl, 1994), to describe the time window after a question has been asked by an instructor. Additionally, Rowe found that teachers allowed the most wait time for high-achieving students in their classes (an average of two seconds) and the least wait time for low-achieving students (an average of nine-tenths of a second), providing strong evidence that teachers' expectations of a student influence the time they allow that student to attempt a response to a question (Rowe, 1978).

Surprised by the briefness of classroom wait times, Rowe collaborated with 50 teachers to study what would occur when instructors deliberately waited 3–5 s after asking a question. The discovered effects of extended wait time are impressive. Rowe and colleagues found that waiting 3–5 s,

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*Quote from Mary Budd Rowe, 1978.

just 1.5–3.5 s longer after asking a question, resulted in dramatic changes in student responses. Students gave longer, more complex answers, on average increasing their response length from 7 to 28 words (Rowe, 1974). Indeed, the number of students answering "I don't know" or refusing to answer declined (Rowe, 1974). In addition, more students were willing to respond to the question, increasing the number of students offering responses from 3 to 37 in one classroom studied (Rowe, 1974). Classrooms became less teacher centered, promoted more dialogue between students about their ideas, and raised the caliber of the discussion in general. The effects of increased wait time were not limited to student behaviors, however, but also altered teachers' behavior. Rowe found that when implementing wait times of greater than 3 s, teachers' decreased the percentage of class time they spent talking. When they were talking, teachers asked more challenging and cognitively complex questions. In addition, the differential wait times for high- and low-achieving students was reduced (Rowe, 1978).

Upon reflection, however, it should be unsurprising to cell biologists, especially, that longer periods of time following a question could have these dramatic effects. For what is cognition but cellular communication, and cellular communication takes time. Extending wait time allows the brains and minds of students to engage completely in all of the cell biological wonders of considering and answering a question—auditory sensation, synaptic transmission, memory retrieval, multisensory cognitive integration, and the neuromuscular coordination required to speak. All things considered, 3–5 s still seem "hardly enough." One thousand one, one thousand two, one thousand three, one thousand four, one thousand five. Try it out yourself. Five seconds is longer than you think!

If insufficient wait time can discourage student participation and decrease the potential for quality responses, then the remedy seems simple—just wait, and wait some more. Rowe's and others' studies on wait times in typical classrooms suggest, however, that it is not all that easy. Perhaps unlike the student teacher quoted above, most of us tend to abhor the vacuum of silence our questions inadvertently create. If students perceive this discomfort and sense that we do not have the tenacity to wait, the majority of them will remain knowingly silent until we move on, or worse, until we rush in to fill the silence with our own answers. Fortunately, alternatives to simply waiting do exist, and many instructors have found resolve in using classroom strategies that structure the question-to-answer time interval in a way that compels the wait. In doing so, these structures not only increase our comfort with waiting but also promote student thinking during the wait time. Three such strategies that can be easily implemented in a diversity of cell biology course settings are highlighted here: 1) Multiple Hands, Multiple Voices; 2) Think-Pair-Share; and 3) One-Minute Papers.

Multiple Hands, Multiple Voices

Perhaps the simplest of strategies that can complement the wait-time strategy is "Multiple Hands, Multiple Voices." Especially in secondary and collegiate classrooms with large numbers of students, waiting can commonly lead to a stubborn lack of response or a willingness to answer by only one or two students. The silence seems interminable, and both instructor and students know that the power to end the pain lies with the instructor who created it to begin with. As such, extending wait time alone does not necessarily lead to more thinking or more and better answers. However, when the instructor follows his/her question with a statement such as, "I'm going to wait until I see hands from five (pick a number appropriate for your setting) volunteers before we hear an idea from anyone," the power to end the silence is clearly shifted from the instructor to the students. For the waiting to end, five students have to be willing to share their thoughts. Seemingly simple, this statement or a variant thereof can be immensely helpful to both instructor and students in allowing time for the whole class to really think over the question. Additionally, it ensures the quickest thinkers are not the only ones allowed enough cognitive processing time to benefit from the question. One can further attempt to recruit new voices into the conversation, by requesting responses from new voices with statements such as, "I'd like to see hands from five folks that I haven't heard from yet."

Think-Pair-Share

Another classroom strategy (Lyman, 1981) to structure wait time is commonly known as "Think-Pair-Share" (National Institute for Science Education, 1997). Although more complex than Multiple Hands, Multiple Voices, it nevertheless is a relatively easy activity to integrate within an existing lecture or laboratory course framework, and takes relatively little time to plan and implement (as little as 10 min). Think-Pair-Share is a *cooperative learning* (Johnson and Johnson) strategy, where student pairings are informal and brief, eliminating the need for monitoring strategies recommended when groups work together for extended periods of time. The basic steps for carrying out a Think-Pair-Share activity go as follows:

1. Pose a question at the same point during the class session in which you would ordinarily ask that question or would choose to open up a topic for discussion.
2. Allow time for individuals to think independently. Give students about 30 s (or longer if the question is more complex) to think about how they would answer the question. Ask students not to say anything out loud until you give the cue for Step 3. Often, charging students to jot down their ideas on paper helps maintain both the silence and the independence of the thinking.
3. Form the pairs. Invite students to discuss their ideas with a classmate seated nearby and allow several minutes for pairs to share their ideas with one another and perhaps prepare a composite response. If the class is large or students unacquainted with one another, some may need your assistance in finding a discussion partner.
4. Invite pairs to share their ideas with the whole class. Ask for volunteers or call on pairs. The number of pairs that it is most beneficial to hear from typically depends on the complexity of the question. A tip for concluding the class discussion when time is at a premium is to listen for the point at which pairs begin to repeat the same answers. At that point, ask if there are any pairs who have different ideas to contribute.
5. Provide summative commentary on the responses.

Although it is tempting to use the time when pairs are discussing the question to organize your thoughts, walking around the room to monitor the discussions has many advantages. Listening in on the conversations will give you a sense of when the class is ready to move on to Step 4 (the whole class discussion). It allows you to preview student ideas, which can help with flow of the whole class discussion—you can call on pairs whose choice comments you overheard if the discussion later stalls or responses seem to lack the wished-for depth or insight. An acknowledgment to the class that you heard some good ideas during the pairs' discussions can help some students overcome their reluctance to reveal their thoughts in front of the whole class. Most important, listening to the pair discussions is an opportunity for assessing what concepts students have understood, where they are still struggling, and what misconceptions may have arisen during the class.

By structuring wait time, Think-Pair-Share allows students time to both think on their own and have an opportunity to try out their ideas with another person in a low-stakes discussion. This not only promotes greater class participation and higher quality responses, but it also actively engages students in recalling, processing, and communicating what they have learned. A last, but not trivial benefit is that it gives students a chance to meet each other, which can help to lessen the sense of isolation that they commonly report feeling in large enrollment science classes (Seymour and Hewitt, 1997).

One-Minute Paper

Another strategy for structuring wait time is the "Quick Write" or the "One-Minute Paper" (Mazur, 1996). As a variation of Think-Pair-Share, the One-Minute Paper is suited for more complex questions or when the instructor wants to collect more in-depth information from all students about their individual understandings of the course material. In this classroom strategy, a brief writing period (more than just jotting down ideas) is allowed after a question is posed during class. This writing period can also be inserted between the thinking and pairing steps of Think-Pair-Share. Students write down individual comments on an index card or half-sheet of notebook paper and turn them in to the professor. The One Minute Paper (Paulson and Faust, 2002) can be used with instructor-prescribed questions or in a more intriguing open-ended version. In its original open-ended formulation, students are asked to write a short reflection 3–5 min before class ends about the most confusing ("What was the muddiest point in today's class?") and/or most important points ("What did you learn the most about in today's class?") made during a lecture, topic, or reading. Since students hand in their responses as they leave (anonymously, until they come to trust that there will be no penalty for honest expression), these reflections can help to inform the teacher of what concepts or ideas need to be revisited or reviewed in a subsequent class. Additionally, in a large class setting, if students hand in their One Minute Papers by passing them across the rows of seats they can be asked to read their peers' comments and place a check mark next to any comments with which they agree before passing them on across the row. This strategy is a quick way to find out which responses are the most frequent ones, and therefore among the most important to address.

Use of these strategies—Multiple Hands, Multiple Voices, Think-Pair-Share, and the One-Minute Paper—serves as a reminder to wait for quality responses and to wait for responses from students seated beyond the eager first row. In addition, they share the common advantage that they require little or no preparation beyond formulating the questions that one would have asked anyway. In structuring the wait time, these strategies increase the likelihood that waiting will actually occur, optimizing the possibility for the positive outcomes documented in the original studies—more responses, longer responses, and responses from more students. But do these strategies always work as intended? Well, not always . . . but when they do not, it may be that the problem lies not with the strategy, but with the original question that was asked. In the next "Approaches in Cell Biology Education" feature, we will explore how to construct and ask questions worth answering.

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