The CREATE Strategy Benefits Students and Is a Natural Fit for Faculty

Analysis of scientific literature using the CREATE approach allows students to learn microbiology while involving them with the process of science

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Given how much time microbiologists spend reading and analyzing research articles, it is surprising that so many teach lecture courses based on textbooks, inadvertently depriving their students of the excitement of scientific discovery that comes with analyzing current research. Such faculty members typically spent years learning to do scientific research, designing experiments or carrying out observational studies, troubleshooting, and integrating findings from current literature with their hypothetical frameworks. As they developed more sophisticated insights into study design and data interpretation, including an awareness of the need to constantly challenge their own assumptions, future college faculty gained an ever-increasing fluency in the language of data analysis.

Unfortunately, few bring this insider understanding of the scientific process to the courses that they teach. Instead, too many courses are lecture-based, presenting information that students memorize, while developing little sense of how important conclusions were reached. Some colleagues find this approach to be a time-saving necessity or may note that “lectures are the way I was taught, and that method worked for me.” Traditionalists suggest that lecturing is the only way to cover sufficient content. Even faculty with a sense that traditional teaching is overdue for an upgrade may not feel they have time to overhaul their assigned courses.

CREATE Moves beyond Lecture to Engage Students in the Research Process

Actively engaging students in classrooms can be more effective than are traditional lectures. Even after taking courses that include laboratory exercises, many undergraduate biology majors have difficulty grasping key ideas fundamental to working scientists. Persistent misconceptions among such students about fundamental issues in biology argue that repeated exposure to key ideas in traditionally taught courses does not produce understanding.

The lecture-with-slides approach forces students to be passive listeners without encouraging them to engage the topics at hand, undermining learning and understanding. Overall, lectures and textbooks tend to disconnect students from the process of scientific discovery, which can turn them away from science altogether. Another major problem with standard lectures is that they steer faculty away from conveying their mastery of the logic of scientific analysis to their students.

In response to these challenges, we and colleagues developed the “consider, read, elucidate hypotheses, analyze and interpret the data, think of the next experiment” (CREATE) strategy to demystify and humanize science through close analysis of research articles. We had three main goals: leveraging the unique insights of faculty

SUMMARY

➤ Students taught in traditional ways tend to have difficulty understanding or applying key scientific concepts, and retain misconceptions about important ideas in biology.

➤ The “consider, read, elucidate hypotheses, analyze and interpret the data, think of the next experiment” (CREATE) approach to teaching microbiology builds on the deep understanding faculty members have for the research process.

➤ In following this approach, students prepare for class using tools that consolidate their knowledge of key scientific concepts and how to design studies.

➤ This approach encourages faculty members to guide students into examining how studies were carried out and what data mean in a lab-meeting-like atmosphere.
members into the research process, helping students learn how scientific knowledge develops and why people choose research careers, and consolidating students’ understanding of key biological concepts. The CREATE approach makes the journal article, not the textbook, the focus of class discussion, using research reports to convey to students insights into authentic processes of science.

Courses focus on sets of papers published sequentially from a single laboratory or, alternatively, from competing labs chasing the same scientific question, and follow the progression of these scientific studies. Any topic can be explored, and faculty can choose papers based on course goals and their own expertise, including from a variety of topics in microbiology (Table 1 and www.teachcreate.org). Rather than telling students what data mean, faculty members run courses like lab meetings, discussing and interpreting charts, graphs, and photomicrographs. CREATE teaching thus challenges students to understand and explain figures and tables in research papers as if they had carried out the experiments themselves. In addition to analyzing data, students are asked to propose experiments related to the papers and to analyze one another’s proposals. Such activities allow students to experience the creativity and teamwork of science while also learning to argue collegially and defend their ideas. E-mail exchanges with the authors of those research reports, who voluntarily respond to student-generated questions, add a personal touch to the process, humanizing researchers and helping to dispell stereotypes about them. Traditional teaching rarely gives students the opportunity to “talk science,” and the open-ended discussions typical of CREATE classrooms provide opportunities for students to experience scientific analysis and discourse. This classroom experience aligns with recommendations set forth in the seminal 2011 Vision and Change document that focused on the teaching of undergraduate biology (Table 2).

Properly Prepared Students Enable Faculty to Focus on Scientific Thinking in Classes

In contrast to courses that use research articles by having individual students present full papers, or by assigning different figures to different students, in CREATE courses all students are challenged to master all figures of each research report. The learning tools used in the CREATE approach are designed to facilitate students’ ability to begin to decode research papers be-

### TABLE 1.

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<tr>
<th>Sample Microbiology Modules Developed in CREATE Workshopsa</th>
<th>Author</th>
<th>Suggested Student Level</th>
<th>Module Focus</th>
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<tbody>
<tr>
<td>Acquired or Specific Immunity? Miriam St. Clair, Northern Virginia Community College</td>
<td>Community college students in a pre-nursing program</td>
<td>Module investigates aspects of acquired and specific immunity, examining work of I Adlerberth at the University of Gothenburg, 2006–2012.</td>
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<tr>
<td>Discovery and Determination of the Mechanism of Action of Listerialysin O Terri Ellis, Ph.D., University of Northern Florida</td>
<td>Senior undergraduates</td>
<td>Module follows issues of bacterial virulence, intracellular survival and immune system interactions, focusing on the DA Portnoy laboratory at University of California, Berkeley from 1988–2003.</td>
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<tr>
<td>Symbiosis Between Leaf-cutting Ants, a Parasitic Fungus, and a Bacterium Elizabeth Shank, Ph.D., University of North Carolina</td>
<td>Upper-level undergraduates</td>
<td>Module follows the evolution of ant-microbe symbiosis, exploring the work of the CR Currie lab at University of Wisconsin, Madison, from 1994–2009.</td>
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See www.teachcreate.org for teaching outlines and additional modules.
fore each class convenes, as preparation for in-class detailed analysis. Pre-class concept mapping, sketching of experimental designs, and annotation of figures are key tools in the CREATE strategy. These drive students’ review of fundamental biological concepts, help students visualize how experiments were done, and promote engagement with the data, preparing students for active discussion in class.

Students compile their concept maps, annotated figures, and sketches as well as additional information about experimental techniques or foundational concepts that they looked up before class to bolster their understanding of each report in portfolios. These are brought to every class and serve as references for open-book exams given twice per semester.

This fine-grained preparation allows CREATE faculty to use their strengths as scientists to guide students through the complexities of each study and the development of data interpretation skills. Thus, in the CREATE classroom, faculty move beyond describing microbiology content and instead encourage students to apply their understanding of the content as they decipher experimental questions—for example, examining how techniques were applied and why particular controls were used. The faculty member coaches students into examining the hypotheses or questions that underlie each study, the design of each experiment in it, and the logic of the overall approach.

When students analyze the data, they are encouraged to think independently about what conclusions they would draw rather than to summarize outcomes stated by the authors. Small-group work in each class (Fig. 1) gives students the opportunity to work with peers while learning that different groups may reach different answers in response to the same scientific question.

The CREATE approach has been used primarily in elective courses with enrollments of 30 or fewer students. We have begun experimenting with ways to integrate CREATE into large-enrollment courses, possibly in single sessions during labs or recitation periods, or by initiating CREATE activities in such sessions and then

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<th>TABLE 2.</th>
<th>How CREATE courses embody Vision and Change recommendations</th>
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<td><strong>“Integrate Core Concepts and Competencies throughout the Curriculum”</strong></td>
<td><strong>CREATE Approach</strong></td>
</tr>
<tr>
<td>“Introduce the scientific process to students early, and integrate it into all undergraduate biology courses.”</td>
<td>CREATE curricula integrate and reinforce scientific process at each year of a Biology major.</td>
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<td>“Define learning goals so that they focus on teaching students the core concepts, and align assessments so that they assess the students’ understanding of these concepts.”</td>
<td>CREATE activities are narrowly focused and challenge students to review and apply key concepts as they interpret data and analyze published results in the context of a research question. Students demonstrate understanding through integrated course activities, discussion and homework.</td>
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<td>“Relate abstract concepts in biology to real-world examples on a regular basis, and make biology content relevant by presenting problems in a real-life context.”</td>
<td>CREATE modules are based in bona fide published scientific studies providing real-world context for key biological principles.</td>
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<td>“Develop lifelong science-learning competencies.”</td>
<td>CREATE courses build transferable analytical skills via the CREATE toolkit.</td>
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<td>“Introduce fewer concepts, but present them in greater depth. Less really is more.”</td>
<td>This approach is fundamental to CREATE (see Hoskins et al., 2007; Hoskins and Stevens, 2009. “Learning our L.I.M.I.T.S.—Less is More in Teaching Science”)</td>
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<td>“Stimulate the curiosity students have for learning about the natural world.”</td>
<td>CREATE courses stimulate curiosity by encouraging students to develop their own interpretations of data and to devise their own creative follow-up studies, which are vetted in classroom grant panels.</td>
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<td>“Demonstrate both the passion scientists have for their discipline and their delight in sharing their understanding of the world with students.”</td>
<td>CREATE students gain unique insight into individual scientists’ work and personal lives through paper authors’ thought-provoking written responses to class-generated e-mail surveys.</td>
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completing them in larger classroom settings. Such approaches would likely entail training lab instructors, typically graduate students, to work with the CREATE approach.

Both Students and Faculty Members Like the CREATE Strategy

For students accustomed to passive learning through lectures and skimming abstracts instead of reading papers, the level of preparation and detailed analysis required of them in taking a CREATE course is surprising and challenging. Students may resist changes in teaching approaches, particularly if such students were successful in traditionally taught classes.

However, our students react largely positively to CREATE classes. In interviews, our students at City College of New York (CCNY) reported that CREATE strategies such as concept mapping, sketching, and annotation were helping them in other courses. Upper-level CCNY CREATE students also suggested that we develop a first-year version of the course, arguing that the strategy would have helped them throughout their academic careers. On the five New York and New Jersey campuses where seven faculty that we trained in CREATE strategies taught their first courses, 79% of the 103 anonymous student survey comments were positive. Thus, the fear of student backlash should not deter faculty from trying CREATE.

Like students, faculty members are satisfied with CREATE. Faculty surveyed five years after adopting CREATE all reported continuing to use the strategy in some or all courses. When asked about the extent to which CREATE changed them as a teacher, faculty members offered a variety of observations. One faculty member noted that CREATE teaching made him realize that he had not previously been aware of the extent to which students were learning, and another noted the need to make classes student-centered and focus on helping students own the material. A third respondent described her enjoyment of
high-level discussions where students had the “freedom to explore their own ideas” and described the CREATE strategy as “liberating.”

CREATE Prepares Students for 21st-Century Science

We view CREATE as a way to address practical challenges of teaching and the more fundamental problem of traditional courses producing students who neither retain content that was covered nor feel enthusiastic about science. Through CREATE, highly trained researchers bring their research expertise to the classroom, share their passion for discovery, and break from the linear path of “teaching by telling.” Requiring students to prepare for each class using CREATE tools also spares faculty from being the source of all basic facts, freeing them to bring stories from their own research experiences to the classroom.

For example, in one CREATE class, we looked at reports outlining the discovery that some ulcers have a bacterial origin. In it, students read some of the personal writing of Barry Marshall, in which he describes his difficulties with the scientific establishment. This example helps to illustrate how well-established scientific “facts” may change, and that new findings may not be met with universal acceptance. This portrayal of what science is and how it works is not typically a part of content-heavy traditional courses, but it helps to make the field vivid, illustrating creativity, controversy and its resolution, and the ability of individuals to make a difference. We think these classroom experiences can deepen our students’ understanding of science and may lead them into research careers.

This shift from merely covering content to using content to develop how students think while emphasizing how scientific knowledge develops will serve students well into the future. Microbiology knowledge is developing rapidly, with journal articles covering new developments far faster than textbooks. Intensive examination of this literature via the CREATE strategy can provide students with significant learning gains, transferable analytical skills, and unique insights. We encourage faculty members to bring the skills they already possess to the classroom, focus on the scientific process, and teach CREATE.

Suggested Reading


