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Feature
Approaches to Biology Teaching and Learning

The Role of the Lecturer as Tutor: Doing What Effective Tutors Do in a Large Lecture Class

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Most instructors at one point or another in their careers—during office hours, in the laboratory setting, or as a tutor—have had the luxury of sitting down one-on-one with a student to help him or her learn. For many, the reward of watching the proverbial lightbulb go on over a student's head was a first, addictive step into a career that involved teaching. Now imagine—or for many of us, remember—standing in front of 30, 60, 100, 150, 200, 300, 700, or even 1000 students in a traditional college or university lecture setting. Did you sometimes wish you could just sit down and talk with students from your large lecture individually, and then they would finally get it? What is similar and different about your instructional choices in a large lecture versus a one-on-one situation? To what extent can we translate what is known about effective tutoring to a large lecture setting?

One-on-one human tutoring has been extensively studied. Insights into what makes it effective is of great interest in a variety of fields, including computer-based tutoring program development, general education research, and training of future teachers. It is well accepted that one-on-one tutoring promotes both greater student learning and increased student motivation to learn compared with traditional, formal classroom teaching and learning settings (Slavin, 1987). However, examination of the research literature on effective tutoring would suggest that this mode of instruction and our approaches to fostering student understanding in large biology lecture classrooms need not be as dramatically different as one might assume. In fact, the differences in what instructors choose to say and do, as well as what they choose *not* to say and do, in each of these settings may be more critical for learning than the setting itself or the numbers of students involved.

In this paper, we share insights into what is known about what effective tutors do and do not do, and we present specific approaches for adapting effective tutoring strategies and applying them to large biology lecture classes.

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INSIGHTS FROM RESEARCH ON WHAT EFFECTIVE TUTORS DO

Research on effective approaches to human tutoring is broad and extensive. In this paper, we present brief introductions to a few key studies from education research, psychology, and cognitive science published over the last three decades to provide the reader with entry points for further reading (Bloom, 1984; Chi *et al.*, 1994, 2001; Chi, 1996). In addition, we describe a synthesis of effective tutor practices by Lepper and Woolverton (2002) that emerged from several studies.

Tutoring Can Produce Learning Gains Two Standard Deviations above Traditional Classroom Learning Gains

Perhaps better known for his work on the development of Bloom's taxonomy, Benjamin Bloom also contributed significantly to insights on the effectiveness of tutoring (Bloom *et al.*, 1956; Bloom, 1984). In 1984, Bloom published an influential report about a phenomenon he termed the "2 sigma problem." Bloom and his graduate students in education at the University of Chicago randomly assigned school-age students with comparable initial interests, aptitude test scores, and prior achievement to groups of 30 that were subjected to different learning conditions. In the Conventional Condition, representing traditional classroom practice, students learned subject matter with a teacher, and tests were given periodically to measure student learning. In the Tutoring Condition, students learned the same subject matter with one or two other students under the guidance of a "good tutor," who used periodic formative tests to measure student learning but no other particular practices.

Strikingly, the Tutoring Condition produced student learning gains that were typically two standard deviations above the Conventional Condition, as measured by subject matter tests (Bloom, 1984). In the Tutoring Condition, moreover, there was a lower correlation of students' prior aptitude test scores and their final achievement scores, indicating that students of all aptitude levels had the potential to reach higher levels of learning. In presenting these results, Bloom and his students posed the challenge of finding "methods of group instruction as effective as one-to-one tutoring" (Bloom, 1984).

Tutoring Is Effective When Students Engage in Self-Explanation

In hundreds of subsequent studies, researchers have sought to learn what specific tutor and tutee behaviors contribute to effective tutoring and Bloom's 2 sigma effect. In a series of studies in the 1990s, cognitive psychologist Michelene Chi and colleagues discovered one key aspect of how effective tutoring improves student understanding: It elicits student self-explanations (Chi *et al*., 1994; Chi, 1996). In their study, two groups of middle school students were asked to read an expository text passage about the human circulatory system. The first group of students was instructed simply to read the text twice. The second group was explicitly prompted to read each line of the passage and then explain to themselves the meaning of the text before proceeding to the next line, and to repeat this for each line of text. All students participated in pre- and posttests to measure their understanding of the circulatory system before and after the reading exercise.

Analyses of learning gains demonstrated that students who were prompted to engage in systematic self-explanation scored significantly higher than those in the unprompted condition, especially on higher-order assessment questions. Moreover, students who engaged in more extensive self-explaining showed greater learning gains than those who engaged in less. The immediate implication for effective tutoring practices is that student talk is key and that student-generated self-explanations appear to have significant positive effects on learning (Chi *et al*., 1994). Further studies by many research groups have examined how tutor questioning, probing, and scaffolding can drive student talking and, in turn, produce similar outcomes (e.g., Graesser *et al.*, 1995; Chi, 1996).

Tutoring Is Equally, If Not More, Effective When Tutor Talk Is Suppressed

Chi and colleagues more recently published a detailed observational study to determine the relative effectiveness of three tutoring strategies: 1) a tutor-centered approach, 2) a student-centered approach, and 3) a tutor–student interaction approach (Chi *et al*., 2001). College students with expertise in the area of the human circulatory system were observed as they tutored middle school students one-on-one about this topic. The middle school students were pre- and posttested on their understanding using a range of assessment questions from lower to higher cognitive levels. In addition, the behaviors and statements of both tutors and students were recorded and analyzed in detail. The authors found evidence that each of the three approaches could be effective, but one finding in particular was striking. In examining the tutor-centered approach, the researchers discovered that student assessment evidence suggested only shallow learning resulted when tutor explanations dominated the tutoring session.

Intrigued by the potentially neutral or perhaps even negative role of tutor explanations in student learning, the researchers conducted an additional investigation using the same tutors who participated in the original study, interacting with a new set of students on the same ideas about the human circulatory system. In this second study, however, tutors were explicitly instructed to "suppress giving explanations, feedback, and other extra information" and instead were asked to attempt to invite dialogue with students from a list of suggested prompts that were content-free (e.g., "Could you clarify?," "Why?," "How?," "Any thoughts on that?"). Analyses of transcriptions confirmed that tutors did indeed change their behavior patterns from their original "explaining" to a more "prompting" stance.

Strikingly, assessment of student learning demonstrated overall student learning gains similar to those in the previous study, with *increased* student performance on higher-order postassessment questions. Chi and colleagues concluded that "surprisingly, students learned just as effectively even when tutors were suppressed from giving explanations and feedback."

SEVEN KEY CHARACTERISTICS OF EFFECTIVE TUTORS: THE INSPIRE MODEL

What makes some tutors more effective than others? When Lepper, Woolverton, and their colleagues studied a group of experienced tutors in primary and secondary school mathematics, they discovered that the most effective in terms of student learning employed a characteristic set of approaches and strategies (reviewed in Lepper and Wolverton, 2002). A key finding was that these strategies focused not only on the tutees' cognitive progress, but also on their motivational and affective states. The researchers identified seven characteristics of the most successful tutors, which they identified by descriptors that spell out the acronym INSPIRE (Table 1). While some of these characteristics seem intuitively obvious, others are less so.

Intelligent

Not surprisingly, the best tutors had a superb command of their subject matter (content knowledge), allowing them to draw on appropriate information for whatever problems might arise in the tutorial situation. In addition, however, they possessed considerable knowledge and intuitive understanding of how students learn and how best to teach them (pedagogical content knowledge). This knowledge was not simply general, but also content-specific, so that they understood, for example, why tutees might perceive certain problems to be more difficult and others to be simpler than in reality they were. Interestingly, although the best tutors all had some educational training, none had been specifically trained in one-on-one tutoring.

Table 1. The INSPIRE model of expert tutoring and results for tutees

Characteristics and behaviors of expert tutors	Results for tutees
Intelligent: Superior content as well as pedagogical content knowledge	Difficulty of questions optimally matched to students' levels of understanding
Nurturant: Establish and maintain personal rapport and empathy with students	Feeling accepted, supported, and free to explain their thinking
Socratic: Provide almost no facts, solutions, or explanations, but elicit these from tutees by questioning	Constantly thinking, doing, and responding
Progressive: Move from easier to progressively more challenging cycles of diagnosis, prompting toward a solution, and posing of a new problem	Moving in small steps to higher competency through deliberate practice
Indirect: Provide both negative and positive feedback by implication; praise solutions, not the student	Working in a nonjudgmental atmosphere
Reflective: Ask students to articulate their thinking, explain their reasoning, and generalize to other contexts	Gaining insight into their own thinking through metacognitive reflection
Encouraging: Use strategies to motivate students and bolster their confidence (self-efficacy)	Experiencing productive learning and gaining confidence in their abilities

Nurturant

Also not surprisingly, the best tutors were skillful at establishing rapport with tutees and empathizing with students' struggles to solve challenging problems. These tutors were caring, attentive to their students' level of motivation or frustration, and supportive of tutees' efforts. Effective tutors projected confidence in the ability of their charges to succeed. In addition, the best tutors often began their sessions on a personal note, asking students about aspects of their personal lives, not just the subject at hand.

Socratic

More surprising, but consistent with Chi's results above, was the authors' finding that the best tutors told their tutees almost nothing! They offered little factual information and did not explain the solutions to problems their students had difficulty solving. Instead, they proceeded by continual prompting and probing, trying to elicit appropriate approaches to the problem at hand. In transcripts of their sessions, greater than 90% of their remarks were questions. Tutees, on the other hand, rather than listening to explanations, spent most of their time responding to questions that led them toward the desired understanding. When tutees became stuck, these tutors provided not answers, but only hints, which were at first general and became more specific only as a last resort. In the process, these tutors were alert for "productive" errors of thinking that could be explored in further questioning for the tutee's benefit.

Progressive

Using carefully chosen diagnostic problems at the outset of a session, the best tutors quickly gained an accurate picture of a tutee's level of understanding or misunderstanding. They then proceeded progressively to more challenging work in a predictable routine: posing a new problem, diagnosing the difficulties, providing leading questions and hints until a solution was reached, and then moving on to a more difficult problem. In so doing, they engaged tutees in what educators call "deliberate practice," repeating the problem-solving process many times in the course of a session.

Indirect

The best tutors never criticized tutees or their mistakes directly. They drew attention to errors by implication and through subsequent questioning, so that tutees themselves had to reconsider and change their ideas. Interestingly, these tutors also used a similar indirect approach in giving positive feedback, praising good solutions but not the tutees personally, and thus avoiding a judgmental atmosphere. In these ways, effective tutors constructed tutee-centered situations, dominated by student self-analysis, as opposed to tutor-centered situations, in which feedback, positive or negative, came from the tutor.

Reflective

In the course of problem solving, effective tutors frequently asked tutees to articulate what they were doing and learning, to explain how they approached and solved a problem, and to generalize their understanding to other contexts and situations from the real world of the tutees. This process of reflection on the learner's own thinking, which educators call metacognition, is known to be a crucial component of how people learn (National Research Council [NRC], 1999).

Encouraging

Effective tutors used several strategies to motivate and encourage their tutees: piquing their curiosity with problems relevant to their lives, allowing them some control of the tutorial session, confronting them with problems that were challenging but soluble with effort, and providing frequent, indirect, positive feedback. In the process, these tutors were able to build tutees' confidence in their own abilities.

TRANSLATING EFFECTIVE TUTORING STRATEGIES TO THE LARGE LECTURE SETTING

Why should expert tutoring be so much more successful in promoting student learning than traditional classroom instruction? Although Bloom (1984), Chi *et al.*, (1994, 2001), and Lepper and Woolverton (2002) were working with younger students, it is common experience at the undergraduate level

Table 2. A comparison of traditional classroom and expert tutorial instruction

Traditional lecture in a large class	Tutorial with an expert tutor
Instructor transmits facts and explanations to students by lecturing and presenting visuals.	Tutor poses problems, asks questions, and provides occasional hints but little explanation.
Students sit passively and record information from lecture and visuals.	Student answers questions, works at problem solving, and engages actively in deliberate practice.
Instructor focuses entirely on content, most of it factual information.	Tutor focuses not only on content, but also on student's affective state, motivation, and metacognitive awareness.
Students receive feedback on their progress only periodically, through high-stakes, summative exams.	Student receives continual feedback through formative assessment in the form of questions.
Instructor does not know how well students are understanding concepts until after a high-stakes exam and cannot tailor presentation to student needs.	Tutor continually monitors student's understanding through questioning, knows student's level of understanding precisely, and can adjust strategy accordingly
Students may learn factual and conceptual information only in the context of the course.	Student is required to apply new knowledge to new situations and generalize it to other contexts.
Instructor has little or no personal interaction with individual students.	Tutor establishes rapport with student and encourages and supports the learning process.

as well that many students can learn far more readily from a good tutor than from traditional lecture classes. In asking why, we tend to focus first on the numbers; of course one-on-one instruction will be more effective than teaching hundreds of students in a large auditorium. But that is by no means the whole story, as is evident from comparing the marked differences in pedagogy between tutorials and traditional lecture courses (see Table 2).

How different do these two teaching situations have to be? Might large-class instruction be more effective if instructors adopted the teaching strategies of expert tutors? At first this idea may seem impossible, but we will argue that it is not, using examples of teaching approaches that some college-level instructors are already using to good effect in transforming large classes into more productive learning environments. In this section, we consider each characteristic of the INSPIRE model in turn, and how each can be incorporated into classroom teaching.

Intelligent

Although most instructors at the university level have the necessary content knowledge to teach their courses, few have had any formal introduction to pedagogical content knowledge. Fortunately, this situation is beginning to change through the efforts of professional development programs, such as the National Academies Summer Institute for Undergraduate Education in Biology for existing faculty (Handelsman *et al.*, 2004; Pfund *et al.*, 2009), the NSF-supported First IV program (Lundmark, 2002), and the CIRTL network (www.cirtl.net) for future faculty at the postdoctoral and graduate-student levels, respectively; in addition, there are a number of centers for teaching excellence at individual colleges and universities. More widespread pedagogical content knowledge will be helpful in achieving the other improvements in teaching approaches discussed here.

Traditional instructors typically utilize their extensive content knowledge to transmit information by lecturing, while expert tutors, as we have seen, do not. But while the research literature on effective tutoring suggests that maximizing student talking and self-explanation is key, that same literature also suggests that there are ways in which tutor talk can promote learning. In particular, the theory of cognitive apprenticeship suggests that instructor talk explicitly describing how an expert may have previously misunderstood the ideas at hand or how he or she approached a given problem can be supportive of student learning *after* students themselves have explored their own thinking on the topic. This "cognitive coaching" approach, avoiding instructor explanation until after students have had the opportunity to explore a concept and reflect on prior knowledge, aligns well with learning-cycle models developed in the fields of education and psychology (Tanner, 2010). For example, Schwartz and Bransford (1998) showed that students learned more from lecture material if they had previously wrestled with a related problem on their own. Likewise, Smith and colleagues (2011) found that an instructor's explanation after students had attempted, discussed, and revoted on a challenging clicker question (see section entitled, Progressive, below) substantially enhanced student learning beyond either discussion or instructor explanation alone. In biology, such cognitive coaching can sometimes be achieved simply through relaying the history of scientific thinking on a topic with which a lecturer with superior content knowledge in that field would be conversant. Engaging students in analyzing key experiments in the history of science can alert students to ways of thinking that are currently considered incorrect, but that often show how common student misconceptions are reflections of historical scientific thinking. An often-used example is the seventeenth-century investigation by Jean Baptiste van Helmont, which debunked the common thinking of the time that plants gain their mass from the soil only to replace it with another incorrect idea attributing the entirety of the mass gain to water (e.g., Ebert-May *et al.*, 2003).

Nurturant

It is obviously much more difficult to establish rapport and empathize with a diverse group of hundreds of students than with an individual tutee. However, the most effective instructors manage to do this to some extent by treating students with respect, learning as many of their names as possible, sharing the learning goals of the course explicitly, and attempting to relate content to students' everyday experiences and real-world concerns. In addition, these instructors avoid assumptions about students, their backgrounds, and their motivations. It is a significant challenge to see the world from a novice learner's perspective, and perhaps even more so with a population of learners that may differ significantly from the instructor culturally, generationally, and linguistically. Consequently, nurturing practices in a large lecture classroom require cultural competence on the part of the instructor (Tanner and Allen, 2007) and a commitment to seeing the learning situation from a student perspective.

Socratic

This characteristic of effective tutors is perhaps the most important for traditional instructors to incorporate into large classes. Given the technologies now at our disposal, it is also entirely feasible. It replaces, or at least supplements, the instructor's role of "telling"—transmission of information and explanations—with "asking"—posing problems and eliciting active student engagement in response (Table 2). Expert tutors follow this advice, as we have seen, and many college and university biology instructors use Socratic instruction effectively in large classes. Moreover, classes provide an advantage that even the best individual tutorial cannot, namely, the opportunity for interactions among students in discussion and problem solving. Learning research has shown clearly that the process of wrestling with a problem in a small-group discussion can enhance both student understanding and problem solving (NRC, 1999; Tanner *et al*., 2003).

More generally, the Socratic approach to teaching emphasizes use of class time for students to engage in deliberate practice, learning by actively thinking and doing activities related to the concepts under discussion. Active-learning activities can take many forms, including brainstorming, think–pair–share, concept mapping, conceptual clicker questions, structured and unstructured problems, or case studies (see Handelsman *et al.*, 2007; Allen and Tanner, 2009). All these activities can involve student interaction, taking advantage of the small-group process in facilitating comprehension and problem solving. They also provide formative assessment of student thinking, with valuable feedback to the instructor, as discussed in the section below entitled, Progressive.

Conceptual multiple-choice questions, most conveniently posed using an audience response (clicker) system (Caldwell, 2007), provide a good example of how the Socratic characteristic of tutors and group work can be incorporated into a large-classroom setting. Good clicker questions are challenging, demanding higher-order cognitive skills, such as applying previously discussed concepts to a new problem situation. An effective way to administer such questions is to ask students to first vote individually, with no prior discussion. A well-designed, challenging question will frequently lead to a split vote, with no convergence on the correct answer. Showing students the voting results can generate suspense: "Who is right? Me, or the people who chose 'B'?" This is a teachable moment, when students are emotionally, as well as intellectually, involved in resolving the disagreement. If they are allowed to debate the question in small groups and then revote, the results almost always converge on the correct answer, sometimes strikingly so (Wood, 2004). The physicist Eric Mazur, who inadvertently discovered the power of this approach, coined the term "peer instruction" to describe it (Mazur, 1997). However, a more recent study suggests that it may not be so much "instruction"—one student explaining the answer to others—as the give-and-take of group discussion itself that leads students to understanding, as in the tutorial situation (Smith *et al*., 2009). This result further supports the view that students talking, whether to the instructor or to each other, promotes learning (Tanner, 2009).

Progressive

The expert tutor poses diagnostic problems at the outset of a session to determine the tutee's initial level of understanding before proceeding to build on it. In contrast, many classroom instructors simply assume that if students have "had," for example, meiosis in a previous course, they understand it, but often, of course, they do not. A fairly simple way to measure initial understanding is with a pretest consisting of conceptual questions stripped of jargon with which an incoming student will be unfamiliar. Such tests, often called concept assessments or concept inventories, have been developed for several areas of biology (Knight, 2010). Such a pretest is often given again as a posttest at the end of a course so that student learning gains can be measured (e.g., Smith *et al*., 2008).

More generally, the use of conceptual assessment need not be elaborate or time-consuming to inform both students and instructor of the students' current level of understanding. Approaches as simple as having students respond to a question on an index card at the end of class or defend briefly in writing their agreement or disagreement with an assertion (which could be a well-known misconception) offered by the instructor may be all that is needed to inform and significantly alter the instructor's choice of how best to proceed (e.g., Schinske, 2011).

The progression toward and student success with more difficult material achieved by expert tutors depends on continuous feedback from the student and deliberate practice with the study material. One obvious way that tutoring differs from traditional lecturing is in the immediate flow of information from student to instructor about how the student is thinking and what the student is struggling to understand. In fact, ineffective tutoring is characterized by a *lack* of this flow of information from student to instructor, likely caused by too much instructor talk and not enough student talk (Chi *et al*., 2001). However, gaining immediate access to student thinking is by no means impossible in a large lecture course. This feedback can be obtained by formative assessment using any of the active-learning activities already discussed: comments on index cards, clicker questions, and so on. In addition, online course-management systems enable instructors to easily collect similar information outside of class time from hundreds of students, as discussed below under *Reflective*.

Online course-management systems also allow the structuring of deliberate practice, beyond what students have time for during even a primarily student-centered class. Homework cannot be individually designed in a large-course setting, but the role of the lecturer in assigning tasks for students can nevertheless be very similar to what tutors do. Unfortunately, in traditionally taught large lecture classes, student homework assignments are often limited to textbook reading without any clear tasks that would scaffold students' engagement with the reading or provide practice in applying the concepts about which they are reading. Possible tasks include the construction of concept maps from a set of key terms, seeking out evidence that could resolve a case study, or a variety of other higher-order, conceptually challenging questions and problems (Crowe *et al*., 2008; Allen and Tanner, 2003; National Center for Case Study Teaching in Science [http://sciencecases.lib.buffalo.edu/cs]). These practice tasks, especially for large-enrollment classes, need not be graded in an evaluative manner. However, their completion should be rewarded through participation grading to convey to students that instructors value this work as part of the learning process. In addition, instructors need not read every piece of student work for every assignment to gain insight into key confusions and level of difficulty for the students. Reading a random 10% of student concept maps, for example 30 submissions from a 300-person class, may take only about 30 min but yields a variety of insights that can guide decisions about what to clarify or when to embark upon new concepts for the next class session. To follow the progressive principle, the instructor can then assign tasks of increasing difficulty based on evidence of increasing understanding shown in student work.

The combination discussed above, of reading with scaffolding tasks outside of class as homework, also provides the answer to a conundrum faced by all instructors striving toward less lecturing and more active learning in classes, namely, how can all the necessary content be "covered"? Scaffolded homework not only provides the deliberate practice required for mastery of course concepts, but also frees up in-class time for discussing, unpacking, and examining these concepts further through Socratic dialogue and small-group discussion. Two versions of this approach that have been described in detail and assessed for effectiveness are "just-in-time-teaching" (Novak *et al*., 1999) and the simpler "learn before lecture" (Moravec *et al*., 2010).

Indirect

The effective tutor does not criticize or praise tutees directly. In lecture classes, the cognitive coaching aspect of instructor talk discussed above under *Intelligent* can be applied to provide feedback by implication, as opposed to simply telling students that they are wrong, which is both unproductive and discouraging. For example, after showing the split results from a challenging clicker question, an instructor might say, "It looks like we need to work together to come to consensus on this question," rather than "Well, 60% of you are wrong about this." Further, the instructor can promote a class dialogue by asking students in pairs to try explaining why an individual might choose one particular answer, regardless of the answer they themselves chose. Then the instructor can function as a cognitive coach by facilitating a whole-class discussion of why some incorrect ways of thinking may appear reasonable and what evidence would make them unattractive to an expert in the field. An example of an assessment question ripe for this type of cognitive apprenticeship approach is to probe students' thinking on what is the ultimate source of the mass of living things (e.g., Ebert-May *et al.*, 2003; Thinking Like a Biologist website [http://biodqc.org]). In line with the Socratic characteristic, this approach promotes student self-explanation (pair discussion) and provides cognitive coaching (whole-class discussion), as well as furnishing indirect feedback to students whose thinking is not yet aligned with biological experts.

Reflective

Expert tutors foster metacognitive awareness, continually asking tutees to articulate their thought processes, explain their reasoning, monitor their level of understanding, and generalize concepts to other contexts. Again, online course-management programs make this possible in a large-class setting. By asking students to regularly write 200–300 words reflecting on how they have changed their ideas about course material and what their confusions are, the instructor can both gain invaluable insight into student thinking and promote students' metacognitive awareness. Once again, such reflections need to be rewarded through participation points to encourage systematic participation, but they need not be evaluated with grades. Participation points can be awarded based on reaching the requested word limit, which is often automatically calculated by the online learning system, making assignment of credit quick and painless. And again, every piece of student writing need not be read for every assignment. The goal is to increase student opportunities to reflect on their own understanding and increase the flow of information about student thinking to instructors.

A powerful way for either in-class or out-of-class activities to promote students' ability to transfer understanding from the course setting to other contexts is to relate assigned tasks to real-world issues that are pertinent to the concepts at hand. For example, an outbreak of cholera and a surge of deaths in a developing country can provide a case study in which students are challenged to apply their understanding of osmosis and its relevance to human disease.

Encouraging

Good teachers in any setting encourage their students by being inspiring, enthusiastic, caring, supportive, and liberal with positive feedback. This characteristic overlaps significantly with "nurturant," and to some extent "indirect," as discussed above. The value of these qualities is similar among effective teachers of all kinds, from tutors to instructors of large classes. In particular, ways of being encouraging in a large lecture class may include explicitly engaging students' curiosity through assigning homework that explores current events and relates the biology being learned to real-world contexts involving individuals to whom students can directly relate. In addition, encouragement for large numbers of students can come through simply being on their side (much as a tutor is explicitly on the side of a tutee), using language that puts both instructor and students on the same team (Tanner, 2011). Finally, cultivating a genuine belief that students *can* really achieve is a critical aspect of establishing an encouraging environment in a large lecture setting. For students, sensing this belief can be a powerfully motivating force for learning.

CONCLUSION

Can application of the INSPIRE tutorial model make large-class settings approach the effectiveness of individual tutoring sessions? In many ways, what promotes student learning with an expert tutor is highly similar to practices that have been shown to be effective in a variety of teaching and learning environments and across disciplinary boundaries (reviewed in Wood, 2009). As one example, a recent large-class study documented an apparent increase in mean learning gains greater than Bloom's 2 sigma target using these types of approaches (Deslauriers *et al.*, 2011). Perhaps we need only strive to remember the key characteristics of effective tutoring and doggedly attend to them in designing our learning environments for students, regardless of the size of the physical classroom or the number of people in it.

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