DEBATING WHETHER DINOSAURS SHOULD BE "CLONED" FROM ANCIENT DNA TO PROMOTE COOPERATIVE LEARNING IN AN INTRODUCTORY EVOLUTION COURSE

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ABSTRACT

An interactive, internet exercise enabled students to engage in cooperative library and web research on a controversial topic in science (and ethics), specifically the cloning of extinct forms of life. To debate the many complex issues embedded in this topic, students had to apply knowledge acquired from course readings, lectures, and in-class discussions about dinosaurs, their evolutionary history, diversity, distribution, physiology, behavior, environmental requirements, and extinction. They also had to achieve a general understanding of the techniques used to discover and retrieve ancient DNA and to produce a clone from a living adult animal. During an in-class "trial", two teams of students representing six types of specialists argued cases for and against dinosaur cloning. Student "judges" heard testimony, posed questions to the specialists, and rendered their verdict about whether dinosaur cloning should be allowed. Working cooperatively in small groups and arguing a position in an authoritative fashion required students to exercise their communication (written and oral), collaboration, and critical thinking skills. This exercise also created a dynamic learning environment in a moderately large introductory geology course and demonstrated the importance of scientific literacy in the contemporary experience.

Keywords: Earth science — general; education — geoscience, biology, evolution; education — undergraduate; education — cooperative problem-solving; education — science case studies.

INTRODUCTION

In both university and small college settings, instructors may be challenged to maintain an effective learning environment in introductory courses with moderate to high enrollments (>50 students) (Kobluk, 1993). As class size increases, sustaining personal contacts among faculty and students becomes more difficult. Student interest in the course may be diminished by a lack of personal contact, students' perceptions that scientific knowledge is irrelevant, or enrollment in the course primarily to satisfy a distribution requirement (Kobluk, 1993; Murck, 1999). Poor attendance, mental disengagement, lack of active participation, and poor performance on academic opportunities may be symptomatic of feelings of alienation or anonymity and lack of involvement in the course (Kobluk, 1993; Feldmann et al., 1998; Murck, 1999). Low grades resulting from poor class attendance may produce a "spiral of declining academic achievement" by leading to more frequent class absences, thereby exacerbating an already negative experience for instructor and student alike (Feldmann et al., 1988; Jones, 1984).

A greater diversity of students in large introductory courses also presents a challenge to the instructor to develop a variety of pedagogical strategies to accommodate students with different learning styles as well as different academic, cultural, and social backgrounds (Macdonald and Korinek, 1995). Lecturing, the most common teaching format in entry-level science courses, may lead to passivity among students, a lack of deep engagement, and limited critical thought about the subject matter (Macdonald and Korinek, 1995; Tewksbury, 1995). Even if the instructor explores alternative teaching tools to promote active learning, some students in large classes may be reluctant to participate in discussions or pose questions in front of so many of their peers either because of shyness or uncertainty about how other students may react.

Cooperative activities have been successfully used in science courses to enhance student learning (Macdonald and Korinek, 1995; Tewksbury, 1995). Problem-based exercises, particularly those focused on controversial or contemporary issues relevant to students' lives and requiring student collaboration, can elevate student interest, strengthen personal contacts, and increase motivation. These in turn can improve class attendance, help develop abilities to work with others, and promote learning and the successful application of knowledge to novel situations (Macdonald and Korinek, 1995).

At Colgate, Soja teaches an introductory course entitled "Evolution: Dinosaurs to Darwin," which focuses on dinosaurs and extinct mammals, including hominids, as vehicles for exploring evolutionary theory, patterns and processes. The course is open to all undergraduate students with enrollment restricted to ~ 70; most students in the course are non-science majors fulfilling part of a two-course science/math distribution requirement. Primarily lecture-based, the class meets twice weekly in 80 minute sessions to allow for classroom discussions and five specimen-based exercises during the term. Although overall a very satisfying course to teach, Soja experienced some of the challenges described above for entry-level science courses. To improve the academic experience for instructor and students alike, a three-part, library- and web-based, interactive exercise that complements as well as reinforces topics explored in lectures, reading materials, and in-class discussions was developed.

CLONING EXERCISE

Cooperative Aspects and Set-Up - About midway through the semester, we devoted three class days to a futuristic, interactive exercise set in the year 2020. The goal of the exercise was to engage students in cooperative library and web research in preparation for a debate about a controversial topic in science (and ethics), specifically whether dinosaurs should be "cloned" from ancient DNA. Students used the web exercise to explore this controversy by applying knowledge discussed earlier in the course about dinosaur physiology, behavior, environmental requirements, and extinction. They also had to learn about the revolutionary techniques used to discover and extract ancient DNA and the challenges associated with producing living clones. To fully examine the many issues embedded in the case, two teams were designated that allowed students, representing six types of specialists, to present arguments either for or against dinosaur cloning during an in-class "trial". Three student judges were responsible for making the final decision about dinosaur cloning after hearing from the specialists on each of the two teams.

Team composition was determined in class by each student selecting a specialist's role out of a hat (paleontologist for cloning, ecologist against cloning, etc.) To accommodate the large enrollment, students with the same specialty worked in groups of five. The judges also picked their roles out of the hat; however, they had the option of selecting a different role if they chose not to take on broader responsibilities as judge. Although specialists and judges obviously had different responsibilities, the roles were fairly equitable in the amount of preparation time involved. Specialists had to focus on developing specific arguments relevant to the role they were assigned and needed to work closely with team members to coordinate their presentations. The judges had to be cognizant of both sides of the cloning dispute and were expected to ask questions during the final trial. Afterwards, the judges compared their assessments of the arguments they found the most compelling so that they could reach a majority decision about whether to allow dinosaur cloning to proceed.

Once the composition of the judicial and specialist teams was finalized, a master list of the assignments was posted on a web site before the exercise officially began so that the students knew who was assigned to which role and team. In addition, a photocopy of Part I of the web exercise was distributed in class as a reference guide to the exercise's format, student responsibilities, and how grades would be assessed. This also ensured that interruptions in network connections to the internet would not prevent the exercise from beginning on the date prescribed in the syllabus.

Day One: Debriefing Session and Web Site Introduction - On the first full day devoted to the exercise, the year 2020 was written on the blackboard to establish the futuristic and role-playing aspects of the exercise. Students were welcomed back to Colgate as if they had pursued various careers in the 20 or so years since their college graduation. We explained that because of their knowledge about evolution and the dinosaur fossil record (a course each had completed when they were undergraduates at Colgate), they had been asked to participate as experts with various backgrounds and interests in a landmark case to decide if dinosaurs should be cloned from ancient DNA.

During a debriefing session (see Part I of the web exercise for more details), we continued to role-play by reminding these "former" students that dinosaurs were the dominant forms of life on land for more than 100 million years (Cowen, 2000). We urged them to recall that mammals, particularly large-bodied taxa, underwent an evolutionary radiation and rose to dominance in terrestrial ecosystems only after dinosaurs became extinct at the end of the Cretaceous (Kumar and Hedges, 1998; Bromham et al., 1999). By the year 2020, we explained that scientists had compelling evidence to support the theory that dinosaurs became extinct not because of "bad genes" or a lack of adaptability but because an extraterrestrial event wiped out a significant percentage of the Earth's species at the end of the Mesozoic (Alvarez et al., 1980). We further surmised that recent advances in molecular biology could potentially reverse this unfortunate set of circumstances for the dinosaurs, undo the after-effects of the asteroid, and return to Earth closely managed members of the dominant life forms that preceded us in time.

We presented a potential justification for dinosaur cloning by noting that many scientists believed that *Homo sapiens* had propagated a new mass extinction, the so-called "Sixth Extinction", that began in the Pleistocene as recently as 50,000 years ago when humans as hunters or disease vectors began a worldwide decimation of megafauna (Martin and Klein, 1984; MacPhee, 1999; Miller et al., 1999). With revolutionary new cloning techniques available in 2020, we suggested that scientists had within their grasp the capability to reverse the deadly decline of global biodiversity and reinstate critical members of past global ecosystems.

The debriefing session came to a close as we emphasized that the decision to determine the ultimate fate of the dinosaurs rested in their hands. We asked them to decide if dinosaurs should be doomed to extinction or be brought back to Earth. We allowed them two weeks to evaluate the situation, become familiar with the latest research on cloning, and prepare a report and oral arguments based on scientifically accurate information that would enable the judges in this historic case to reach a final decision.

After this brief overview, the judges and each specialist group were assigned to computer labs on campus that had terminals reserved for them and teaching assistants nearby to assist. The students were instructed to meet with their partners and very carefully go through both Parts I and II of the web site and, if time permitted, to begin exploring references on reserve in the science library. They were given one hour to decide what the issues were for their particular specialty, how they might share re-

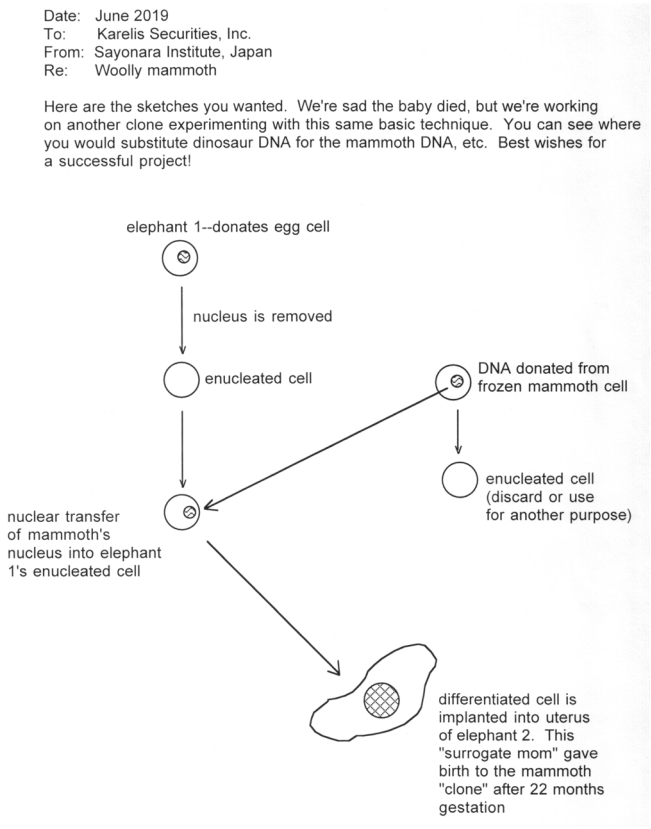

Figure 1. "Memo" from the web site's cloning e-folder showing the basic technique used to produce a clone of an adult mammal.

Geneticist against Cloning
New advances in genetic engineering are on the cusp of bringing extinct species back to life, but nobody explains how difficult, risky, and expensive this is—especially given the high percentage of failed attempts before a successful live birth is achieved. Problems with verifying it's really dinosaur DNA and changes in DNA over the past 66 million years can't be ignored, either—you're concerned about the possibility of creating a "Frankenstein"-like hybrid that will be out of control and beyond the limits of Nature and natural selection in the Darwinian sense. It still isn't clear how a dinosaur clone would be created—for example, would the clone be a bird-dinosaur or crocodile-dinosaur hybrid? After considerable expense, it's still unknown if the hybrid would be fertile or sterile and which dinosaur would be resurrected—*T. rex* perhaps? You plan to explain to the court that dinosaur cloning is an improper use of scientific technology that shows little regard for the animals being brought back into a world unprepared to receive them. Is it really desirable to clone dinosaurs with the express purpose of making them into living drug factories for pharmaceutical companies? If dinosaurs are cloned, what's next—cloned trilobites? You even heard mention of a report that someone wants to search for frozen sperm in the mummified Ice Man, …Ötzi, and clone him 5000 years after his death in the Italian Alps! It was a mistake to attempt the cloning of the mammoth last year, and cloning even older forms of life would only create more problems. You hope to convince the judges that we have absolutely no right to play God!

Table 1. Sample (abbreviated) of a specialist's page

sponsibilities for the assignments, and when they would meet to work together as a group.

In Part II of the web site, the judges and specialists each have a page devoted to their particular roles (Table 1). We designed these pages to give starter ideas for an approach to take and clues about how a person with that specialty might think. Discussion questions were posed to encourage critical thought about the many stages involved in recreating a dinosaur and to interface with the video shown on Day Two of the exercise. We used web links, a cloning e-folder (Fig. 1), and a cloning video (Cloning: How and Why, 1998), placed on reserve in the science library, to guide students through the complexities of recent advancements in cloning research and the technologies that could potentially resurrect extinct species.

Additional resources on reserve in the science library (Table 2) included 11 journal articles that focused on attempts to clone a woolly mammoth and on ancient DNA. We also had folders on reserve about "Dolly" (the first animal, a sheep, cloned from the cells of an adult, living animal), opinion pieces, and recent news clippings. Ten minutes before the class ended, the students returned to the lecture hall for an opportunity to ask questions and clarify any aspects of the exercise's goals and objectives.

Day Two: Video and Preparation for "Trial"

In the next class, the students received a handout of the "Discussion Questions" (in Part II of the web site) with spaces for taking notes as they watched a video entitled "The Real Jurassic Park." Michael Crichton, Bob Bakker and John Horner are featured in the video, which illuminates precisely those questions the students should be exploring. Answers to the Discussion Questions are provided in the video so they were not explicitly covered in class; rather the questions were designed to emphasize the importance of students working together as judges or specialists to understand more about the science of cloning; genetic engineering of ancient DNA; how to develop a dinosaur embryo and successfully raise it to adulthood; animal husbandry issues related to supporting a living, adult dinosaur under post-Mesozoic conditions; safety issues; and ethical issues.

After watching the video, the specialists and judges met in their respective groups for 20 minutes of discussion

Magazine and Journal Articles (on reserve in the library):

"Cloning the Woolly Mammoth." Richard Stone. Discover, vol. 20, April 1999, p. 56-63.
"Ancient DNA." Svante Paabo. Scientific American, vol. 269, November 1993, p. 86-92.
"Ancient DNA." George Poinar, Jr. American Scientist, vol. 87, September-October 1999, p. 446-457.
"Dino DNA: The Hunt and the Hype." Virginia Morell. Science, vol. 261, 9 July 1993, p. 160-162.
"The Use of Ancient DNA in Paleontological Studies." Lori M. and Zvi Kelman. Journal of Vertebrate Paleontology, v. 19, March 1999, p. 8-20.
"The Real Jurassic Park." Mary Schweitzer and Tracy Staedter. Earth, vol. 6, June 1997, p. 54-57.
"Will the Dinosaurs Rise Again?" Mary H. Schweitzer and Raul J. Cano. In DinoFest (edited by Gary D. Rosenberg and Donald L. Wolberg), 1994, p. 309-326.
"DNA Sequence from Cretaceous Period Bone Fragments." Scott R. Woodward et al. Science, vol. 266, 18 November 1994, p. 1229-1232.
"Detecting Dinosaur DNA." [various authors.] Science, vol. 268, 26 May 1995, p. 1191-1194.
"Dino Hunter." Josh Fischman. Discover, vol 19, May 1999, p. 72-78.
"Is Science Dangerous?" Lewis Wolpert. Nature, vol. 398, 25 March 1999, p. 281-282.

Cloning E-Folder/Video:

Memo dated September 1996
Memo dated June 2019
Video on "Cloning: How and Why"

Folders (on reserve in the library):

"Dolly"
News Clippings
Opinions

Internet Sites:

Recreating Dinosaurs: Fact or Fiction?

http://www.nhm.ac.uk/sc/amber
http://www.gplatt.demon.co.uk/amberdna.htm
http://unmuseum.mus.pa.us/dnadino.htm
http://www.sciam.com/askexpert/biology/biology1.html
http://www.newscientist.com/nsplus/insight/rexfiles/backfrom.html
http://www.slsc.org/docs/mod3/mod3_2/mod3_22/ep2517g.htm
http://dinosaurs.eb.com/dinosaurs/index2.html

Cloning Info

http://www.sciam.com/explorations/030397clone/030397beards.html
http://www.sciam.com/1998/1298issue/1298wilmut.html
http://www.newscientist.com/nsplus/insight/clone/clonelinks.html
http://www.cabi.org/whatsnew/cloneani.htm

Books (on reserve in the library):

The Science of Jurassic Park and The Lost World or, How to Build a Dinosaur. Rob DeSalle and David Lindley. 1997. BasicBooks.
The Quest for Life in Amber. George O. Poinar. 1994. Addison Wesley Longman, Inc.
Clone: The Road to Dolly and the Path Ahead. Gina Kolata. 1998. W. Morrow & Co.
Remaking Eden: Cloning and Beyond in a Brave New World. Lee Silver. 1997. Avon Books.
Biology. N.A. Campbell. 1987. Benjamin-Cummings Publishing Co.

Table 2. Leads and sources recommended to students for use in cloning exercise.

and planning. During the week between these two planning/discussion class sessions and the actual "trial," class met as usual although some class time was used to clarify questions that students raised about the upcoming trial. After that, students had 12 days remaining to prepare for the "debate" on whether or not to clone dinosaurs.

Day Three: The "Trial" - Classroom set-up — To facilitate the court proceedings in class, a table and chairs for the three judges and five chairs for each group of specialists were arranged at the front of the lecture hall. The Chief Judge called the specialists in succession, beginning with one specialist group in favor of cloning followed by its opposing counterpart. Each specialist group had five minutes for its presentation and had to ensure that each member of the group spoke without duplicating statements made by other members of their group. That allowed one-half hour for each side of the issue to complete its arguments. To keep the proceedings on track, the judges were equipped with a gavel, timer, notepads, and pencils. They were encouraged to ask questions to the specialists. We also had multimedia equipment (slide and overhead projectors, computer projection system) available for use; one group put it to good use with a power point presentation. Before the end of class, each student handed in a

Arguments in Favor of Dinosaur Cloning	Arguments Against Dinosaur Cloning
Dinosaur tissues/organs could be used in human transplants and to help cure diseases.	Potential for disaster is too great with so many unknown aspects ofdinosaur biology.
Dinosaur theme parks could generate large sources of revenue for investors and local businesses.	Animals as intelligent as dinosaurs are unlikely to be contained in high-security parks.
Society should not impose limits on scientific experimentation.	Scientists shouldn't tamper with natural, evolutionary processes.
Cloning experimentation will advance scientific understanding of DNA and advance society by pushing the limits of understanding.	Financial costs are too high in cloning process and maintaining viable populations.
Cloning research will yield educational insights into dinosaur behavior, physiology, extinction, etc.	"Artificial" clones would be unlikely to reveal worthwhile information about dinosaurs' natural tendencies and behaviors.
Better understanding of dinosuars and their extinction will enable humans to predict the future better and help prevent our own extinction.	Cloned dinosaurs might accidentally cause species extinctions by reintroducing Mesozoic viruses or diseases into modern ecosystems.
Dinosaurs could always be destroyed if they become too dangerous.	Dinosaur cloning is a high-tech form of animal cruelty.
If dinosaurs caused human extinction, evolution would proceed without us.	Resurrected dinosaurs would be "aliens" in contemporary world and suffer because of insufficient knowledge about their needs.

Table 3. Summary of testimony presented in favor of and against dinosaur cloning.

two-page paper detailing his or her individual testimonies during the trial for part of the assessment.

Trial testimony — Most of the ideas presented by students on the two opposing teams were embellishments of commentary provided in the web site's pages for each specialist role. For example, students in favor of dinosaur cloning proposed many positive aspects, including medical, economic, and scientific benefits. Arguments made by students against dinosaur cloning emphasized fear, the enormous costs, and ethics. Themes reiterated by those against dinosaur cloning included the potential damage that the dinosaurs could cause to humans, personal property, and other species. Refer to Table 3 for specific ideas presented at trial.

Trial results — After hearing all of the testimony, the judges distributed ballots to the class, asking them to vote "outside" of their specialty roles in favor of or against dinosaur cloning and to state one reason for their vote. The judges collected the ballots as students were leaving the lecture hall and tallied the votes before our next class meeting. At the beginning of the next class, the judges reported that the students had voted against cloning dinosaurs (1/3 yes, 2/3 no). Upon reviewing the evidence presented by the specialists, the judges concurred with the class vote, and each gave a one minute presentation to explain his/her reasoning. We then initiated a discussion to invite additional comments and to gain an initial assessment of how the students felt the exercise had worked. Recent news about attempts to clone a woolly mammoth enabled us to emphasis the relevance of this issue in contemporary life (Stone, 1999; Wade, 1999).

STUDENT CRITIQUES

Introduction - As a way to help assess if we had achieved our objectives, the students were given the opportunity to evaluate the exercise as one of several extra-credit (and attendance-incentive) opportunities during the semester. We were wary of leaving their evaluations until the end of the semester during the time students traditionally complete Student Evaluation of Teaching (SET) forms at Colgate. Past experiences indicated that few students referred on the SET forms to specific exercises, especially ones completed several weeks before the semester's end. The extra-credit "opportunity" assignment was due one week after the "trial" and requested that students write a one-page critique of the cloning exercise in response to the following two questions:

- Was the cloning exercise worthwhile (e.g. was there anything of significance you learned by taking part in this exercise, including anything about collaborative learning)?
- What would you do next time to improve this exercise? Please be specific and offer constructive comments. (For example, do you recommend new roles be added? Was 2 weeks enough time to prepare? Other ideas?)

Overall Assessment - Of the 59 participants in the class exercise, 39 wrote evaluations. All were enthusiastic about the experience, what they learned, and the collaborative approach. Many felt it had been a challenging but valuable experience because of the opportunity to be creative within a framework of scientific reasoning and to do something different from regular lecture. Others felt it had been a "unique learning tool" that provided another way to perform and demonstrate knowledge. Several expressed the view that the exercise was better than a traditional lecture because students became more actively involved in course material.

For some, the most challenging aspect was having to rethink personal views, including setting aside personal beliefs to defend an opposing point of view; several felt they had learned more from this aspect of the exercise because it was a "real world" issue they were likely to face in the future. Others felt challenged by giving an oral presentation in front of the class but were glad to have had the opportunity to practice an important skill for the future.

Virtually everyone confirmed that two weeks was the right amount of time to prepare for this case, but several students suggested that more time be allotted for the trial. They reasoned that given the size of the class and the number of presenters, one class period did not allow students to ask questions or prepare rebuttals; some recommended that the trial be held at night to allow more time for each specialist group to present its case. In the following sections, student comments are distilled and synthesized into three main categories of responses relevant to the exercise's goals.

Scientific Aspects - Overall, students expressed positive feedback about what they had learned scientifically from the exercise. They felt the exercise had been a helpful way to gain deeper insights into dinosaurs by analyzing an issue that extended beyond classroom topics but taught more about dinosaurs at the same time.

"A beneficial thing about this exercise is that we have spent the semester learning about dinosaurs, their physiology, behavior, lifestyles, history, and this puts a new twist on using what we have learned about the animals, applying it to a new situation with real life, people, and new possibilities. We can reflect back on what we have learned and tie it to topics of current life—it is a nice juxtaposition of ancient and modern life."

"The ability to set up a possible future court case and have it apply to what you are learning in the classroom helps you see how learning extends beyond just textbooks and tests. I learned more about the overall subject of cloning and not just about the cloning of dinosaurs."

"The trial class was very entertaining because we learned things that normally would not have been touched on in class. For example, through one group's research we learned the calculations of how much one dinosaur would eat and drink in a day. The numbers were shocking."

"This exercise made me give serious thought to things I had only before considered as science-fiction, or at least as issues that would not really be pertinent until the distant future."

"The exercise had been definitely worthwhile. It taught the class the scientific aspects of creating a real-life Jurassic Park, while also forcing us to examine the ethical dilemma. We were forced to ponder the potential consequences of cloning dinosaurs."

"As a religion major, I enjoyed this opportunity to learn about the process of cloning, and I found that I could compare many of the ethical issues to my current specialization in the humanities. You did not have to be a bio-engineer to understand. I am not a science minded person, and I was pleased that I understood the topic just as well as anyone else in the class."

"Some of us may very well be the ones who help decide the future of cloning and we can draw on the experience from this exercise as well as the opinions formed because of it."

Research/Critical Thinking Aspects - Students appear to have enjoyed the opportunity to do their own research while pursuing leads about DNA technologies.

"It was especially a good exercise for me in narrowing down sources in order to construct a relevant argument. It was important to figure out which of these sources would help to support our case. In addition to being a creative exercise and something we could play around with, it was a good research endeavor."

"This project was good for me because it forced me to use more than just my initial feelings, I had to think hard and come up with reasoning for pro-cloning."

"This cloning exercise was very worthwhile in terms of being given the opportunity to read about DNA research and the technology used to do this type of research. I never really knew anything about the research being done in trying to obtain DNA from dinosaurs."

"It was exciting to learn about cloning. Through my research I was able to learn things beyond the cloning of Dolly. I found myself totally interested in learning more about genetics and dinosaur fossils. Perhaps my favorite part was the way it forced me to learn enough that I could make an informed decision about a timely controversial issue."

"I learned not only about dinosaurs and cloning, but also about listening to the arguments and figuring out what to believe and what to be skeptical about."

"I especially enjoyed the problem-solving tactics employed by 3 of us in my group, once we had become disen-

chanted with the scientific strength of our specialty's argument. Pondering the question, I was able to really work through some rather interesting (if unlikely) justifications."

Collaborative Learning - Trying to coordinate a group of people can be challenging, but benefits result from the greater diversity of ideas that emerge when groups work together. These ideas were echoed in many student comments. Another take-away message concerned the insights students gained into how many different specialists in the "real world" may be required to work together to achieve goals and solve problems.

"Collaborative projects can be difficult but beneficial at the same time. Difficult because it is hard to coordinate a group and find times when everyone can meet; beneficial because there are more ideas that are likely to emerge."

"I found the most challenging part to trust others that you didn't know to be equally as interested and prepared. Group projects are always hard. Adding to the equation that the groups were chosen at random and not personally picked added the element of working with strangers. I was relieved, and slightly surprised, to learn that my group had the same work values that I did."

"This exercise demonstrated the power of teamwork. The diversity of information might not have been exposed if we all just researched the general field of cloning."

"The real experience was working with a group. Some people were helpful, others needed help. Some were hard to meet with, others very receptive and open. I learned a lot about my leadership skills and teaching ability."

"I especially enjoyed the format and how we had to depend on each other to get the report done efficiently and effectively. One must learn how to collaborate with others and work on a team. You can learn more from each other than any book can ever teach you."

"I liked that each group member was responsible for doing his or her share of the work. We each prepared our specific section of our position, yet we all had to rely on one another and communicate to get information and details. It was definitely a fun challenge."

"I had to learn how to work with differences of opinion."

"I felt a lot more confident about our positions after we had all put our heads together."

"Working in groups helped me to get to know some of the other students on a different level than is possible in a classroom setting."

"I learned to collect and share information in a group; that communication is necessary for a quality presentation; that collaboration can be fun!"

CONCLUSIONS

A futuristic problem requiring cooperation to decide the fate of the dinosaurs was successful in engaging students in library and web research that complemented and reinforced topics discussed in class. The futuristic format enabled students to be inventive within a scientific framework, contribute to a debate about a controversial issue in science and ethics, and gain an appreciation for the relevance of science in contemporary and future life. The interactive and collaborative aspects of the internet exercise strengthened problem-solving, critical thinking, and presentation skills and allowed students to explore the values and challenges of successful teamwork.

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About the Authors

Trained as an invertebrate paleontologist, Constance Soja enjoys teaching about dinosaurs and extinct mammals to stimulate greater interest in and knowledge of science and evolution. A student of evolution, science librarian Deborah Huerta uses case studies in writing courses to promote active learning about scientific research methods.

I could only wonder, if such scientific truths as I had now obtained were concealed in a single well, what untold treasures must there be in the whole Rocky Mountain region. This thought promised rich rewards to the enthusiastic explorer in this new field, and thus my own life work seemed laid out before me.

Othniel C. Marsh