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Using the Web to Encourage Student-generated Questions in Large-Format Introductory Biology Classes

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Students rarely ask questions related to course content in large-format introductory classes. The use of a Web-based forum devoted to student-generated questions was explored in a second-semester introductory biology course. Approximately 80% of the enrolled students asked at least one question about course content during each of three semesters during which this approach was implemented. About 95% of the students who posted questions reported reading the instructor's response to their questions. Although doing so did not contribute to their grade in the course, approximately 75% of the students reported reading questions posted by other students in the class. Approximately 60% of the students reported that the Web-based question-asking activity contributed to their learning of biology.

INTRODUCTION

Large-format introductory-level science classes are a fact of life at many colleges and universities. This circumstance prevails due to resource limitations, not for sound pedagogical reasons based on how people learn (Bransford *et al.*, 2000). Students in such classes, assuming they are present and alert, often sit passively, listen to the instructor, and perhaps take notes. However, even when students sit passively in a lecture, for learning to occur they must be mentally active—selectively taking in and attending to information, and connecting and comparing it with prior knowledge and additional incoming information in an attempt to make sense of what is being received. Encouraging these metacognitive acts is challenging in large classes. Cooper and Robinson (2000) write, "It is a sad commentary on our universities that the least engaging class sizes and the least engaging pedagogy is foisted upon the students at the most pivotal time of their undergraduate careers: when they are beginning college" (p. 7).

Effective teaching is crucial for making postsecondary introductory science courses more intelligible and meaningful for all students. This is particularly important in an era when the United States is losing its competitive edge in science and technology (Schmidt *et al.*, 1999) and the "science professorate (has) a comfortable 'elsewhere' focus; for advocating K–12 reforms rather than coming to grips with the hemorrhaging of the student pipeline that occurs during the college years" (Schaefer, 1990). Tobias (1990) reported that many bright postsecondary students opt out of science as soon as possible, a finding supported by the more comprehensive work of Seymour and Hewitt (1997).

The very size of many postsecondary introductory classes creates obstacles to implementing what is known about effective teaching, thereby exacerbating the difficulties students have in developing a deep understanding of fundamental science concepts. For example, students have limited opportunity to learn how to ask questions that will aid their learning and for practicing this important cognitive act. A related challenge in large-format classes is encouraging a wide range of students to ask questions about the subject matter.

Asking questions about the concepts is an important aspect in student learning (Balzer *et al.*, 1973). Evidence exists linking students' retention of content to question generation (Davey and McBride, 1986; King, 1989). Harper *et al.* (2003) report that students who ask deeper-level questions directed at concepts, their coherence, and their range of application exhibited higher conceptual achievement. Asking effective questions also has been linked to improvement in students' problem-solving abilities (King, 1991; Dori and Herscovitz, 1999). Marbach-Ad and Sokolove (2000) note that independent learning is promoted by having students ask questions.

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Asking meaningful questions requires students to first consider information being presented in a lecture or textbook, determine areas of confusion, and structure a question to help clarify their thinking (Miyake and Norman, 1979). These metacognitive acts demand mental engagement and promote learning. In addition, the questions that students ask help the instructor better understand students' thinking, thereby making possible instructional decisions that are better tailored to their needs (Heady, 1983; Etkina, 2000; Etkina and Harper, 2002). For example, knowing the difficulties students are having helps an instructor provide analogies, clarification, examples, and questions that assist students in understanding the content.

Learning to ask effective questions is also crucial for students intent on someday conducting research in the natural sciences. Many scientists and philosophers of science have emphasized that asking questions is at the heart of progress in science. Einstein and Infeld (1938) wrote, "To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science" (p. 93). However, science education too often emphasizes answers and ignores the importance of questions. Barnard *et al*. (1993) summarize this in the following way: "Asking the right questions in the right way is a fundamental skill in scientific enquiry, yet in itself it receives surprisingly little explicit attention in scientific training" (p. vii). Thus, a crucial focus in biology instruction, and perhaps science instruction generally, should be to teach students how to ask effective questions and to make question asking an integral part of the learning experience.

Student-generated questions are often rare in large-format classes, and they frequently come from a minority of the students. Unfortunately, some instructors find students' questions in large classes to be annoying or potentially embarrassing, leading to active discouragement of student questions (Penner, 1984). When students do ask questions, they often address matters not related to deeply understanding science concepts (e.g., "What will be on the exam?", "How will the assignment be assessed?", "Would you repeat that?").

Given the learning potential inherent in student-generated questions, many postsecondary instructors would like to encourage all students to ask effective questions that will aid both teaching and learning. This is evident in literature addressing student questions. For example, Harper *et al*. (2003) used structured weekly reports to encourage students to pose questions about physics; yet, they relay that 30% of the reports contained no questions. Marbach-Ad and Sokolove (2000) provided a question classification scheme to students in a traditional instructional setting and in an active-learning setting. In the active-learning class, students were required to pose two original questions on each of three different assignments. The questions were graded and returned with written comments. Students in the traditional setting were not required to ask questions, and they did not receive individual feedback on how to improve their questions. Marbach-Ad and Sokolove (2000) reported that students in the active-learning setting learned to ask better questions. Exley and Dennick (2004) provide a range of useful approaches for making large "lecture" classes more interactive, but they suggest no strategies for stimulating student generation of questions. Penner (1984) emphasizes the importance of encouraging students to ask questions (p. 193) but provides no strategies beyond being "welcoming" of student questions to accomplish this goal.

Despite some success reported in encouraging and improving student questioning in large-format classes, further efforts are sorely needed. Understandably, limited class time severely curtails the number of questions that can be addressed. However, even in the Harper *et al*. (2003) study where students were encouraged to pose questions in weekly reports, almost one third of the reports did not include questions. In the active-learning setting that Marbach-Ad and Sokolove (2000) studied, time devoted to improving students' questions, grading students' questions, and providing written feedback undoubtedly motivated and helped students ask more research-oriented questions, but it consumes more time in and out of class than many instructors of large-format class settings would be willing to devote.

The study reported here investigated the use of Web-based discussion boards as a mechanism for encouraging students to pose questions about course content. This forum also provides a medium for the instructor to answer the questions outside of class time in a manner that makes the responses accessible to all students in the course. Using this strategy, the time and effort expended responding to questions is far less than what would be required to accurately grade students' questions and provide detailed feedback about the quality of their questions. Given the time constraints facing many instructors of large-format classes, the strategy used in this study may be a practical solution for encouraging meaningful student questions. Here, we report the results of using the WebCT course management tool in an effort to encourage student-generated questions in large-format introductory biology classes.

METHODS AND FRAMEWORK OF STUDY

The study reported here was conducted during spring 2001, 2002, and 2003 semesters at a research-extensive university in the upper Midwest. The study took place in Biology 202, the second semester of a two-semester introductory "principles of biology" series intended for biology and other life science majors. The major topics addressed in Biology 202 are cell and molecular biology, metabolism, plant structure and function, and animal structure and function. The initial enrollment in this course is approximately 200 students. No graduate teaching assistants are assigned to this course. A separate laboratory course (Biology 202L) is usually, but not always, completed in conjunction with Biology 202.

To encourage student-generated questions, students were offered a small amount of "extra credit" that amounted to approximately 2% of their final course grade. To earn the extra credit, students were asked to post questions related to the course material on an electronic discussion forum by using the WebCT course management tool. Maximum extra credit could be obtained by posting five (spring 2001) or four (spring 2002 and 2003) questions during the semester. Although students could ask as many questions as they wished, multiple submissions per day only counted as one question toward earning extra credit.

A few minutes were spent during the first class of the semester explaining to the students how they could earn the extra credit by asking meaningful questions about biology content. Examples of meaningful questions were provided to illustrate what would and would not receive credit. For example, questions about course organization and procedures (e.g., "When is the assignment due?") would not be accepted for credit. The instructor (J.T.C.) provided answers to students' questions as quickly as possible, typically within 24 h. In addition to providing the response, the instructor also politely provided general feedback on the quality of the question (e.g., "That's an excellent question." "I can't give you credit for this question, because it is not about our subject matter, but . . . ," "Good question to clarify in your mind."). The instructor kept a log of time spent answering student questions in a similar course for 32 consecutive days during a subsequent semester when using the same approach. Approximately 20 min/d was required to respond to student questions.

Other students in the class could see both the questions posed by their peers and the answers provided by the instructor. In addition, the instructor selected some questions for use in class. In some instances, the questions were used to review challenging ideas, whereas other questions were used to introduce new topics or intriguing sidelights. The student's name was located next to the question he or she posted on WebCT, but students' questions used during class were done so anonymously. Representative student questions are shown in Box 1.

Box 1. Student questions.

"Since primary structure of polypeptides dictates the formation of particular proteins, what determines the primary structure of polypeptides?"

"I was wondering what happens to the introns after they are spliced out? Are they simply recycled or are they lost in some other form?"

"In glycolysis if only the glyceraldehyde phosphate isomer proceeds to the kerb cycle what happens to the dihydroxyacetone phosphate molecule, or does it get used also?"

"I guess I should preference this question by saying that I am a runner, so this is of interest to me. I know that the body produces lactate when the body does not have enough oxygen, but what exactly is lactate?"

"In class Thursday you said that CO_2 is obtained from the Calvin cycle from the air. Can't plants utilize the CO_2 produced by their own cells through glycolysis, the Krebs cycle, the electron transport chain, and photorespiration?"

"Today in lecture you said that legumes provided/made their own nitrogen. Does that meant that in agriculture it is not needed to provide fertilizer, like ammonia, to add nitrate to the soil to enhance the plant performance?"

The purpose of this study was to determine the number and nature of questions students posted on the electronic discussion forum and to determine the extent that students report 1) reading the answers posted by the instructor, 2) looking at questions posed by other students, and 3) feeling this activity aided their learning of biology.

Determining the total number of questions posted by students in a class is a straightforward process. However, understanding the nature of the questions students asked is necessary for drawing meaningful conclusions about the effectiveness of the strategy used in this study. Hence, 150 of the 482 questions submitted by Biology 202 students during spring semester 2003 were randomly selected and coded independently by two authors using a scheme, developed by Marbach-Ad and Sokolove (2000), for coding undergraduate biology student questions. The coding scheme (Appendix A in the Supplemental Material) categorizes questions according to the type of cognitive process conveyed by the content of the question. Intercoder agreement was 0.97. Spring 2003 semester was selected because it was the only semester for which student questions were still available at the time the coding was performed. Student-generated questions from the other semesters had been deleted during WebCT upgrades.

Data regarding students' perceptions of the question-generating strategy used in this study come from anonymous course evaluations filled out by students who completed Biology 202. Questions addressing the Web component of Biology 202 were appended to the standard university course evaluation form. Subjects in this study came from classes during spring 2001 (n [number of students completing the course evaluation] = 156; spring 2002, n = 159, and spring 2003, n = 1500). The specific questions and response format are presented in *Results*.

RESULTS

Students Asking Questions

During each of the three spring semesters the study was conducted, at least 400 student-generated questions were posted on the electronic discussion forum. On the end-of-semester course evaluation form, data compiled from all three Biology 202 classes in which this study was conducted showed that approximately 80% of the students reported asking at least one question on the electronic discussion forum. Table 1 provides the breakdown of the results.

One hundred and fifty randomly selected questions posed by students in Biology 202 during the spring 2003 semester were coded using the taxonomy created by Marbach-Ad and Sokolove (2000). The results of our study are shown in Table 2 along with the results reported in Marbach-Ad and Sokolove (2000) from an active-learning setting. After the second assignment in their study, a substantial amount of

Table 1. Student self-reported data regarding number of questions posted to WebCT

% Posted to WebCT	SD	Student self-reported data
19.6	2.5	Asked no questions
36.7	2.5	Asked fewer questions than required for full credit
31.0	5.2	Asked the number of questions required for full credit
15.0	3.0	Asked more questions than required for full credit

time was devoted to assisting students in learning how to recognize the differences between the categories of questions. Moreover, at that time the instructor in that course also made known his preference for category 5 and 6 questions. Not surprisingly, more students afterward asked category 5 and 6 questions. In our study, we took a more liberal view regarding meaningful student questions and valued equally questions in categories 2 through 6. In our study, 63% of student questions fit within categories 2 through 6. This finding is similar to the 61 and 65% of student questions coded in categories 2 through 6 on the first two assignments in the active-learning setting reported in Marbach-Ad and Sokolove (2000) but lower than the 78% reported after the extensive effort and time was exerted to improve students' questions.

Some questions were specific in trying to clarify a point of confusion from class. Other questions addressed larger concepts or attempted to relate material from class to their life experiences (Box 1). For example, "I know fiber plays an important role in human digestion, even though we lack a mechanism to digest cellulose. I was just wondering, since cows are able to digest cellulose, do they have an alternate means of performing the function that fiber plays in human digestion; in other words, to put it bluntly, how do cows 'stay regular'?"

Although four of five students in a large-format class were enticed to ask at least one meaningful science content question (and at least half of students asked more than one such question), we wanted to know the following. First, to what extent do the students take the time to read the answers posted by the instructor? Second, to what extent do the students report looking at questions posed by other students? And third, to what extent do the students report that this activity aided their learning of biology? Each of these questions was posed on the course evaluation form, and the results are addressed below.

Students Reading Instructor Responses to Questions

Whether students take time to read posted answers is crucial given the substantial time required for an instructor to write responses to 400 or more student-generated questions during the semester. If most students were simply posting the questions for extra credit, but not reading the instructor's response, justifying the time required to respond to questions would be difficult. The following question was posed to students on the course evaluation form to address this issue, "Did you check back to read the instructor's answer (to your question)?" Possible student responses were "never," "sometimes," and "always." Only student data from those who reported they asked questions were analyzed. Summarizing the data in this manner revealed that an average of only 3.7% (SD = 1.2) of those students who asked questions reported never reading the instructor's response (Figure 1).

Students Reading Questions Posed by Peers

Whether students would choose to read questions posted by other students in the class is also of interest. Any student's question probably addresses shared areas of interest and confusion and would help others learn from their peers' questions. Although students received no credit for reading questions posted by other students, the data reported in Table 3 indicate that almost three fourths of all Biology 202 students (those who did and did not pose questions of their own) reported looking at questions posted by their peers.

Of those students who posted at least one question, 82.3% (SD = 2.5) reported that they looked at questions posted by

Table 2. Marbach-Ad and Sokolove (2000) question categories and comparison

Category	Biology 202 (spring 2003), % (n = 150)	Marbach-Ad and Sokolove (2000) data: Assignment 1 % (n = 182)	Assignment 2 % (n = 188)	Assignment 3 % (n = 173)
(0) Catch-all category including questions that do not make sense, reflect misunderstandings, misconceptions, or do not fit other categories	3	15	13	8
(1a) Questions about simple definitions concepts, or facts that could be found in the textbook	15	12	11	5
(1b) Questions about more complex definitions, concepts, or facts explained fully in the textbook	19	12	11	9
(2) Questions addressing ethical, moral, or sociopolitical issues related to the content	4	1	3	2
(3) Questions where the answer is a functional or evolutionary explanation	23	10	10	2
(4) Questions that seek more information than is available in the textbook	21	20	32	30
(5) Questions resulting from extended thought and synthesis of prior knowledge and information	14	23	13	30
(6) Questions that contain within them the kernel of a research question	1	7	7	14

their peers. Remarkably, nearly half (44.3% [SD = 6.7]) of the students who reported not asking any questions of their own reported looking at questions posted by other students.

Students' Perceptions Regarding the Value of Asking Questions

The most important question that one might ask of any pedagogical approach is, "Did the approach help the students learn the course content?" Table 4 reports students' perceptions regarding whether the Web-based question-asking activity aided their learning of biology. Overall, approximately 60% of the students reported that the question-asking activity had at least some positive impact on their learning of biology.

The course evaluations also provided opportunities for students to make written comments about the Web-based question-asking component of the course. Students commented about being able to ask questions in a less intimidating environment ("I liked being able to ask questions about biology in an indirect setting"), valued other students' questions ("Being able to read other student's questions" and "I like the . . . questions part because I think that some students ask some good questions that I want to know"), and expressed appreciation for the answers provided by the instructor ("I appreciated the opportunity to ask questions of the instructor. It was helpful to clear up confusion or to find a little further information" and "The . . . questions with your answers were *very* helpful").

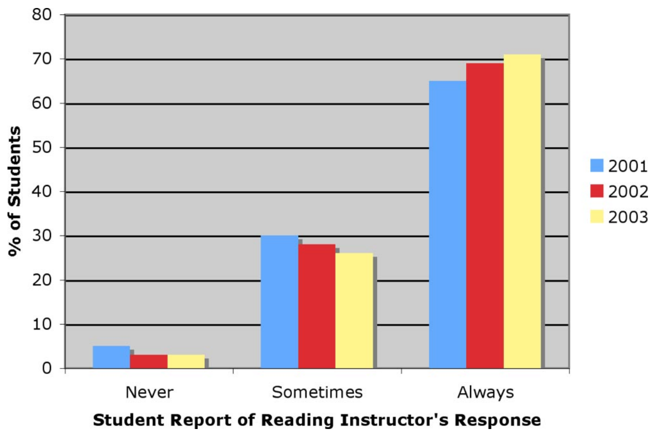

Figure 1. Percentage of students who reported that they read the instructor's answer to their own question(s). The data presented here include only those students (approximately 80% of total enrollment) who posted questions.

DISCUSSION

Large-enrollment classes and tightly constrained class meeting times frequently discourage students from asking questions and having interaction with instructors. This situation, in turn, hinders instructors from understanding what concepts students find difficult and then using that knowledge to make effective pedagogical decisions that help students learn. Implementing the question-asking strategy described in this report encouraged 80% of the students in a large introductory biology course to pose at least one question by using the WebCT course management tool. This figure compares favorably to efforts reported in the literature to encourage student questions. Harper *et al*. (2003) encouraged students to pose questions about physics in structured weekly reports, but they provided no credit for doing so, and they reported that 30% of the submitted reports contained no questions. They also noted "Colleagues who have tried to make the questioning more optional (through a website or anonymous scraps of paper turned in at the end of class) report they receive few if any student questions" (p. 788). The percentage of students posing questions in our study far exceeded the 50% of students who asked questions in a traditional class setting studied by Marbach-Ad and Sokolove (2000), despite those students also being offered extra credit for formulating questions.

Marbach-Ad and Sokolove (2000) also investigated the kinds of questions asked by students in an active-learning setting. Much effort and time in that active-learning setting was devoted to teaching students to ask better questions, grading the questions students submitted on three assignments, and providing written feedback. We applaud that effort and the higher number of category 5 and 6 questions

Table 3. Student self-reported data regarding whether students looked at questions posed by other students (includes students who did and did not pose questions of their own)

% Posted to WebCT	SD	Student self-reported data
25.7	1.5	Reported never looking at questions posted by other students
17.3	3.5	Reported looking at "1 or 2 questions"
42.7	3.1	Reported looking at "a few" questions posed by other students
14.3	4.2	Reported looking at "many" questions posed by other students
0.7	0.6	Reported looking at "all" the questions posted by other students

Table 4. Student self-reported data regarding whether the Web-based question-asking activity had aided their personal learning of biology

% Posted to WebCT	SD	Student self-reported data
20.3	2.1	Reported that the question-asking activity aided their learning
41.3	5.0	Reported that the question-asking activity aided "some" in their learning
29.0	1.0	Reported that the question-asking activity aided "little" in their learning
9.0	3.6	Reported that the question-asking activity did not aid their learning

that resulted, but we question whether most postsecondary instructors of large-format classes have the time or assistance necessary to replicate it on an ongoing basis. Moreover, questions in categories 2 through 6 all have value in helping teachers understand students' struggles and learn biology. An interesting future study might replicate our strategy but include a handout or Web-based tutorial to students early in the semester that presents a question classification scheme, provides questions illustrating each category, and makes clear that earning extra credit is contingent on avoiding questions that can simply be answered by closely examining the class textbook. This approach might significantly improve students' questions without the considerable time and effort expended in the Marbach-Ad and Sokolove (2000) study.

Perhaps Biology 202 students asked questions solely because of the small amount of extra credit they received for doing so and the ease of posting questions on WebCT. In one sense, that is irrelevant. If having students learn to pose questions is an important objective in large-format introductory biology courses, then providing a small amount of credit or extra credit for doing so is of little consequence. However, that approximately 95% of those students who asked questions reported reading at least some of the instructor's responses to their questions, and that so many students reported looking at questions posted by other students (despite receiving no credit in both cases for doing so) may be interpreted as indicating students put thought into their own questions, were genuinely interested in the instructor's written response to questions, and found value in the question-asking strategy used. That <10% of students reported the question-asking activity did not aid their learning bolsters the interpretation that students genuinely found at least some value in asking questions, in viewing the questions posed by peers, and in receiving responses to those questions. Another factor encouraging students to pose questions may have been that the Biology 202 instructor, although not accepting for extra credit any question posed, was very respectful of students' questions and politely responded to all of them. The ease of submitting questions, respectful response of the instructor to students' questions, small amount of extra credit earned, and answers to their questions all probably factored into the results achieved in our study.

The results of our study should reassure instructors that the time required to answer questions posed by students on Web-based discussion boards is worthwhile. The high level of students reporting that they read the instructor's responses to questions is not limited to our particular course, Biology 202. More recently, the Web-based, question-asking approach was implemented in the first semester Principles of Biology course, Biology 201, during the spring 2005 and fall 2005 semesters. Surveys at the end of these semesters indicated that, of the students who posed questions, 79.2% reported always looking at the instructor's response, 17.7% sometimes looked at the instructor's response, and only 3.1% never looked at the instructor's response. So with both large-format courses, >95% of the students posing questions report looking at the response from the instructor.

That many Biology 202 students (approximately 75%) reported viewing questions posed by their peers, even though they received no credit toward their grade in the course for doing so, is potentially significant for students' learning. Many students in a course are within the same zone of proximal development where a learner cannot alone comprehend an idea, but with appropriate assistance from a teacher or peer, the concept may be understood (Vygotsky, 1978, 1986). Jones *et al*. (1998), p. 968, write, "These more capable peers assist development in the zone by prompting, modeling, explaining, asking leading questions, discussing ideas, providing encouragement, and keeping the attention centered on the learning context." Sharing the same zone of proximal development makes it likely that any single posed question will often reflect conceptual struggles by many students in the class. This may explain why so many students attended to other students' questions, why they read the instructors' responses to questions, and why approximately 60% of students reported that the question-asking activity was helpful in learning biology. Providing a Web-based forum in which students are encouraged to ask questions about course content, although time-consuming, seems to be helpful in students learning the material, and it is readily participated in by students.

Our study relied on students accurately reporting whether they 1) read the answers posted by the instructor, 2) looked at questions posed by other students, and 3) felt the activity aided in learning biology. These self-report data were collected anonymously and in proximity to the question-posing activity. Thus, students had little reason to respond in a dishonest manner, and they were unlikely to have forgotten how they participated in the question-posing activity. The small amount of extra credit that amounted to approximately 2% of their final course grade was unlikely to be sufficient to inflate their expressed views regarding the question-posing activity.

Our study also made no attempt to directly link student learning to questions students posed. Empirical evidence already exists linking question generation to many desired student goals, including learning content (Davey and McBride, 1986; King, 1989, 1991; Dori and Herscovitz, 1999; Harper *et al*., 2003). Additionally, learning is undeniably linked to students' mental engagement in wrestling with concepts, and generating meaningful questions about biology content is a mentally engaging activity. The primary purpose of our study was to determine whether use of a Web-based forum along with the possibility of earning a very small amount of extra credit would encourage students to ask meaningful questions.

An unintended outcome of this approach was improving teaching in large lecture classes by easily importing students' questions (already in electronic form) into class presentations (PowerPoint format) to address common conceptual difficulties, emphasize key concepts, precipitate a review of a challenging idea, explore an aspect of course content that relates to students' life experience, or introduce a subsequent topic in the course. Students probably pay more attention in class at those times when questions they, or their peers, asked are used within instruction. Although large format classes are not ideal learning environments, Web-based technology can be used to engage students in the intellectual enterprise of learning a particular discipline.

Although not a substitute for smaller class sizes and personal interaction between students and instructors, the Web-based question-asking activity reported here increases students' engagement with the course content and encourages students and instructors to intellectually "interact" asynchronously outside of class. The question-asking activity presented here resulted in far more questions and interaction about disciplinary content than what typically occurs in large-format classes. In addition, a far wider diversity of students asked questions using this approach than is typical in large-format classes.

The approach described here has value to the overarching goal of encouraging students to really think about, and become curious about, the discipline of biology. Successfully achieving this goal clearly requires more of students than simply providing "correct answers" on exams. To deeply understand biology, and, for those who wish, to become biologists, students must learn to ask appropriate questions. Like any other challenging activity, learning to ask appropriate questions requires practice. As Bain (2004) states, "When we can successfully stimulate our students to ask their own questions, we are laying the foundation for learning" (p. 31).

The approach described in this report shows promise in encouraging students to begin practicing effective question-asking skills early in their college biology learning experiences.

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