# Integrative Biology: A Capstone Course for an Introductory Biology Core

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*A capstone to the biology introductory curriculum was developed with the specific goals of enhancing integration of course content, promoting development of oral presentation skills and critical reading and thinking skills, and introducing ecological principles omitted from the rest of the core. Classes of 12 to 16 students were team taught by biologists with different subdiscipline specialties in a seminar format, using a variety of problem-solving exercises and critical analysis of the primary literature. The effectiveness of this pedagogy in promoting course goals was determined by feedback from students on their end-of-course surveys and by comparison of scores on exams and oral presentations throughout the semester. More than 90% of students agreed that the capstone course helped them appreciate global issues and read and critically analyze primary literature. Although the capstone course is extremely valuable preparation for upper division biology courses, it is costly to staff and demands more time to prepare and teach it effectively.*

Recent efforts to improve science education in U.S. college classrooms have focused on the role of active learning in promoting acquisition and retention of knowledge as well as critical thinking, deep and enduring understanding, and oral and written communication skills. A number of studies have provided evidence that active learning in the classroom enhances student performance, deep conceptual understanding, and long-term retention (Dinan, 2002; Freeman et al., 2007; Handlesman et al., 2004; Knight & Wood, 2005; O'Sullivan & Copper, 2003; Prince, 2004; Prince & Felder, 2006; Smith, Sheppard, Johnson, & Johnson, 2005). In addition, interactive activities such as problems, cases, role-play exercises, debates, and inquiry-based investigative labs encourage students to gather and synthesize information to practice application and analysis. These activities are essential for improving critical-reasoning abilities, as several recent studies have documented (Camill, 2006; Chaplin, 2009; Chaplin & Manske, 2005; Herreid, 2004; Prince & Felder, 2006). Many studies have described a variety of successful methods of introducing students to the primary literature, and most have documented the impact these exercises have on improving science literacy, critical thinking, and/or understanding of the scientific process in their students (Brill & Yarden, 2003; Houde, 2000; Jacques-Frick, Hubert, & Miller, 2009; Janick-Buckner, 1997; Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006; Levine, 2001; Mangurian, Feldman, Clements, & Boucher, 2001; Muench, 2000; Mulnix, 2003; Roberts, 2009; Wenk & Tronsky, 2011). Working in collaborative teams on a complex problem or a journal club presentation of primary literature has also been shown to enhance critical thinking and deep conceptual understanding, as students share information and stimulate each other to greater insights (Gokhale, 1995; Henderson & Buising, 2000; Tsui, 1999; Yuretich, 2004).

The recent American Association for Advancement of Science (AAAS; 2011) report, *Vision and Change in Undergraduate Biology Education: A Call to Action*, recommends a set of strategies with a central focus on promotion of student-centered activities in an active-learning environment: exploration of real-world applications of concepts; use of multiple modes of instruction, cooperative learning, frequent and multiple forms of feedback on progress; and integration of content around core principles for deep understanding.

In this article, we describe a unique biology core capstone course with objectives and activities that promote many of the recommendations of the AAAS report, with illustrations of how they might be implemented. The essential nature of this course was developed and taught by several members of the biology faculty at the University of St. Thomas in Minnesota, including the authors. We describe the pedagogy the authors have used to integrate the core biology principles across the hierarchy of biological organization (molecules to ecosystem level), the activities used to promote the student-centered classroom, and the structure implemented to support a primary literature-based experience with its emphasis on development of critical thinking as well as oral presentation skills.

## Background and goals of the capstone course

From 1988 to 2002, the biology core curriculum at the University of St. Thomas included three 4-credit courses, each with lab. It was designed to provide a foundation in key conceptual areas of biology. Students typically begin this core sequence in the fall of their first year and ideally finish by the end of their sophomore year. A capstone "half-course" (two credits, no lab, meeting once a week) was added to the required core sequence in 2002 and gradually evolved over the next 8 years to have specific content and process goals as follows:

1. Introduce major ecosystem and conservation biology concepts not covered in previous courses.
2. Learn about those concepts within the context of significant, selected global ecological issues.
3. Integrate principles of molecular, cellular, and organismal biology into this examination of global ecological issues.
4. Further develop student abilities to apply ideas to new contexts, to analyze data, to engage in critical thinking and decision making.
5. Develop skill in analysis of the primary literature—a skill not

**TABLE 1**

**Assigned reading and content emphasis for three units of the biology core capstone course, illustrating the intentional integration of concepts from previous core courses. Unit 1 did not follow this format (see description in "Overall Structure" section).**

| Unit topic | Assigned background readings | Concepts from previous core courses integrated into the unit | Application of core concepts |
|---|---|---|---|
| **Unit 2. Conservation of biodiversity** | 1. Conservation biology chapter in Campbell's *Biology* text<br><br>2. Review article: Ashley, M. V. (1999, January/February). Molecular conservation genetics. *American Scientist, 87,* 28–35. | PCR; restriction digests; evolution; genetic drift; population size; inbreeding; mitochondrial DNA; repetitive DNA; phylogenetics; basic Mendelian inheritance; extinction vortex | Multistage analysis of the Florida Panther case (developed by the instructors); includes morphological and physiological information; minisatellite DNA fingerprints; mitochondrial haplotype data; phylogeny construction |
| **Unit 3. Environmental effects of genetically modified organisms** | 1. Community ecology chapter in Campbell's *Biology* text<br><br>2. Review articles:<br>a. Wolfenbarger, L. L., & Phifer, P. R. (2000). The ecological risks and benefits of genetically engineered plants. *Science, 290*, 2088–2093.<br>b. Schmidt, C. (2005). Genetically modified foods: Breeding uncertainty. *Environmental Health Perspectives, 113,* A527–A533.<br><br>3. Websites on genetic engineering of plants | Plasmids; restriction digests; transformation; cloning; tissue culture; DNA; selective environment; community interactions; resistance to drugs | 1. Application of concepts to a case study on effects of Bt corn pollen on the Monarch butterfly<br><br>2. Constructing a GMO: development of a poster that illustrates steps for how to make Bt cotton<br><br>3. Take-home exam based on multiple research articles on the effectiveness of refuges; student task is to evaluate the recommendations of University Extension Service for refuge structure when using GMO corn. |
| **Unit 4. Anthropogenic impacts on nutrient cycling** | 1. Ecosystem biology chapter in Campbell's *Biology* text<br><br>2. Review article: Vitousek, P., et al. (1997). Human alteration of the global nitrogen cycle: Causes and consequences. *Issues in Ecology* #1.<br><br>3. Website on dead zones: http://www.epa.gov/msbasin/hypoxia101.htm | Photosynthesis; respiration; symbiotic relationships – N fixation; biochemical conversions; enzyme activity and temperature; N containing biochemicals (proteins, DNA, RNA) | 1. Modeling the N cycle using the American Society for Microbiology Education Instructional Library *Voyage of a Nitrogen Atom,* developed by Marcia L. Cordts, Rebecca Kapley, M. LigiaCarvalhal, and Sherman Hom<br><br>2. Students' examination of their carbon footprint using Web-based calculators: www.carbonfootprint.comand/or http://www.epa.gov/climatechange/emissions/ind_calculator.html |

deliberately developed in previous courses in the core.
6. Develop oral presentation skills.

Whereas the other courses in the biology core are all large lecture-section courses (50–100 students/section) with smaller lab sections (16–24 students/lab), the capstone course is a seminar with 12–16 students/section. Originally, to more easily facilitate the integration of material from other core courses into the capstone, the course was team-taught with an ecologist or physiologist and a cell biologist. Currently solo instructors, primarily ecologists who worked previously in a team, teach the course to reduce staffing costs.

## Overall structure of the capstone course

Content of the capstone course is structured around four global ecological issues taught in the following order: endocrine disrupters (2 weeks); conservation of biodiversity (4 weeks); genetically modified organisms as invasive species (4 weeks); and anthropogenic disruptions to nutrient cycling (4 weeks). Unit 1 is atypical in that it is much shorter and is structured primarily to introduce students to the format and expectations of the rest of the course. In each of the latter three units of the course, the students engage the topic through a set of activities described next and illustrated in more detail in Table 1.

At the beginning of a unit, students read assigned background material (see Table 1) relevant to the issue under study and answer a set of questions designed to help them summarize the key points. Following short introductory lectures (about 30 minutes) to introduce essential concepts at each unit's first class meeting, students engage in a variety of active learning exercises over the next couple of weeks to apply what they have just learned and practice problem solving. Active-learning exercises might take the form of case studies that integrate essential core concepts, or discussion of integrative application questions, or role play in a jigsaw format to make decision-oriented recommendations (Table 2).

During at least two weeks of the unit, significant time is given to critical reading, analysis, and presentation of an assigned article from the primary literature that uses particular core concepts of interest in that unit (Table 3). Students are divided into groups of 3–4, and each group is assigned to read a particular article. Each student e-mails answers to basic analytical questions on their assigned article to the instructor prior to the next class. The questions are designed to help identify key features of the article, connect the published study to the unit, and begin the analysis of the Results and Discussion sections of the article. Written answers inform the instructor of students' level of understanding of the article and potential misconceptions that should be addressed. During the next class, each group discusses and analyzes their article with an instructor and makes decisions about what and how to present the article to the rest of the class. The following class session is then devoted entirely to group presentations and discussion facilitated by the instructor(s), reemphasizing the important concepts of that unit. Instructors write comments on the presentations to each student to provide constructive feedback for their improvement along with their individual and group grades for the activity.

Prior to the introduction to the next unit, students take an exam on the completed unit, answering questions that intentionally challenge them to interpret and analyze data they have not seen before and apply their foundational knowledge to the solution of a problem (Table 4). Exams emphasize not only the ecological concepts but also the integrative connections they should be making with content from previous core courses. A major portion of the final exam is an analysis of a primary literature article (not previously assigned) that integrates concepts across units of the course. For example, students analyzed an article on the effect of elevated $CO_2$ on insect-plant interactions in a Bt-cotton-herbivore system (Coviella, Morgan, & Trumble, 2000), which addressed impacts on the ecosystem, population, and organismal (physiological) levels.

## Assessment of course goals

Several types of assessments were used to evaluate whether the capstone course accomplished the objectives established for this experience. In particular, we were most interested in whether this approach (a) increased student appreciation of global ecological problems, (b) helped students integrate concepts from previous core courses, (c) promoted critical thinking by engaging in reading and analysis of the primary literature, and (d) increased their confidence and achievement in presenting scientific information orally.

*End-of-course surveys* were completed by students in nine sections of the course taught by 12 instructors (in pairs) over the period from 2002 to 2005 ($n$ = 110 student responses, approximately 90% of the total student enrollment in those sections). Students responded to a set of questions that asked them to rate the success of the course in promoting the particular learning goals iterated above (see Table 5). Students rated their assessment on a Likert scale from 1 (*not successful*) to 5 (*very successful*) and were encouraged to provide written comments as well. The percentage of all students in each section answering the question with a 3, 4, or 5 versus a 1 or 2 was calculated from the distribution of responses.

*Oral presentations* based on reading and analysis of articles from the primary literature were assessed both on an individual and a presentation

**TABLE 2**

**Selected examples of active learning exercises in the biology core capstone course.**

| Unit | Topic | Active learning exercises |
|---|---|---|
| **Unit 1: 2 weeks** | Endocrine disrupters | ***Atrazine in Minnesota***<br>Students read materials about atrazine as a potential endocrine disrupter.<br><br>• Hayes, T., et al. (2002). Hermaphroditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses. *Proceedings of the National Academy of Sciences, USA, 99,* 5476–5480.<br>• Syngenta news release: http://www.syngentacropprotection.com/news_releases/news.aspx?id=117989<br>• EPA review of the data: http://www.epa.gov/oppsrrd1/reregistration/atrazine/atrazine_update.htm<br><br>Students learn about the role of atrazine in Minnesota farming and, using a jigsaw process, develop a recommendation to their state senator for the use of atrazine in Minnesota. |
| **Unit 2: 4 weeks** | Conservation of biodiversity | ***Florida panther case study***<br>To give students practice with applying the various concepts in the conservation biology unit, the instructors developed a multipart case study about the endangered Florida panther using results from published studies:<br><br>• Culver, M., et al. (2000). Genomic ancestry of the American puma (Puma concolor). *Journal of Heredity, 9,* 186–196.<br>• O'Brien, S. J., et al. (1990). Genetic introgression within the Florida panther Felis concolor coryi. *National Geographic Research, 6,* 485–494.<br>• Roelke, M. E., et al. (1993). The consequences of demographic reduction and genetic depletion in the endangered Florida panther. *Current Biology, 3,* 340–350.<br><br>In Part I, students consider anatomical, physiological, and reproductive data that asks them to apply concepts such as inbreeding depression, bioaccumulation of toxics in the environment, human impacts on habitat quality and fragmentation, extinction vortex, and minimum viable population size.<br><br>In Parts II and III, students analyze results of allozyme data, followed by minisatellite DNA fingerprints, and mtDNA haplotypes. They construct a potential phylogeny using haplotype data that places these panthers in relation to others in the Western hemisphere. The extent of genetic diversity in these panthers is evaluated (% polymorphic loci; average heterozygosity), and again concepts regarding inbreeding, drift, and genetic bottlenecks are considered.<br><br>In Part IV, students develop a recommendation for the restoration of the Florida panther based on evidence from previous parts of the case. |
| **Unit 3: 4 weeks** | Enviromental effects of genetically modified organisms | ***Monarch butterfly as a nontarget species***<br>Students analyze data from, for example:<br><br>• Losey, J. E., et al. (1999). Transgenic pollen harms monarch larvae. *Nature, 399,* 214.<br>• The Colorado State website, regarding the impact of Bt corn on Monarch butterflies (http://cls.casa.colostate.edu/transgeniccrops/hotmonarch.html)<br>• Oberhauser, K. S., et al. (2001). Temporal and spatial overlap between monarch larvae and corn pollen. *Proceedings of the National Academy of Sciences, USA, 98,* 11913–11918.<br><br>Students then develop a synthesis of these data for this issue. This case also provides an opportunity for talking about the press and science news. |
| **Unit 4: 4 weeks** | Anthropogenic impacts on nutrient cycling | ***Carbon footprint analysis***<br>Students use two web-based programs (www.carbonfootprint.com and http://www.epa.gov/climatechange/emissions/ind_calculator.html) to analyze their carbon footprint, particularly examining what choices make the biggest impact on their footprint. |

team basis three times during the semester. For 77 students in 7 sections taught by the authors from 2005 to 2009, we compared the means of all individual scores for the first, second, and third oral presentations to assess improvement in quality over the course of the semester. In addition, we calculated the percentage of students achieving an "A" grade (at least 90% of the points) on each of the three presentations as another indicator of improvement in oral presentation skill.

*Critical analytical thinking* was assessed by evaluation of the scores on the final exam, which concentrated on analysis of an article from the primary literature that the students had not previously read or discussed. The authors independently rated the seven exam questions on the Bloom, Engelhart, Furst, Hill, and Krathwohl (1956) scale of higher-order thinking, agreeing that four of the seven challenged students at the analysis or synthesis level. We calculated the mean percentage correct of all exam questions for each of eight sections of the capstone course taught by the authors in 2004 to 2009 ($n$ = 93 students). We also calculated the percentage of students in each section that performed at a "B" level (at least 80% correct).

## Results and discussion

### Course objectives

We found no significant differences ($P > .10$, using a Kruskal-Wallis nonparametric test) among nine sections of the core capstone course for student responses to the end-of-course surveys in 2002 to 2005. We therefore merged all responses into one data set for analysis. Chi-square goodness-of-fit tests indicated that the distribution of responses in the end-of-course surveys was significantly different ($P <$ .0001) from the expected (i.e., equal representation of all Likert scores) because of the high proportion of students responding to items with Likert scores of 4 or 5 and low proportion of students responding with Likert scores of 1 or 2 (Table 5).

### Goal: Appreciation of global ecological problems

Much of the ecological content of the capstone course was new to the majority of students, and as a result 96.4% of them rated the course moderately to very successful in helping them appreciate the biological significance of global ecological issues (Table 5). This is especially heartening in light of our departmental mission "to promote our conviction that biologists have a particular responsibility to respect and help protect the Earth's natural ecosystems . . ." coupled with the fact that the majority of students pursuing the biology major at the University of St. Thomas have a prehealth professions orientation. Learning concepts in a specific context of a case study has been shown to help students relate that information to their particular interests and engage them more successfully in constructing their own knowledge (Camill, 2006; Chamany, Allen, & Tanner, 2008; Chaplin, 2009; Dinan, 2002; Gallucci, 2006; Herreid, 2004).

### Goal: Integration of content from previous core courses

The overwhelming majority (89%) of students found the capstone course moderately to very successful in helping them integrate core concepts. Our strategy of approaching a case study from multiple levels of the biological hierarchy (e.g., the Florida panther case in the Conservation of Biodiversity unit, see Table 2) promoted use of foundational knowledge from other core courses to solve problems about a novel situation. There are several other means of achieving this goal of integrating knowledge across disciplines or subdisciplines. For example, Almeida and Liotta (2005) took advantage of a course pairing of first-semester Organic Chemistry

**TABLE 3**

**Examples of primary literature used for student analysis and presentations in the biology core capstone course. Unit 1 did not include a primary literature exercise.**

| Unit | Topic | Example of a primary literature assignment | Concepts relevant to the topic |
|---|---|---|---|
| **Unit 2** | Conservation of biodiversity | Berry, O., et al. (2005). Effect of vegetation matrix on animal dispersal: Genetic evidence from a study of endangered skinks. *Conservation Biology, 19*, 855–864. | Gene flow, extinction, microsatellite DNA, drift, habitat fragmentation, individual genotype, migration |
| **Unit 3** | Environmental effects of genetically modified organisms | Sasu, M. A., et al. (2009). Indirect costs of a nontarget pathogen mitigate the direct benefits of a virus-resistant transgene in wild *Cucurbita*. *Proceedings of the National Academy of Sciences, USA, 106,* 19067–19071. | Resistance, genetically modified plant, community interactions, gene flow, fitness |
| **Unit 4** | Anthropogenic impacts on nutrient cycling | Melillo, J. M., et al. (2002). Climate system, soil warming and carbon-cycle feedbacks to the climate system. *Science, 298*, 2173–2176. | Carbon cycle, nitrogen cycle, fertilizer, photosynthesis, temperature and enzyme activity, respiration, decomposers, carbon sink, carbon source |

and Cell Biology to add an integrative seminar in which students could use their background in biological and chemical techniques in investigative research projects. Suggestions for interdisciplinary lecture or seminar courses (e.g., neuroecology or behavioral endocrinology); interdisciplinary project-based lab exercises that use chemistry, physics, or math methods and principles; and collaborative research projects that bring disciplinary specialists together to work in teams can be found in *Bio 2010: Transforming Undergraduate Education for Future Research Biologists* (National Research Council, 2003).

### Goal: Promote critical thinking by reading and analysis of primary literature

Almost all students (97.2 %) rated the capstone course as moderately to very successful in helping them read and interpret primary literature (Table 5). A variety of efforts, such as journal clubs, oral or poster presentations on a particular research article, or laboratory research projects incorporating primary literature, have been used to introduce research articles into science teaching. Several studies have reported how such activities have increased student confidence in reading the literature and in understanding the scientific process as they gather, analyze, apply, and synthesize information from outside sources as well as the article itself. In doing so, they are engaging their higher-order critical thinking skills (Almeida & Liotta, 2005; Houde, 2000; Jacques-Fricke et al., 2009; Janick-Buckner, 1997; Kozeracki et al., 2006; Levine, 2001; Mulnix, 2003; Roberts, 2009).

A few studies have documented the actual improvement in critical-thinking skills that result from such activities. For example, Mangurian et al. (2001) measured statistically significant increases in students' scores on the Watson-Glaser Critical Thinking Test during a semester in which they engaged in a case study project requir-

**TABLE 4**

**Sample exam question for the biology core capstone course, illustrating the application and analysis level of evaluation of student learning.**

***From the Conservation of Biodiversity unit:***
Silvery gibbons on the island of Java are found in closed-canopy evergreen forests exclusively. In the Central region of Java, these forests have been chopped down in recent years by an expanding human population and remnants of once extensive forests of this type are all that remain, with silvery gibbons inhabiting those remnants. Another population of silvery gibbon exists on Java—in the Western part of the island, a considerable distance away from the central populations. Each of the Central region remnants as well as the Western population is thought to harbor around 50 gibbons.

Consider the following additional information about this situation:
Microsatellite analysis of hair obtained at numerous locations in the Central region and from the Western population yielded the following information:

| | Average no. of alleles per locus | Average Heterozygosity per locus |
|---|---|---|
| **Central habitat locations** | | |
| 1 | 5.6 | .54 |
| 2 | 5.3 | .60 |
| 3 | 4.9 | .50 |
| 4 | 6.0 | .53 |
| **Western population** | 3.1 | .23 |

Additionally many of the microsatellite alleles seen in the Central region are not found in the Western population and vice versa; some alleles present differ among the Central region populations as well. Infant gibbons in the Western population are rare, while the Central population females are often seen to have babies they are carrying. It is speculated that male Silvery gibbons have a dominance hierarchy with only the most dominant male having the opportunity to breed with the females in his immediate vicinity.

a) As a conservation biologist, what are your concerns for the long-term survival of the Western population?
b) For the Central region, propose a strategy for maintaining the diversity currently present within these fragmented populations and in this whole metapopulation of gibbons. Justify your proposal.

*Note:* Based on "Genetic variability in mtDNA of the Silvery gibbon: Implications for the conservation of a critically endangered species," by N. Andayani et al., 2001, *Conservation Biology, 15,* 770–775.

ing library research and analysis of primary literature, as well as team written and oral presentations on the project. Brill and Yarden (2003) and Wu (2009) scored the types of questions asked or answers given according to a Bloom et al. (1956) scale of higher-order thinking to show that guided analysis of a research article significantly improved cognitive processing. Similarly, Wenk and Tronsky (2011) documented statistically significant improvement in abilities of introductory natural science students to explain hypotheses, experimental design, and results of primary literature papers using exercises designed to promote understanding.

In this study, we used students' scores on a final exam that was mainly composed of questions that asked for analysis of a primary literature article as a means of evaluating critical-thinking skills. This article was new to the students and was analyzed by them in preparation for the final exam. The mean scores for students in eight sections (total $N = 93$ students) of the capstone course taught by the authors (2004 to 2009) on these questions ranged from 81% to 90% (Figure 1), with 53% to 92% of the students achieving at least 80% of the total points for the exam. Prior to the capstone course, students taking the biology core courses at St. Thomas had only been asked to read selected portions of a primary article and had never been asked to analyze it. Thus, we feel the scores on our final exam accurately reflect development of this type of higher-order analytical skill.

### Goal: Increase achievement and confidence in presenting scientific information orally

Almost 83% of the students surveyed in 2002 to 2005 rated the capstone course as moderately to very successful in helping them present scientific literature to their peers. In addition, analysis of the performance of students in seven sections taught by the authors in 2005 to 2009 ($n = 77$ students) revealed that students made significant gains in oral presentation skills throughout the semester (Figure 2). The mean score for individual presentations increased from 8.6 to 9.0 from the first to the third presentation, but more important, the mean percentage of individuals that achieved at least 90% of the total points for their presentation increased from 37.6% to 49.4%. Part of this success was no doubt due to the iteration of a familiar process for the students, but we also observed far fewer of the common errors made in oral presentations on the third presentation. By providing an open period for group discussion of the article following its oral presentation, our students benefitted from an additional, immediate feedback on their understanding and interpretation of the important content.

### *Caveats for use of this model*

Significant challenges exist for those teaching such a capstone, including a very steep learning curve for instructors teaching outside their expertise. Although instructors greatly appreciate the added value of working as a two-person team, this adds to the time spent on planning and coordination. The diverse goals for this course also necessitated development of a variety of activities and assessments new for some instructors, which further added to the heavy demand on their time. The cost of staffing a course with a pair of faculty members is also significant and is one of the reasons that solo instructors now have the full responsibility with only half-course compensation.

Last, an important consideration for teaching such a course is its infrequent meeting schedule. Organization of course activities is critical, including intentional design of class work during and outside of class time to keep lower-division undergraduate students engaged.

**TABLE 5**

**Distribution of student responses to end-of-course survey items about the success of the biology core capstone course in achieving specific course goals. Response choices were on a Likert scale: 1 = *not at all successful*, 2 = *minimally successful*, 3 = *moderately successful*, 4 = *definitely successful*, 5 = *very successful*.**

| Course goal | End-of-course survey question | Number of responses | % Likert scores 1 or 2 | % Likert score 3 | % Likert scores 4 or 5 |
|---|---|---|---|---|---|
| Introduce new ecology content in the context of global issues | Was the course successful in helping you appreciate aspects of ecological concern of which you were unaware? | 109 | 3.6 | 17.3 | 79.1 |
| Integrate core course concepts | Was the course successful in helping you see how material in the other core courses are integrated with one another? | 102 | 11.0 | 40.4 | 48.6 |
| Develop critical thinking skills by analysis of primary literature | Was the course successful in helping you learn to read and interpret the primary literature? | 103 | 2.85 | 32.4 | 64.8 |
| Develop oral presentation skills | Was the course successful in helping you present scientific material to a class? | 104 | 17.4 | 27.5 | 55.1 |

## Conclusions

Overall, student perception and performance measures suggest that this model for a capstone course for the biology core has been successful at promoting integration of core concepts, appreciation of global ecological issues, and analytical and oral presentation skills of the primary literature. All instructors teaching this course have commented on its value in the curriculum and benefit to student learning. The model should also be applicable to other curricula and has in fact been used to help design a core capstone for our biochemistry major as well. ■


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**FIGURE 1**

**Performance of students on the final exam, which is mainly composed of questions about a primary literature article. Data are from eight sections of 7–15 students (total *N* = 93) taught by the authors (2004–2009). Mean scores and standard deviations are shown in blue; percentage of students scoring above 80% on this exercise shown in red.**

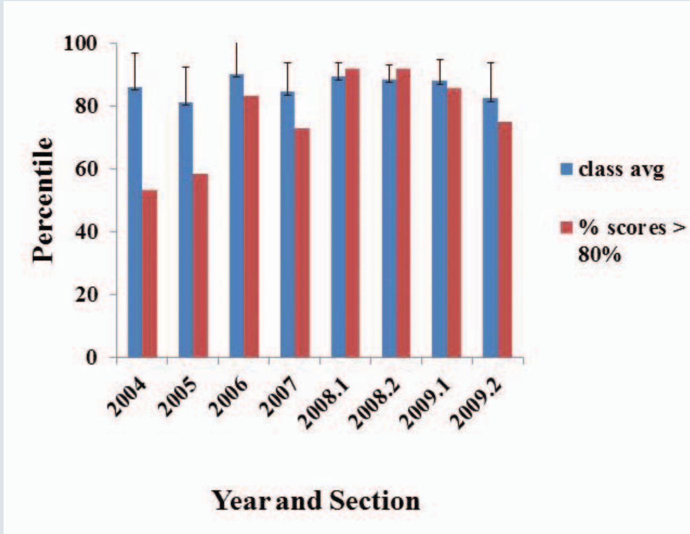
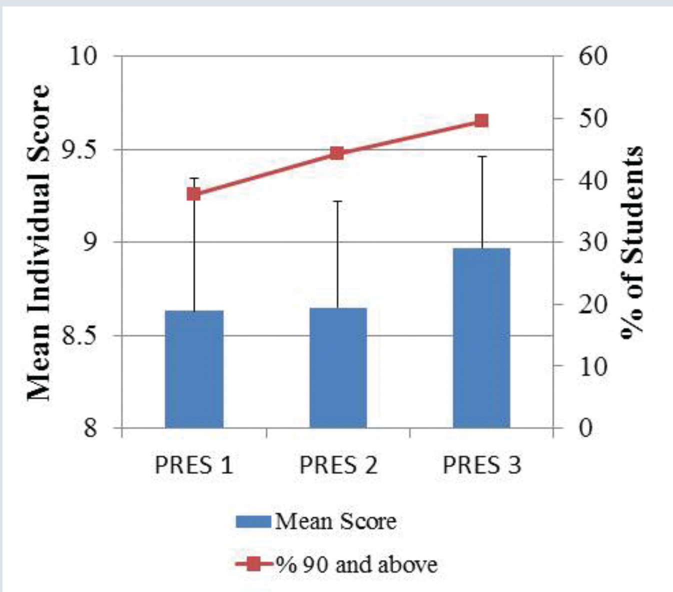



**FIGURE 2**

**Mean and standard deviation of individual scores (blue bars) for three successive oral presentations in seven sections (*N* = 77 students) of the capstone course taught by the authors (2005–2009). The percentage of students that achieved at least 90% on their individual part of the group presentation (red line) increased over the duration of the semester. PRES = presentation.**



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