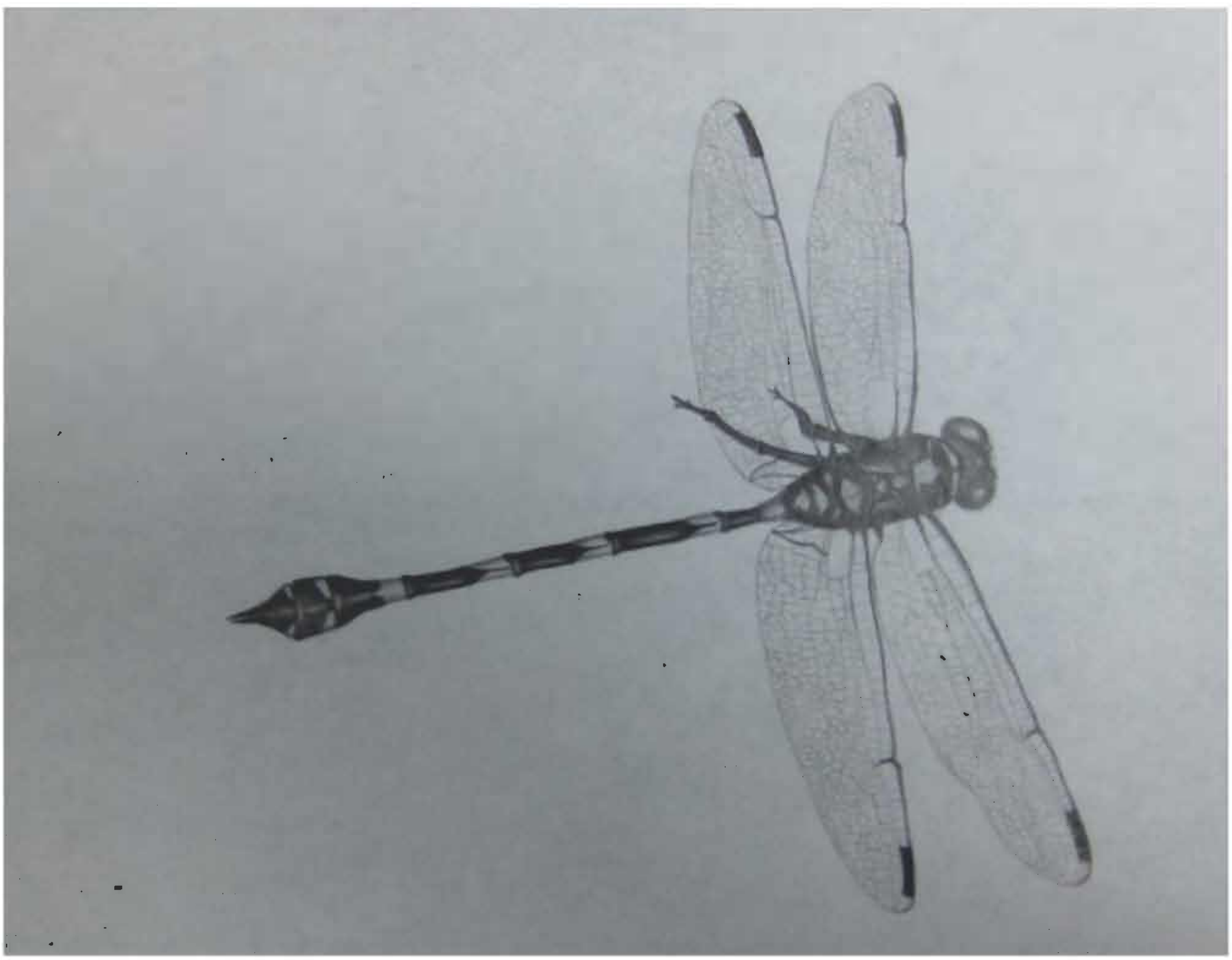
Bioscene

Journal of College Biology Teaching



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Bioscene

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Stephen S. Daggett
Avila University

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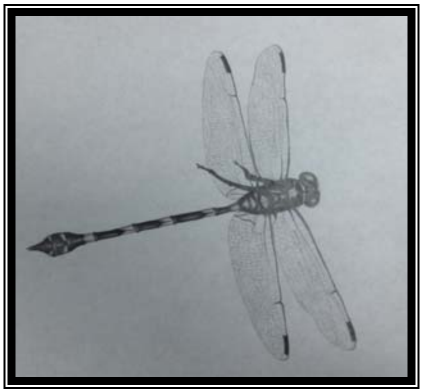

Cover image: Drawing of a dragonfly (*Cordulegaster boltonii*) by Courtney Thomason, an undergraduate at Murray State University. Photograph of drawing provided by Terry Derting.

Articles:

Laboratory Exercises

News & Views

Bioscene: Journal of College Biology Teaching
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Editor

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Bioscene: Journal of College Biology Teaching

Guidelines for Submissions

I. Submissions to *Bioscene*

Bioscene: Journal of College Biology Teaching is a refereed quarterly publication of the Association of College and University Biology Educators (ACUBE). Submissions should reflect the interests of the membership of ACUBE. Appropriate submissions include:

- Articles: Laboratory and field studies that work, course and curriculum development, innovative and workable teaching strategies that include some type of evaluation of the approaches, and approaches to teaching some of the ethical, cultural, and historical impacts of biology.
- Reviews: Web site, software, and book reviews
- Information: Technological advice, professional school advice, and funding sources
- Letters to the Editor: Letters should deal with pedagogical issues facing college and university biology educators

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II. Preparation of Articles

Submissions can vary in length, but articles should be between 1500 and 4000 words in length. This includes references, but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract, but not figure or table legends. Concision, clarity, and originality are desirable. A complete submission will consist of the following:

A. Cover letter: All submissions should come with a cover letter indicating that the manuscript is being submitted exclusively to *Bioscene* and why it is appropriate for this journal. Authors may also offer graphics from the article as possible cover art.

B. Cover Sheet: Submissions should include a cover sheet that includes the title of the article, the number of words in the manuscript, the corresponding author's name, and all co-authors. Each author's name should be accompanied by complete postal and email addresses, as well as telephone and FAX numbers. Even with hardcopy submissions, email will be the primary method of communication with the editor of *Bioscene*.

C. Abstract: The first page of the manuscript should contain the title of the manuscript, the names of the authors and institutional addresses, a brief abstract (200 words or less) or important points in the manuscript, and keywords in that order.

D. Manuscript Text: The introduction to the manuscript begins on the second page. No subheading is needed for this section. This supply sufficient background for readers to appreciate the work without referring to previously published references dealing with the subject. Citations should be reports of credible scientific or pedagogical research.

The body follows the introduction. It is recommended that it be broken into sections with appropriate subheadings including Materials and Methods, Results, and Discussion. Some flexibility is permitted here depending upon the type of article being submitted.

Acknowledgment of any financial support or personal contributions should be made at the end of the body in an Acknowledgement section, with financial acknowledgements preceding personal acknowledgements. Disclaimers and endorsements (government, corporate, etc.) will be deleted by the editor.

A variety of writing styles can be used depending upon the type of article. Active voice is encouraged whenever possible. Past tense is recommended for descriptions of events that occurred in the past such as methods, observations, and data collection. Present tense can be used for your conclusions and accepted facts. Because *Bioscene* has readers from a variety of biological specialties, authors should avoid extremely technical language and define all specialized terms. Also, gimmicks such as capitalization, underlining, italics, or boldface are discouraged. All weights and measures should be recorded in the SI (metric) system.

In- text citations should be done in the following manner:

"…rates varied when fruit flies were reared on media of sugar, tomatoes, and grapes" (Jaenike, 1986).

or

" Ulack (1978) presents alternative conceptual schemes for observations made…"

E. References: References cited within the text should be included alphabetically by the author's last name at the end of the manuscript text with an appropriate subheading All listed references must be cited in the text and come from published materials in the literature or the Internet. The following examples indicate *Bioscene*'s style format for articles, books, book chapters, and web sites:

Articles-
Single author:
DEBURH, L.E. 1991. Using *Lemna* to study geometric population growth. *American Biology Teacher* 53(4): 229-32.
Multi-authored:
GREEN, H., GOLDBERG, B., SHWARTZ, M., AND D. BROWN. 1968. The synthesis of collagen during the development of *Xenopus laevis*. *Dev. Biol*. 18: 391-400.

Books-
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Book chapters-
GLASE, J.C. AND M. ZIMMERMAN. 1991. Population ecology: experiments with Protistans. In Beiwenger, J.M. 1993. *Experiments to Teach Ecology*. Ecological Society of America, Washington, D.C. 170p.

Web sites-
MCKELVEY, S. 1995. Malthusian Growth Model. Accessed from http://www.stolaf.edu/people/mckelvey/envision.dir/malthus.html on 25 Nov 2005.

Note that for references with more than five authors, note the first five authors followed by *et al*.

F. Tables
Tables should be submitted as individual electronic files. Placement of tables should be indicated within the body of the manuscript. All tables should be accompanied by a descriptive legend using the following format:

TABLE 1. A comparison of student pre-test and post-test scores in a non-majors' biology class.

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Figures should be submitted as individual electronic files, either TIFF or BMP. Placement of figures should be indicated within the body of the manuscript. Figures include both graphs and images. All figures should be accompanied by a descriptive legend using the following format:

FIG. 1. Polytene chromosomes of *Drosophila melanogaster*.

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Letters should be brief (400 words or less) and direct. Letters may be edited for length, clarity, and style. Authors must include institution address, contact phone number, and a signature.

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Reviews and informational submissions may be edited for clarity, length, general interest, and timeliness. Guidelines for citations and references are the same for articles described above.

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Article manuscripts may be sent to the current editor either electronically or by hard copy, accompanied by a disc copy. Electronic submissions are preferable. All authors will receive confirmation of the submission within three weeks. Manuscripts should be submitted either as a Microsoft Word or RTF (Rich Text File) to facilitate distribution of the manuscript to reviewers and for revisions. A single-email is required to submit electronically, as the review process is not blind unless requested by an author. If the article has a number of high resolution graphics, separate emails or separate discs mailed to the editor may be required.

If hard copy is sent it must be accompanied by a disc containing the complete submission. Three copies of the manuscript, as well as the original, should be submitted. Standard paper should be used with lines of sections of the manuscripts numbered and enough margin to permit reviewer comments. Two self-addressed stamped envelopes must be included if the authors wish to receive reviews and responses by methods other than email.

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All manuscripts will be sent to two anonymous reviewers as coordinated through the Editorial Board. Reviewers will examine the submission for:

- **Suitability:** The manuscript relates to teaching biology at the college and university level.
- **Coherence:** The manuscript is well-written with a minimum of typographical errors, spelling and grammatical errors, with the information presented in an organized and thoughtful manner.
- **Novelty:** The manuscript presents new information of interest for college and university biology educators or examines well-known aspects of biology and biology education, such as model organisms or experimental protocols, in a new way.

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewers. Acknowledgement of the reviewers' comments and suggestions must be made for resubmission and acceptance. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. The review process can take 4-5 months. Upon final acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website within six months of publication. Depending upon volume, time from acceptance to publication may take up to a year.

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We are soliciting nominations for four (4) *Bioscene* Editorial Board positions (terms through 2010). Board members provide input in the form of reviews and suggestions concerning the publication ot *Bioscene* to the Editor. Board members are also expected to assist in the solicitation of manuscripts and cover art for *Bioscene*. Board members may be called upon to proofread the final copy of *Bioscene* prior to publication. **Preference will be given to individuals who regularly attend the annual meeting.** Also, the Editorial Board of *Bioscene* welcomes cover images for future issues of *Bioscene*. Send images according to the image guidelines given in the guidelines for submissions section of this journal to the editor. If you are interested in serving a 3-year term on the Editorial Board or have cover art for consideration, please email the editor, Stephen S. Daggett, at *stephen.daggett@avila.edu*.

Dance of the Chromosomes: A Kinetic Learning Approach to Mitosis and Meiosis

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Abstract: Understanding mitosis and meiosis is fundamental to understanding the basics of Mendelian inheritance, yet many students find these concepts challenging or confusing. Here we present a visually and physically stimulating activity using minimal supplies to supplement traditional instruction in order to engage the students and facilitate understanding and retention of these concepts. This kinesthetic activity has students modeling the events of mitosis and meiosis by acting as human chromosomes. This exercise has been used in a sophomore level genetics class at a state university, but it should also be suitable for high school and introductory college classes. An on-line survey was used as an assessment of transfer of knowledge, and this also allowed students the opportunity to comment on this exercise as a learning experience. While it was difficult to be quantitative in our evaluation of learning, student responses to the survey overwhelmingly characterized the exercise as advancing their ability to understand or visualize the processes of mitosis and meiosis.

Keywords: cell division, kinetic learning, meiosis, mitosis

Introduction

A challenge in any educational endeavor is finding ways to present abstract concepts to students in a manner that makes the ideas more concrete. Biology, and genetics in particular, seems rife with abstract concepts that serve as fundamental building blocks for other topics and are necessary for scientific literacy in today's society. One common approach is to provide students with interactive opportunities to apply knowledge gained from lecture or reading. Following Gardner's (1983) concept of multiple intelligences, such a learning approach would tap into an individual's spatial and bodily-kinesthetic intelligences. The benefits of externalizing learning in this fashion are widely appreciated in elementary education (Griss, 1994). Our main objective was to assess the effectiveness of a kinesthetic activity for learning about mitosis and meiosis suitable for upper educational levels in a college genetics course. Several hands-on approaches have already been described (Anderson, 1996; Luinstra, 1996; Chinnici et al. 2004). The exercise described here takes a slightly different approach in that it requires minimal materials and provides for more interaction between instructor, audience and participants.

This exercise was tested on large (80-100 students) college classes in genetics during 2003 and 2004, although this exercise may easily be modified to fit the size and scope of any classroom situation. The exercise was conducted during the recitation session that students voluntarily attend, and we designed an on-line survey to assess transfer of knowledge. On the survey students were asked to identify whether they had observed the exercise, participated in the exercise or had been absent from class. Students then answered one of two sets of questions depending on their attendance, and responses to the open-ended questions were assigned to a generalized category for the purposes of quantification. The mitosis/meiosis section of the students' exam was used to assess comprehension of the concepts, and scores of students present and absent from class were then compared statistically using SPSS (v. 10.0).

Methodology & Results

Student volunteers were solicited to act as chromosomes and illustrate the steps of mitosis and meiosis for a diploid cell. In this case we have set up the exercise to use a cell with 2N=6 due to space and time constraints, although this can easily be modified. The materials required are minimal and can be modified by the instructor according to needs and resources. Chromosome identifiers were made by labeling two sets of paper with the numbers 1-3. The maternal and paternal origins of these chromosomes is indicated by the use of pink and blue paper or some other system (e.g. white numbers on a black background and black numbers on a white background). Additionally, six pieces of rope or cord about 2-3 feet long are used to represent centromeres and the point of attachment between sister chromatids.

Before the commencement of the exercise, students may benefit from a brief review of key terms (e.g. bivalents, chromatids, crossing over, synapsis, tetrads). As the volunteers act out mitosis and meiosis, the instructor directs the action through questioning the volunteers and/or audience. Each question/answer segment of the exercise allows the instructor to make important points about the process of mitosis or meiosis. While students act out the movement of the chromosomes, some of the key terms reviewed earlier are perceived in concrete and physical space. This translation of concepts from abstract to concrete can help in understanding the process of mitosis and meiosis.

Dance of the Chromosomes I: Mitosis

The instructor begins the exercise with a question:
QUESTION - If this is a diploid cell with 2N=6, how many chromosomes are we going to need?
The expected student's answer is " 6, there will be three paternal and three maternal chromosomes."
The instructor asks for volunteers, three men and three women, to represent paternal and maternal chromosomes. Each student is given an appropriately colored and numbered piece of paper. Then, the instructor continues to ask questions:
QUESTION - The student chromosomes represent the nucleus at what stage in the cell cycle?
The expected student answer, "Since the DNA has not replicated, this represents Interphase G1."
QUESTION: What event would take place before the cell can begin mitosis?
The expected student answer is "The cell replicates its DNA."
QUESTION: How do we represent the cell with replicated DNA?
The expected student answer is "Add six additional volunteers."
Therefore, the instructor asks for six additional volunteers and gives them a chromosome label as well as a piece of rope. The students are then paired up according to their chromosome color and number, and then they hold the rope between them. The instructor continues to ask questions:
QUESTION - What does the rope represent?
The expected student answer, "The rope is the centromere."
At this point the instructor asks the volunteers to illustrate various chromosome types by holding the centromere in different locations (top of head, shoulder, waist) to represent telocentric, acrocentric and metacentric chromosomes, respectively.
The instructor calls on a student in the audience to describe the action of the chromosomes at the various steps of mitosis—prophase, metaphase, anaphase and telophase. The volunteers then go through the steps of mitosis while the audience monitors the choreography and provides suggestions and corrections. When the choreography is finished, the instructor asks:
QUESTION - So what is the end result of mitosis?
The expected student answer, "Two cells with an identical complement of chromosomes" (Figure 1A & 1B).
Once the students have gone through the exercise, we have them repeat it or begin again with a new set of volunteers if time allows.

Dance of the Chromosomes II: Meiosis

No additional materials are needed for this exercise. The instructor may have the same students perform or request new volunteers. The instructor begins with a series of questions addressed to the volunteers and the audience.
QUESTION - How is prophase I of meiosis different from prophase in mitosis?
The expected student answer is "Homologous chromosomes align. This is called synapsis. Then they move together to the metaphase plate."

QUESTION - What do we call these paired homologous chromosomes?
The expected student answer, "A tetrad." This is another occasion when acting out the movement of the chromosomes provides a visual meaning to the definition of tetrad.

QUESTION - What important event takes place while the homologous chromosomes are synapsed?
The expected student answer, "There may be the actual exchange of genetic material between chromosomes. This action is called recombination or crossing over."

To represent this event, the instructor can have one volunteer from each sister pair exchange his/her chromosome label with another volunteer from a non-sister chromatid in the tetrad. Now some female students will have a paternal chromosome label and vice versa, indicating that genetic material was transferred between homologous maternal and paternal chromosomes. Other chromosomes will remain the same. We have found that this step is potentially confusing for students, so care should be taken to fully explain the significance of these actions.

FIG 1. Each panel (A & B) represents one of the daughter cells produced by mitosis. Each daughter cell has two copies of each chromosome (#1,2,3) - one of maternal and one of paternal origin. The maternal chromosomes are white numbers on black background. The paternal chromosomes are black numbers on white background.

A

B

Next, the volunteers align on the metaphase plate. The instructor continues to ask:
QUESTION - Is there any particular order to how the chromosomes align on the metaphase plate?
The expected answer, “No. Each chromosome moves independently of the others. This is the basis for Mendel's Law of Independent Assortment.”
The instructor may have to intervene at this point to make sure that all the male and female volunteers have not arrayed themselves on opposite sides of the metaphase plate. While this event is indeed biologically possible, the students will perceive more of a difference among the end products of meiosis if there is a mixture of maternal and paternal chromosomes.

The volunteers then proceed through anaphase I and telophase I where the tetrads have separated.
QUESTION - What are the end products at this point?
The expected student answer, “Two cells with dyads that equal the haploid number of the cell. In this case there are three dyads in each cell. This is known as the reductional division.” At this point the instructor explains the significance of the reductional division.
Then the instructor continues to ask:
QUESTION - In preparation for the next stage of meiosis, does DNA synthesis occur again?
The expected student answer, “No.”

Finally, a student in the audience is asked to describe the movement of the chromosomes at prophase II, metaphase II, anaphase II and telophase II. The volunteers proceed through the second division in meiosis while the audience monitors the choreography and makes corrections when necessary. To summarize the process, the instructor asks:

QUESTION - What is the end product of meiosis?
The expected student answer, “Four haploid cells (N=3). This last part of meiosis represents the equational division.”
At this point, the students note the genetic composition of each cell. Each cell represents a mixture of paternal and maternal chromosomes. Also, crossing over has produced variability among these chromosomes (Figure 2).

FIG 2. The four groups of students represent the end products of meiosis. Note that recombination between homologous chromosomes in Prophase I is evidenced by the four students holding chromosome labels that do not match their gender.

Discussion

The exercise and evaluation were conducted on students enrolled in a sophomore-junior level genetics class (BSC 370 Genetics) during the fall semesters of 2003 (n=91) and 2004 (n=94). Students who witnessed or participated in the exercise answered these two questions:

1. At what stage of the "chromosome dance" did you realize the differences between the processes of mitosis and meiosis?
2. Please complete this statement to describe your learning experience using the "chromosome dance" as a simulation. The "chromosome dance" helped me ___________.

A substantial percentage of students in both years (43% & 43.2%) recognized the difference between mitosis and meiosis during the first couple of steps of meiosis (Prophase I - Metaphase I). In particular, the processes of synapsis and crossing over seemed to help students distinguish meiosis from mitosis. Some students (10.1% & 4.5%) incorrectly stated that the difference between meiosis and mitosis was that there were twice as many people in the meiosis simulation. The second question allowed the students to evaluate the exercise as a learning experience. Most of the responses (40.4% & 51.6%) indicated that the exercise helped them visualize or understand the processes of mitosis and meiosis, and only a small percentage (5.6% & 4.4%) indicated that the exercise aided their understanding only minimally.

Students who missed class the day of the exercise answered these two questions:
1.) Explain how you visualize the differences between the processes of mitosis and meiosis?
2.) Based on your current knowledge of the processes of mitosis and meiosis, do you feel that you may have benefited from attending recitation? Explain why.

Most students who missed class reported visualizing the difference between mitosis and meiosis by either the number of cell divisions that took place (40.0% & 41.7%) or relied on figures from the textbook (46.75 & 58.3%). Only two students described some unique model or analogy that provided them with a visualization of the process. In response to the second question, most students responded that they would have benefited from attending class, and their reasons mainly centered on the chance for extra review (53.8% & 50%) or that they would have benefited from a visual aid (23.1% & 41.7%).

The data on exam scores did not meet the assumptions of ANOVA even after square root transformation, so we relied on a nonparametric test to compare the exam scores of students who attended recitation versus those who did not. The Kruskal-Wallace test did not detect a significant difference between the two groups in either 2003 or 2004 (p values of 0.075 and 0.866 respectively). Whether students participated in or witnessed the exercise did not seem to have an influence on their scores (Table 1) as the means of both groups were very close. However, students who missed class or did not participate in the survey tended to have overall lower means. Admittedly, this difference could be attributable to differences in academic aptitude and motivation of students who attend class compared to those who do not. In lieu of a pre-test for this exercise, we assumed a standard level of baseline knowledge among students as each has gone through a similar series of introductory biology courses at a university or junior college. Even though there was not a statistically significant difference in performance on the exam, we consider this exercise to be successful because students' responses to the survey indicated that they were able to identify key steps that differentiated mitosis and meiosis (e.g., tetrad formation, crossing over, reduction of chromosome number in resulting cells). The majority of these students also characterized the exercise as advancing their ability to understand or visualize the processes of segregation and reduction division. Even many of the students who missed the exercise responded that they would have benefited from a visual presentation of mitosis and meiosis. An additional benefit of this activity, one noted by several students, is that it is an interesting and fun deviation from the normal class routine that sparks interest as well as, hopefully, understanding.

Conclusions

Wyn and Stegink (2000) reported that a high school class that role-played mitosis performed better on an identical quiz than a class that did not experience this instructional strategy. This study provided evidence that role-playing gives students a concrete experience to help them understand and appreciate the logical sequence of mitosis. According to Vygotsky (1978, p.90), what is important is "the learner is interacting with people in his environment and in cooperation with his peers.". Thus, using Vygotsky's concept of the influence of socialization on mental development, we speculate that the difference in the learning environment and socialization process contributes to the adaptability of role-playing as an instructional strategy in the high school science classroom.

However, we have observed that college students are less inclined to participate in role- playing than high school students. This could be explained by the familiarity of high school students to one another because, unlike college students, they stay together for much of the day over a school year. In addition, high school students are conditioned to assume an active role in learning (e.g. hands-on activities and class presentations), while college students behave in isolation as passive learners and problem solvers. The results of this exercise have encouraged us to conduct additional hands-on interactive exercises in order that students get used to collaborative learning and stimulate other intelligences to promote an understanding of genetics. We believe that using these various instructional strategies makes the teaching of genetics more amusing and entertaining, which enhances learning and promotes an appreciation of the logic of science.

Acknowledgements

We would like to thank the students in BSC 370 in the fall of 2003 and 2004 at the University of Southern Mississippi for their enthusiastic participation in the activity and the follow-up survey. In particular, we would like to thank the volunteers depicted in the figures: Charmelia Bickham, Richard Darden, Shannon Gandy, Sunny Gooch, Brian Jackson, Sandra McLaurin, Selethia Malone, Alan Niven, Brook Oglesby, Tyler Phillips, Reggie Price and Kimberly Rawls. Tanya Darden provided useful statistical advice, and Debbie Kreiser provided invaluable editorial assistance.

TABLE 1. The characterization and sample sizes of the students in the class as witness to the exercise, participant in the exercise, did not attend class and did not take survey for each year of the study (2003 & 2004). The average, standard deviation and range of the number of points (11 points total) scored by each group on the corresponding exam question is also provided.

Descriptor	Sample size		Avg. # points		Std. Dev.		Range	
	2003	2004	2003	2004	2003	2004	2003	2004
Witness	65	63	8.5	8.6	2.3	2.0	11-1	11-1
Participant	13	19	8.3	8.9	3.3	1.8	11-1	11-5
Missed class	13	13	6.2	8.6	4.2	2.4	11-0	11-3
Did not take survey	24	15	6.8	7.5	2.6	3.4	11-2	11-1

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Influences of Teleological and Lamarckian Thinking on Student Understanding of Natural Selection

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Abstract: Previous research has demonstrated creationist, Lamarckian, and teleological reasoning in high school and college students. These lines of thinking conflict with the Darwinian notion of natural selection, which serves as the primary catalyst for biological evolution. The current study assessed evolutionary conceptions in non-science majors, freshman biology/environmental science majors, and upper-level biology majors at a small liberal arts college. Results indicate that, prior to instruction, both non-science majors and upper-level biology majors appear to rely heavily on teleological reasoning to explain changes in gene frequencies over time. Instruction that incorporated historical context and avoided teleological language improved student understanding of Darwin's concept of natural selection.

Keywords: creationism, Lamarck, teleology, natural selection

Introduction

The concept of evolution by natural selection is central to understanding biology. While the *proximate*, or functional, aspects of biological inquiry can be utilized to explain "how" a macromolecule, organ, or individual performs, an *ultimate*, or evolutionary, way of thinking is necessary to investigate and understand "why." The theory of evolution provides a unifying framework within which many diverse concepts are integrated and explained.

Biological evolution can be defined as changes in the gene pool of a population over time or, as Darwin described it, descent with modification. The concept of natural selection provides a mechanism to explain the evolutionary process and is based on two suppositions: 1) there is considerable variation among individuals within a population, and 2) some variations are advantageous in terms of survival. Individuals possessing these advantageous characteristics are more likely to survive and successfully reproduce. Eventually, organisms possessing the favorable characteristics make up a greater proportion of the population.

Studies of high school (Settlage, 1994; Demastes *et al*., 1995), college (Bishop and Anderson, 1990; Anderson *et al*., 2002), and medical school (Brumby, 1984) populations indicate that misconceptions concerning natural selection are quite prevalent. Student misunderstandings about the mechanism of biological evolution often stem from common erroneous assumptions: 1) changes in traits are attributed to use or disuse of anatomical features, 2) changes in traits are attributed to a goal- or need-directed process, and/or 3) no role is assigned to variation within populations or differences in reproductive success. A poor understanding of the basic concepts of genetics, as well as an inability to distinguish adaptation at species and individual levels, may be partly responsible for these misconceptions (Hallden, 1988).

In 1809, 50 years before Darwin described the process of natural selection, French zoologist Jean-Baptiste Lamarck proposed *la marche de la nature*, a single straight line of evolutionary progress. Lamarck's explanation of species-specific adaptations to local environments was based on the strengthening of body parts through repeated use, or their weakening as a response to disuse. These acquired traits, according to Lamarck, could be passed on to the next generation. Although it is now well established that acquired characteristics are not inherited and do not contribute to biological evolution, students commonly use a Lamarckian approach to explain changes in organisms over time (Settlage, 1994; Crow, 2004).

The Greek word *telos* means end or goal. *Teleological* means end- or goal-directed. A teleological, or goal-directed, description of a biological structure or function implies that any benefit derived from the structure or function is a sufficient reason for its existence, negating the impact of variation. While teleological reasoning may sometimes help students in organizing facts and grasping natural phenomena, the belief that organisms adapt to their environments because they "need to" undermines Darwin's descent with modification by attributing goal-directed properties to the somewhat random process of natural selection.

Teleological evolution implies that change is directed by some outside agent. Even if students do not consider a supernatural creator as a governing factor, they may still consider evolution as being directed by an outside agent such as "nature." Natural selection, to students with this perspective, is a process by which nature selects individuals who are in need to become beneficiaries of helpful changes (Greene, 1990).

Research studies concerning students' conceptions of evolution and natural selection report a limited ability of students to solve problems in Darwinian terms (Jimenez, 1992; Settlage, 1994; Demastes *et al*., 1995). Specifically, they fail to acknowledge the impact of population variation on changes in gene frequency. One possible reason for these difficulties is the influence of inaccurate conceptions of biological evolution. Teleological thinking, in particular, can lead to considerable misinterpretations of evolutionary theory (Greene, 1990). According to Lawson and Weser (1990), even the brightest students may hold naive conceptions concerning certain areas of science. However, those beliefs may be changed when alternate ideas are advanced, especially when evidence and/or arguments are examined to support or refute the deduced consequences of the alternatives.

Conceptual understanding is influenced by the integration of new knowledge with preexisting attitudes and beliefs. Some students may separate the understanding of the theory of evolution from any religious beliefs they might have, whereas others may see evolution and religion as opposing forces and reject evolutionary concepts outright (Smith *et al*., 1995; Dagher and BouJaoude, 1997; Sinatra *et al*., 2003). Lamarckian or teleological thinking would not be an issue with the latter students. It is possible that no amount of instruction, regardless of the strategy, would be effective in changing such rigid, faith-based beliefs (Sinclair and Baldwin, 1996).

The current study assessed understanding of natural selection by students with very different interests and scientific backgrounds. It was hypothesized that non-science majors and freshman biology/environmental science majors would initially express common evolutionary misconceptions more frequently than junior and senior biology majors. Furthermore, it was predicted that all groups would improve their comprehension of evolutionary mechanisms following instruction.

Methods

The current study involved students enrolled at Davis & Elkins College, a private, four-year liberal arts school that stresses small class size and strong faculty-student interaction. BIOL 100 (Basic Biology) is a one-semester survey of basic biological principles, designed to fulfill a general education requirement for non-science majors. BIOL 102 (Principles of Biology II) is the second half of a two-semester sequence designed for first-year students majoring in biology or environmental science. In BIOL 102, ecology, evolution, and biodiversity are emphasized. BIOL 305 (Evolution) is a capstone course for biology majors. The course focuses on the evidence, mechanisms, and genetics of organic evolution. Student understanding of evolution by natural selection was assessed in two sections of BIOL 100 (Fall 2004 and 2005), two sections of BIOL 102 (Spring 2005 and 2006), and one section of BIOL 305 (Fall 2005).

With the exception of the Fall 2005 section of BIOL 100, which was taught by author S.K.S., all courses were taught by author M.L.M. To ensure comparable assessment of BIOL 100 students, the authors collaborated to create a standard format for organizing content presentation. In all courses, lecture outlines and textbook figures were presented via Microsoft PowerPoint. Students had access to all PowerPoint slides and were encouraged to actively participate in the discussion of content. Questions were frequently asked to determine the extent to which students were following the lecture material.

While only two 50-minute and two 75-minute class periods were devoted exclusively to the topic of evolution in BIOL 100 and BIOL 102, respectively, the concept of natural selection was a recurring theme in both courses. When misconceptions about natural selection were encountered, the instructors provided clear and concise arguments to challenge them, while offering simple, understandable evidence to support legitimate scientific notions. Laboratory activities and/or problem solving sessions dedicated to promoting conceptual change were utilized in all courses to help students recognize the inadequacy of faulty preconceptions, while providing support for accurate views of biological evolution. For example, various eating utensils were employed in BIOL 100 to demonstrate differential success in capturing prey (in this case, beans), colored beads were utilized in BIOL 102 to illustrate Hardy-Weinberg equilibrium, and a collection of nuts and bolts provided the basis for a laboratory activity in phylogenetic analysis for BIOL 305 students. Furthermore, in an attempt to promote students' conceptual change from Lamarckian to Darwinian, the conflicting perspectives were placed in historical context to demonstrate the self-correcting nature of science. Finally, the use of teleological language during instruction was monitored carefully. Suggesting that organisms undergo particular adaptations to ensure survival was avoided. For example, statements like "The cheetah,in an effort to keep up with increasingly fast prey species, has evolved a remarkable ability to run at very high speeds for a short period of time" or "The giraffe's neck has gradually gotten longer to allow access to food sources far from the ground" would have created the false impression that organisms adapt according to their needs. While such statements may have helped students to grasp particular aspects of evolutionary biology, they would almost certainly have facilitated misconceptions.

During the first week of each course, prior to any discussion of the mechanisms of biological evolution, students completed a 10-question, multiple-choice survey (Figure 1, appended at end of article). Questions 2, 3, 5, 6, 8, and 10 specifically addressed the concept of natural selection. For each of these six questions, four possible answers were provided to represent the following categories: Lamarckian, teleological, creationist, and Darwinian. Students received scores in each of the four categories. For example, if a student selected four teleological responses and two Darwinian responses, he/she would receive the following scores: Lamarckian = 0%; teleological = 67%; creationist = 0%; Darwinian = 33%. Thirty-four BIOL 100 students, 20 BIOL 102 students, and four BIOL 305 students were recruited to take the pre-test. Toward the end of the semester, after discussions and activities related to natural selection had been completed, students took the survey again. Participating students numbered 31, 18, and four for the BIOL 100, BIOL 102, and BIOL 305 post-tests, respectively.

Two-sample *t* tests were used to compare group means. All *t* tests were two-tailed, and an alpha level of $p<0.05$ was considered statistically significant.

Results

For BIOL 100 students, mean Lamarckian, teleological, and Darwinian scores were significantly higher than creationist scores on both pre- and post-tests. Furthermore, pre-test teleological scores (46.6%) were significantly higher than pre-test Darwinian scores (21%), and pre-test Darwinian scores were significantly lower than post-test Darwinian scores (43%; Figure 2).

For BIOL 102 students, mean Lamarckian, teleological, and Darwinian scores were significantly higher than creationist scores on both pre- and post-tests (Figure 3). When the BIOL 100 and BIOL 102 classes were compared to each other, no significant differences existed between the two groups in any of the categories on either the pre-test or post-test.

BIOL 305 students received Lamarckian, teleological, creationist, and Darwinian scores of 29%, 46%, 0%, and 25%, respectively, on the pre-test. Post-test scores were 8.3%, 25%, 0%, and 66.7% in the Lamarckian, teleological, creationist, and Darwinian categories, respectively (Figure 4). Since only four students were enrolled in BIOL 305 in the fall of 2005, a statistical analysis was inappropriate.

FIG 1. Natural Selection Survey.

1. What is a scientific theory?
    a. A personal opinion regarding a specific scientific topic
    b. An educated guess about the nature of a natural phenomenon
    c. A well-supported explanation of a natural phenomenon, generally accepted by the scientific community
    d. A testable hypothesis, generated in response to a scientific observation

2. Considering the normal vision of their ancestors, how do you explain the non-functional eyes of the cave salamander?
    a. The salamanders had to adapt to darkness in order to survive. Because vision was no longer needed, subsequent generations of salamanders had non-functional eyes.
    b. The first cave salamanders used their eyes less and less. Consequently, their offspring inherited non-functional eyes.
    c. There were varying degrees of eye function in the original salamander population. Individuals emphasizing vision as a sensory mechanism may have been unable to survive and reproduce.
    d. The cave salamander was created to be perfectly adapted to its environment.

3. If their distant ancestors could only achieve speeds between 20 and 30 miles per hour, how do you explain the ability of modern cheetahs to run at speeds in excess of 60 miles per hour for short periods of time?
    a. As the cheetahs used their legs more and more to chase prey, they developed strong sprinting muscles. As a result, their offspring inherited the ability to run at high speeds.
    b. The cheetahs had to adapt to capture fast-moving prey. Because speed was needed for survival, later generations developed streamlined, muscular bodies.
    c. There were a variety of body types in the original cheetah population. Individuals possessing the musculature necessary for short bursts of speed may have been better equipped to survive and reproduce.
    d. Cheetahs, and their prey, were created to run at high speeds.

4. Which of the following is <u>not</u> a product of artificial selection?
    a. African elephants
    b. German shepherds
    c. Red delicious apples
    d. Genetically-modified corn

5. Which of the following is the foundation of Darwin's concept of natural selection?
    a. There is always variation among individuals in a population.
    b. During the life of an individual, environmental pressures bring about permanent changes in the body. Those changes can then be passed on to future generations.
    c. All living organisms are exactly the same as they were when they were originally created.
    d. Organisms adapt according to their needs.

6. How do you explain the fact that some bacterial infections are now resistant to the antibiotics that were developed to treat them?
    a. As a result of mutation, there is a great deal of variation within a bacterial population. Those strong enough to survive the initial antibiotic treatment will reproduce more, and resistance will become more prominent in the population.
    b. Initially, bacterial strains were caught off-guard by antibiotics. Then, they began using more of their natural defenses to resist antibiotic treatments. Now, as a result, current generations of bacteria have acquired resistance to antibiotics.
    c. The bacteria's goal is survival. To ensure survival of the species, resistance to antibiotics was needed. Consequently, bacterial populations have mutated to obtain more and more resistance over the years.
    d. Bacteria were created to be antibiotic-resistant.

7. Can you believe in God and still accept the theory of evolution?
    a. No

b. Yes

8. When it was first developed to treat HIV infection, the drug AZT was very effective at decreasing viral levels in the blood. However, the effect was only temporary, and HIV levels eventually became elevated again. How do you explain this?
   a. The virus was created with a mechanism to resist pharmacological treatment.
   b. The virus gains resistance as it is continuously exposed to AZT. During the asymptomatic phase of infection, the virus will reproduce, and subsequent generations of viruses will inherit the resistance.
   c. As the virus mutates during the asymptomatic phase of the infection, a variety of viral antigens are produced. Viruses bearing antigens unrecognizable by the host's immune system will propagate rapidly.
   d. To survive, the virus needs to resist the effects of the drug. During the prolonged, asymptomatic phase of infection, the virus mutates to meet its needs.

9. If humans evolved from apes, why are apes still around?
   a. The apes that were well-adapted to their specific environments maintained their ape-like characteristics. Other populations of apes, under different environmental pressures, evolved into humans in order to survive.
   b. Humans did not evolve from apes. Each species was created separately.
   c. Humans did not evolve from apes. Evidence suggests that they shared a common ancestor, a species that no longer exists.
   d. Evolution is a gradual, progressive process. Eventually, all apes will evolve into humans.

10. Some plants produce chemical toxins that make them distasteful to herbivores. If ancestral plants were unable to produce toxins, how did this mechanism develop?
    a. The plants had to adapt to the presence of herbivores in order to survive. The production of chemical toxins represents an adaptation of necessity.
    b. Initially, the plants may have produced no toxins. However, at some point, they began to actively synthesize toxic chemicals. After that, subsequent generations of plants would have inherited the ability to produce toxins.
    c. Initially, there was probably a great deal of variation in the plant population. Those plants that were able to synthesize toxic chemicals were more likely to survive and reproduce.
    d. The plants have maintained an ability to synthesize toxins since their creation.

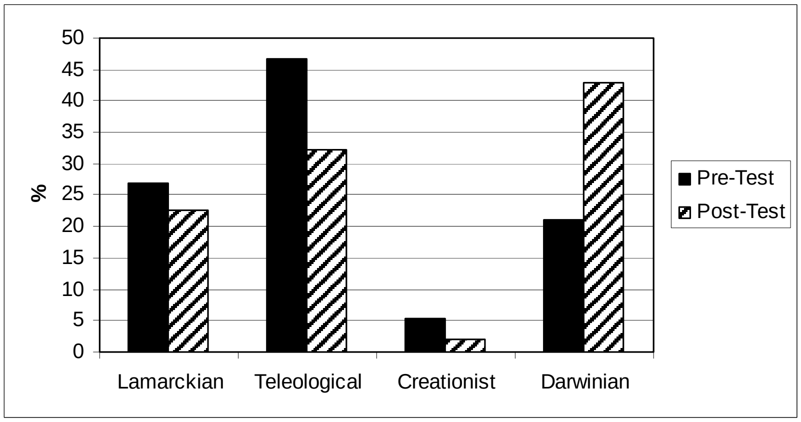

FIG 2. Mean BIOL 100 Scores. Mean Lamarckian, teleological, and Darwinian scores were significantly higher than creationist scores on both pre- and post-tests. Pre-test teleological scores were significantly higher than pre-test Darwinian scores. *Post-test Darwinian scores were significantly higher than pre-test Darwinian scores.

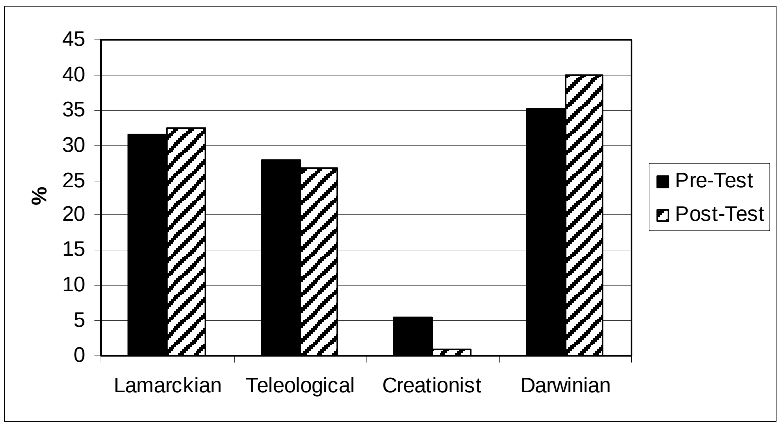

FIG 3. Mean BIOL 102 Scores. Mean Lamarckian, teleological, and Darwinian scores were significantly higher than creationist scores on both pre- and post-tests.

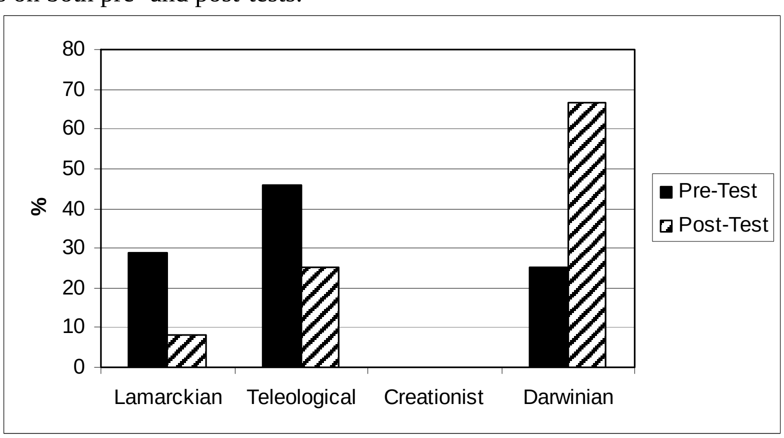

FIG 4. Mean BIOL 305 Scores. Only four students completed the pre-and post-tests; a statistical analysis was not appropriate.

Discussion

Although previous research indicates that many students will reject evidence supporting the theory of evolution because they perceive a conflict with their religious beliefs (Smith *et al*., 1995; Dagher and BouJaoude, 1997; Sinatra *et al*., 2003), the present study demonstrates an overall acceptance of the theory (but not an understanding of the mechanism behind it). Creationist scores were dramatically lower than other category scores in each of the three groups (Figures 2, 3, and 4).

According to Jensen and Finley (1996), the most common evolutionary misconceptions expressed by non-science majors are related to a teleological way of thinking. Moreover, Brumby (1984) found that the primary fallacy in first-year medical students' conceptions of biological evolution is the attribution of a need-directed process to species adaptation. Finally, a study by Richardson (1990) demonstrates that high school students, non-science majors, allied health majors, and medical students express a strong tendency to think of body functions in teleological terms. In the current study, teleological reasoning was significantly more prominent than a Darwinian line of reasoning in BIOL 100 students on the pre-test (Figure 2); a similar, but non-significant, trend was seen in the BIOL 305 students (Figure 4). Research by Keleman (2003) suggests that teleological reasoning develops during childhood. It appears that children use teleology to explain functions of both living and non-living natural phenomena (clouds, rocks, etc.). In contrast, adults seem to limit their teleological explanations to biological phenomena. The notion that biological structures have developed to serve a specific goal or need must be very deeply rooted, as even junior and senior biology majors fall into this line of thinking.

Previous studies on populations of high school students (Demastes *et al*., 1995) and college students majoring in non-science disciplines (Bishop and Anderson, 1990; Demastes *et al*., 1995) assessed curricular strategies similar to the ones used in BIOL 100 and BIOL 102 in the current study. In the previous studies, approximately one week of explicit instruction on the topic of evolution, references to the concept of natural selection throughout the course, relevant laboratory activities, and problem solving sessions designed to confront misconceptions resulted in moderate improvements in understanding of Darwinian concepts. Sheppard and Prischmann (2003) found that the use of an historical perspective of evolution in an introductory biology course for non-science majors allowed presentation of the topic in a less threatening, yet more comprehensive, manner. Furthermore, Jensen and Finley (1996) found success in a non-majors introductory biology course by approaching the topic of natural selection through historically-based discussion in conjunction with relevant problem solving sessions. The current study reports a statistically significant increase in post-test Darwinian scores for BIOL 100 students (Figure 2), and post-test Darwinian scores for BIOL 305 students improved by more than 40% (Figure 4).

A 2003 study by Sandoval and Morrison indicated that high school students generally viewed science as a search for evidence to provide legitimate explanations for phenomena associated with the natural world. However, when asked specific questions about the nature of science, including the concept of natural selection, students' responses were often inconsistent with their overall view of science. The current study illustrates similar inconsistencies. While participating students seemed to accept evolutionary theory as legitimate, they inconsistently designated Lamarckian, teleological, or Darwinian mechanisms as the driving force behind evolutionary change. BIOL 102 students, in particular, epitomized inconsistency. For these students, there were no significant differences between Lamarckian, teleological, and Darwinian scores on pre- or post-tests (Figure 3).

In all three classes we examined, creationist scores were dramatically lower than other category scores. It is possible that students steered away from the word "creation" because they assumed it to be incongruent with a science curriculum. It is also possible that students were able to keep their religious beliefs separate from the science of evolutionary theory. For survey question #7 (*Can you believe in God and still accept the theory of evolution?*), 80% of all participants responded "yes" on the pre-test, and 90% of all participants responded "yes" on the post-test.

In conclusion, the present study demonstrated inconsistencies in student responses to questions regarding the process of natural selection. While teleological responses were quite common prior to any instruction, post-test results indicated an increase in Darwinian responses from non-science majors and upper-level biology majors.

It is apparent that Darwinian reasoning is not intuitive. Many students will enter college with religious beliefs or reasoning strategies that conflict with the concept of natural selection. As indicated by the small sample of BIOL 305 students, even upper level biology majors can fall into a teleological mode of thinking. The theory of evolution is central to understanding biology. Perhaps the concept of natural selection should be even more ubiquitous in biology courses, for both majors and non-majors. If exposure to the concept is maximized, students may be more likely to set their default reasoning gauge to "Darwinian."

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What Do Students' Behaviors and Performances in Lab Tell Us About Their Behaviors and Performances in Lecture-Portions of Introductory Biology Courses?

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Abstract: In a study spanning several years and including more than 1600 students, lab attendance was strongly correlated with lab grades (r = 0.64), lecture attendance (r = 0.49), and course grades (r = 0.60) in an introductory biology course. Regardless of the semester, lab attendance was lowest during the first week of the semester, and students who missed the first lab of the semester were significantly more likely to miss more labs and earn lower grades than other students. Students who missed labs, and especially those who missed more than one lab, earned disproportionately lower grades in lab and in the course than did students who attended all labs. These results indicate that (a) lab attendance is a strong predictor of grades in lecture and lab, (b) students most likely to attend lab are also most likely to attend lecture, and (c) first-week absenteeism can be used to identify students disproportionately likely to earn low grades, and (d) instructors can use lab attendance to quickly, easily, and accurately identify students at-risk for low grades.

Keywords: attendance, grades lab, lecture

Introduction

Class attendance is the most obvious and important indicator of academic engagement because it requires a conscious and ongoing effort that is directly related to students' academic success (Moore *et al*., 2003; Rumberger, 2001). Students *choose* to attend class Nevertheless, absenteeism in introductory courses is often high (e.g., 25 to 50%), even in classes taught by award-winning instructors (Friedman *et al*., 2002; McGuire,2003; Romer, 1993; Thompson, 2002). Romer (1993), who notes that absenteeism in introductory courses is "rampant," describes the situation this way: "A generation ago, both in principle and in practice, attendance at class was not optional. Today, often in principle and almost always in practice, it is" (p. 174).

Introductory science courses are often characterized by especially high rates of absenteeism (Friedman *et al*., 2001) and low grades (Congas *et al*., 1997). Many students skip science classes because they believe they can "make up" their absences by downloading or copying notes, reading the textbook, or talking with a classmate (Moore, 2003a). However, students usually cannot "make up" a missed lab because of the logistical problems associated with offering the lab experience (e.g., the restricted availability of equipment, reagents, and specimens).

Although there have been several studies of students' overall rates of class attendance in lecture portions of science courses (Burchfield & Sappington, 2000; Congas *et al*., 1997; Grisé & Kenney, 2003; Moore, 2003a, b; Sappington *et al*., 2002), there has been no analysis of how attendance in labs is associated with students' performances. This is probably due to the facts that (a) students' lab grades are usually embedded in their overall course grades (i.e., lab is usually not a separate course), and (b) lab instruction is often delegated to teaching assistants, not professors. Given the importance of lab experiences to a liberal arts education and students' introductions to (and understandings of) science, I wondered what an analysis of students' patterns of lab and lecture attendance might tell me about students' performances in introductory biology courses. For example, is there a pattern of absences during a semester, or are attendance-rates unpredictable? How do patterns of attendance in lab compare with those of lecture? Is attendance at labs as important to academic success as it is in lecture? Given the importance of a good start to academic success (Moore, 2004a, b; 2005a), are students who miss labs early in the semester more likely than other students to miss additional labs and/or earn low grades? And finally, how can instructors use these data to identify problems and help improve students' performances in introductory courses?

Methods

Site of the study. This study was conducted in a traditional introductory biology course at the Twin Cities campus of the University of Minnesota. The course, which was taught by various instructors, included two 75-minute lectures and one two-hour lab per week during each of the 13 weeks of the semester. This study included 1,682 students enrolled during six semesters from 2004-2006. These students had an average ACT composite score of 20 (this matches the national average; Hoover, 2003), an average age of 20, and an average gender-distribution of 47% females and 53% males. These students' ethnic diversity was as follows: 17% African American, 2% American Indian, 16% Asian American, 4% Chicano/Latina, 58% Caucasian, and 3% Other. I excluded students who withdrew from the course, students who received grades of incomplete, and students who failed the course because of academic misconduct.

The course and course policy. The course, its policies, and grade distributions were similar every semester of the study (i.e., the same grading policies, textbook, classroom, topics). Labs, which counted 33% of students' overall grade in the course, covered topics typical of a traditional introductory biology course (e.g., cells, genetics, molecular biology). All sections of lab enrolled 12 or fewer students and were taught by teaching assistants (TAs) who completed a weeklong orientation each semester to ensure similarstandards and pedagogical approaches to lab. Grades in lab were based on topics covered in lab (i.e., were not based on information presented in lecture). Similarly, grades in lecture were not based on any information presented in lab. Additional information about this course is provided elsewhere (Moore, 2003a, b).

Measuring attendance. Attendance was recorded at lectures by having students submit a short essay about a topic discussed that day in class. I measured attendance at every class except those at which we gave the three lecture-exams (i.e., at which attendance approached 100%). Attendance at labs was recorded by TAs at every lab by determining students' actual presence in lab (i.e., not with a sign-in sheet on which students could list friends who were absent). To be counted present at a lab, a student could be no more than 30 minutes late for the lab. If, for whatever reason, a student came to lab more than 30 minutes late, they were counted absent, but could still submit lab reports and do the required activities. Although students received no points for merely attending lab, attending lab enabled students to earn points by taking the weekly lab-quizzes and doing the lab activities (which prepared students for the next week's lab-quiz). Regardless of the semester, missing a lab and its quiz meant that students lost 7.7% (i.e., 1/13) of their possible lab grade. Students who missed three or more labs automatically failed the course. There were no minimum attendance requirements in lecture.

All labs began the first week of classes and continued until the end of the semester. This was announced in the class schedule (i.e., when students enrolled in the course) and was repeated at the first lecture (i.e., before the first lab). The importance of lab attendance was emphasized during the first lecture, in each of the first two weeks of lab, in the course syllabus, in the lab syllabus, and in the lab manual. In all instances, presentations of the attendance policy were accompanied by data showing that increased rates of attendance are associated with higher grades in lab (Moore, 2003a). These data were also posted prominently on large posters in and just outside lab (i.e., where students congregate before lab).

Students with "excused" absences (e.g., documented illnesses, emergencies) were allowed to reschedule their labs if they contacted their TA and made arrangements to attend a different lab section during the same week as their scheduled lab. Given the logistics of most labs (e.g., the availability of equipment, reagents, and specimens) and the questionable nature of many students' excuses (Sappington, Kinsey, & Munsayac, 2001), students were not allowed to reschedule their labs if they did not contact their TA before lab or if they could not document their emergency or illness (e.g., students who missed lab because of family vacations, leisure activities, or being hung-over were not allowed to reschedule a missed lab). All labs, lab quizzes, and grading practices were standardized during weekly meetings with the TAs. All labs in all semesters had similar exams, did the same experiments, and had identical grading policies.

Instructors' responses to students' absences. When students missed a lab, they were sent an e-mail notifying them of their absence, their total number of absences in lab, the course's attendance policy, and their probabilities of earning various grades in the course (based on previous semesters' data). These e-mails were sent 0.5 to 3 days after each absence (i.e., well before their next scheduled lab). When students exceeded the maximum number of allowed absences, they received an e-mail informing them that they had failed the course.

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Results

I accommodated all students who requested that they be allowed to attend a different lab. That is, all students who contacted their TA to reschedule their lab and who provided the required documentation were allowed to do the lab and take the accompanying lab quiz. All students who were counted absent from a lab either (a) showed up more than 30 minutes after the lab had started, or (b) never came to the lab and did not contact their TA to reschedule the lab. Our method for determining absences (e.g., being more than 30 minutes late to lab, not turning in the assignments in lecture) was easily implemented and objective; it required no subjective judgments by TAs. For example, TAs did not have to judge students' levels of preparation, participation, or effectiveness in lab; they only measured whether the student was present in lab.

Attendance and grades. Students' average lab grade was 78%, their average course-grade was 72%, their average rate of absenteeism in lab was 2.9%, and their average rate of absenteeism in lecture was 30%. 19% of students missed no lectures, 75% of students missed no labs, and 17% of students missed no labs or lectures. The correlation coefficient (r) of lab attendance and lab grades was 0.64, lab attendance and course grades was 0.60, lecture attendance and course grades was 0.60, and lab attendance and lecture attendance was 0.49.

Table 1 shows the lab grades, course grades, and course-grade distributions of students who missed various numbers of labs. On average, students who missed no labs attended 78% of lectures, students who missed one lab attended 60% of lectures, students who missed two labs attended 41% of lectures, and students who missed more than two labs attended 34% of lectures. Students who missed progressively more labs earned progressively lower grades in lab and in the course.

Attendance patterns in lab. Students' patterns of lab attendance are shown in Figure 1. Regardless of the semester, absenteeism in lab was highest during the first week of classes. First-week absenteeism in lab averaged 4.90 + 0.11%, and first-week absences accounted for 12% of the total absences during the semester. Attendance at the second lab improved dramatically (i.e., absenteeism dropped from 4.9% to 1.6%; $p <$

0.001%), after which it gradually declined throughout the semester, reaching near-peak levels during the final two weeks of the semester. The average rate of absenteeism throughout the semester was 2.93 + 0.13%. The correlation coefficient for attendance over time throughout the semester was 0.22.

Students who missed the first week of lab earned an average lab grade of 59%, and more than half (i.e., 57%) of these students missed at least one more lab during the semester. For comparison, students who did not miss the first week of lab earned an average lab grade of 78%, and only 20% of these students missed a lab during the rest of the semester. Excluding the first week's absences increased the correlation coefficient for attendance over time throughout the semester from 0.22 to 0.70. When I asked an opportunistically-selected sample of students (N = 20) who missed the first week's lab why they missed the lab, the most common response (55% of respondents) was that they did not believe that anything important would occur that week; smaller percentages claimed that they had other conflicts (30%) or did not know that labs met the first week (10%).

Attendance patterns in lecture. Students' patterns of lecture attendance are shown in Figure 2. Attendance peaked during the first week of classes, after which it declined at an average rate of approximately 2% per week throughout the semester. The largest decrease in attendance occurred in the second week of classes, in which attendance dropped an average of 14% (i.e.,from approximately 90% to 76%).During every semester,there was a slight increase in attendance during the final week of classes (i.e., from an average of 56% in the penultimate week to an average of 63% during the last week). The correlation coefficient for lecture attendance over time throughout the semester was 0.85. Early morning (i.e., 8:00 a.m.) classes had attendance rates that were consistently approximately 8% higher than did classes offered later in the day. The correlation coefficients of lecture attendance over time (i.e., r = 0.81 and 0.85 for early-morning lectures and later lectures, respectively) and with grades (i.e., r = 0.71 and 0.63 for early-morning lectures and later lectures, respectively) were similar in both sections.

Discussion

Several studies have reported a strong correlation of lecture attendance and grades in introductory science courses (Launius, 1997; Moore, Jensen, Hatch, Duranczyk, Staats, & Koch, 2003; Street, 1975; Wiley, 1992), and data reported here are consistent with those conclusions. However, data in Table 1 also show that lab attendance is strongly correlated with lab grades. Of course, some of this is to be expected; after all, missing a lab automatically meant that students lost 7.7% of their lab grade (see above). However, students who missed one lab earned grades that were 14% (i.e., [(84-72)/84] = 14%) lower than those of students who missed no labs, and students who missed two labs earned lab grades that were barely half those of students who missed no labs (i.e., 48 vs. 84%, respectively). These results indicate that absences from lab (especially from two or more labs) may have a disproportionately greater impact on lab grades than can be accounted for by the points lost by the absences alone.

Our data also show for the first time that students who come to lab most often earn disproportionately higher grades than do students who miss one or more labs (Table 1). For example, the probability of earning a D or F increased from 18% among students who missed no labs to 47% among students who missed only one lab, and to 95% for students who missed two labs. Similarly, more than half (i.e., 57%) of students who missed no labs earned an A or B, but only 21% of students who missed one lab earned an A or B, and no student who missed two labs earned an A or B. In all instances, the lower overall grades far exceed that which can be accounted for by the points lost because of the students' absences from lab alone. This is probably due to the fact that students' poor rates of lab attendance are a surrogate for other poor academic behaviors. Indeed, students who miss labs are also most likely to miss lectures and ignore other opportunities to raise their grades (i.e., they are much less likely to attend help-sessions or submit extra-credit work; Moore, 2005b, in press).

TABLE 1. Lab attendance, lab grades, and course grades of students who missed various numbers of labs in an introductory biology course. Numbers in the table are percentages.

Number of Absences	% of Students	Lab Grade	Course Grade	Grade Distribution, % A	B	C	D	F
0	75*	84	77	19	38	25	8	10
1	16	72	67	7	14	32	20	27
2	4	48	47	0	0	5	15	80
>3	5	35	33	0	0	0	0	100

* For example, 75% of the students in the course missed no labs; these students earned an average lab grade of 84% and a course grade of 77%. 19% of these students earned an A, 38% a B, 25% a C, 8% a D, and 10% and F.

Figures 1 and 2 are the first large-scale (*N* = 1,682) quantifications of a common anecdotal observation of many science instructors – namely, that students' levels of academic engagement (as measured by attendance at lab and lecture) diminish throughout the semester. Although attendance in lecture and lab is strongly correlated with students' grades, the patterns of attendance in lecture and lab have distinctive differences, and these differences have important consequences.

FIG 1. Rates of lab attendance throughout a semester.

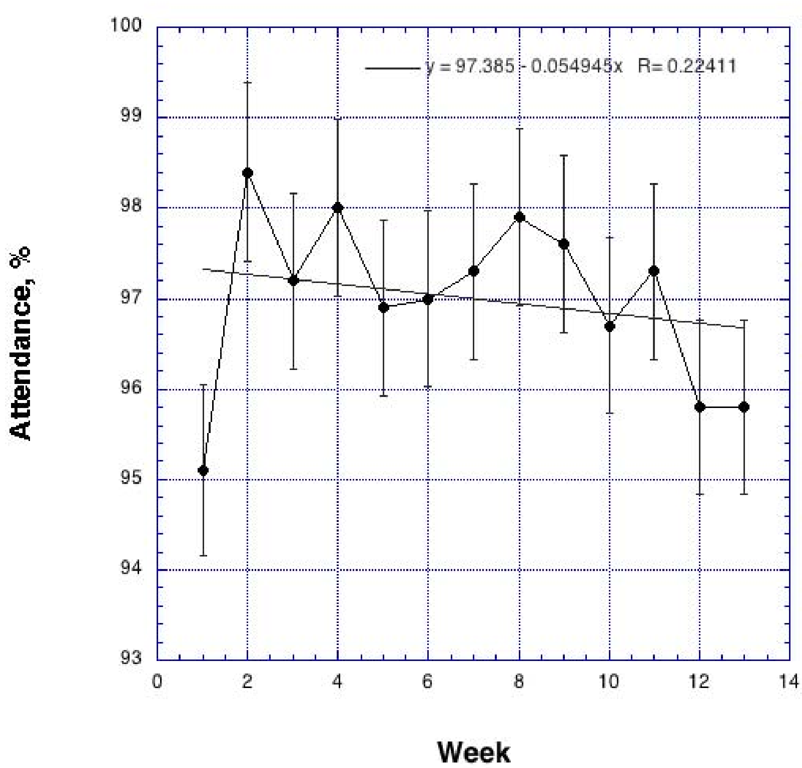
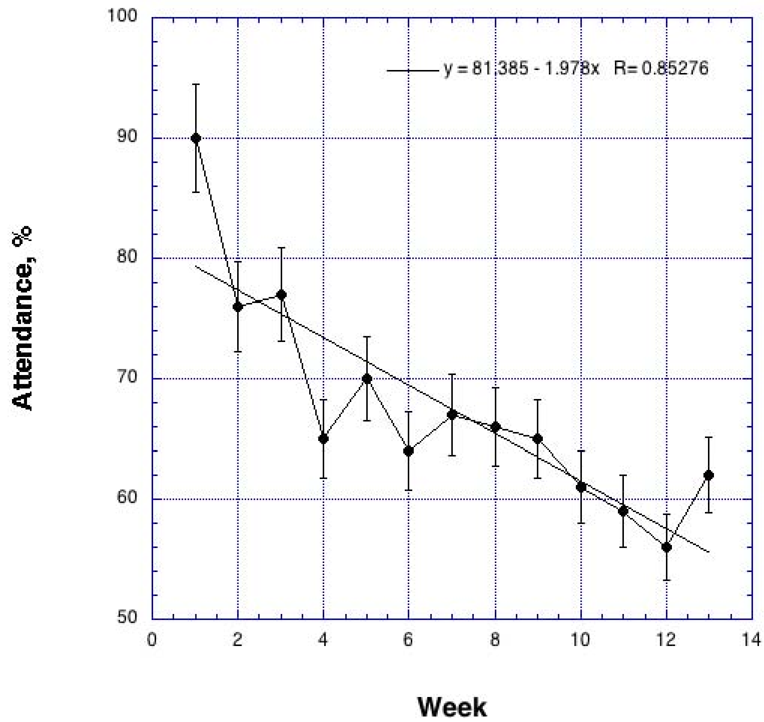


FIG 2. Rates of lecture attendance throughout a semester.



1. Students consistently attended much larger percentages of labs than lectures, despite the fact that lecture-based material accounted for twice as much of their final grades as lab-based material. That is, students are more likely to attend lab than lecture, and are therefore more likely to be exposed to information presented in lab than in lecture. These results suggest that, whenever possible, labs should be used to introduce the course's most important information.

2. Although attendance in both lecture and lab diminishes throughout the semester, the decrease is much more rapid in lecture. For example, the slope of the best-fit line for lecture attendance over time (Figure 2) decreases at a rate of approximately 2% per week, whereas that for lab attendance (Figure 1) decreases at a rate of less than 0.1% per week. These decreases were similar during Fall and Spring semesters, and are therefore not due only to the "Spring Fever" associated with the improving weather of Spring semesters. A more descriptive term for this gradual decrease in attendance throughout a semester might be "attendance fatigue." This fatigue is more than 10-times more dramatic in lecture than lab, possibly because either (a) there were weekly exams in lab, and/or (b) lab met only once per week, whereas lecture met twice per week.

3. In lab, attendance was lowest during the first week, whereas in lecture it was highest during the first week. The relatively poor attendance in the first week's lab was apparently due to some students assuming that "nothing important would happen" at that lab. In lecture, the high rate of attendance during the first week was presumably due to the fact that syllabi containing course policies and exam dates were distributed during the first week of classes. Many students apparently believe that the rewards for attending the first week's lectures (i.e., at which they receive the course syllabus and hear about course policies and exam dates) exceed those of other classes in the course.

4. Absenteeism in the first week's lab is a strong indicator of future problems in the lab and course. That is, students who miss the first week's lab are disproportionately more likely to miss at least one more lab and earn lower lab grades and course grades than students who did not miss the first week's lab. Instructors can use this information to design intervention strategies (e.g., notifications) to help educate students about the likely consequences of their academic behaviors.

Although academic behaviors such as attendance are strongly correlated with academic success in introductory science courses, correlation does not necessarily imply cause. For example, students' higher rates of lab attendance might help produce high grades, or students' desires to earn high grades might underlie their high rates of lab attendance, or both. Moreover, some students who attended every lab earned a poor grade, and some who missed one lab were able to earn an A or B. Nevertheless, the conclusions here are unmistakable; on average, (a) students who come to lab and lecture earn disproportionately higher grades than students who miss labs and/or lectures, and (b) lab attendance can be used to easily, objectively, and accurately identify students at-risk for low grades in introductory biology courses.

For many students, the findings reported here are moot; these students come to virtually all lectures and labs, and usually earn higher grades than do students who miss lectures and labs.When instructors *can* improve attendance, students' grades often improve.But how can instructors do this? As most instructors know, it's not easy. This is probably due to the fact that students' attitudes about, and habits regarding,class attendance are formed in high school, where high rates of absenteeism are strongly correlated with academic disengagement and dropping out (Rumberger, 2001). For many high school students, absenteeism increases gradually; data reported here show that in lectures and labs of a college biology course, the same thing happens, and these increased rates of absenteeism are associated with lower grades (Table 1, Figures 1 & 2). It is often difficult to change these entrenched behaviors. Even failing a course because of poor attendance seldom changes students' behaviors; most students who repeat introductory courses because of poor grades repeat the same behaviors, and earn similarly low grades (Moore, in press). However, repeatedly using quantitative data such as those shown in Table 1 to emphasize the importance of attendance for good grades does improve the attendance rates of approximately 20% of students (Moore, 2003b).

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Call for Applications -- John Carlock Award

This Award was established to encourage biologists in the early stages of their professional careers to become involved with and excited by the profession of biology teaching. To this end, the Award provides partial support
for graduate students in the field of Biology to attend the Fall Meeting of ACUBE.

Guidelines: The applicant must be actively pursuing graduate work in Biology. He/she must have the support of an active member of ACUBE. The Award will help defray the cost of attending the Fall meeting of ACUBE. The recipient of the Award will receive a certificate or plaque that will be presented at the annual banquet; and the Executive Secretary will provide the recipient with letters that might be useful in furthering her/his career in teaching. The recipient is expected to submit a brief report on how he/she benefited by attendance at the meeting. This report will be published in *Bioscene*.

Application: Applications, in the form of a letter, can be submitted anytime during the year. The application letter should include a statement indicating how attendance at the ACUBE meeting will further her/his professional growth and be accompanied by a letter of recommendation from a member of ACUBE. Send application information to: Dr. William J. Brett, Department of Life Sciences, Indiana State University, Terre Haute, IN 47809; Phone: 812-237- 2392; FAX: 812-237-4480; Email: lsbrett@scifac.indstate.edu.

If you wish to contribute to the John Carlock award fund, please send check to: Dr. Tom Davis, ACUBE Excecutive Secretary, Department of Biology, Loras College, 1450 Alta Vista, Dubuque, IA 52004-0178

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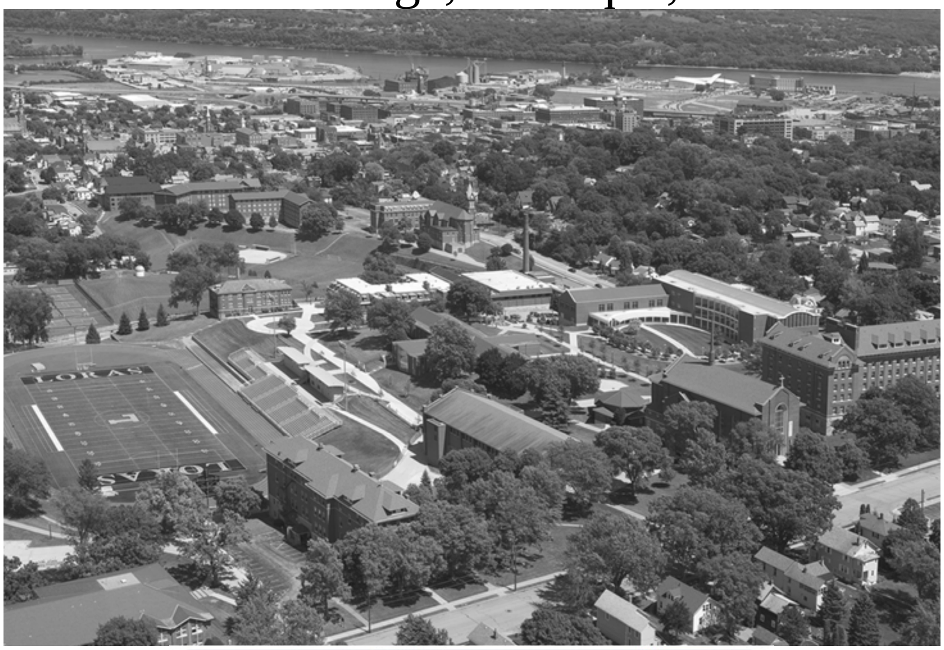
51st Annual ACUBE Meeting

Learning by Doing: The Integration of Research and Teaching in the Biology Classroom

Oct. 4 -6, 2007
Loras College, Dubuque, Iowa



Area Map, Campus Map and Driving Directions to Loras College available at:
www2.loras.edu/college/maps

Dubuque does have its own airport served by American Eagle only. Other regional airports include **Cedar Rapids**, 1 hour 20 minute drive from airport to Dubuque, **Moline**, also about one hour and 20 mintue drive to Dubuque, **Madison, WI** a 2 hour drive to Dubuque, or **Rockford, Il**, a 2 hour drive to Dubuque

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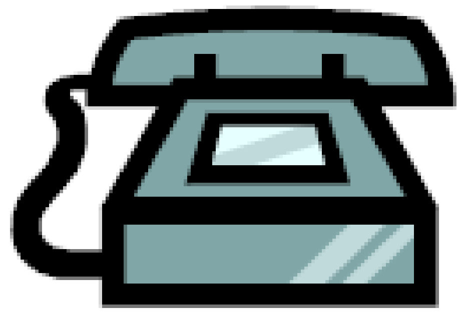
Housing Preview

51st Annual ACUBE Fall Meeting

Learning by Doing: The Integration of Research and Teaching in the Biology Classroom

Loras College
Dubuque, Iowa

October 4-6, 2007



Note: Lodging for ACUBE meeting in Dubuque; each hotel has a block of rooms set aside for our group for Thursday Oct. 4 and Friday Oct. 5, 2007.

Holiday Inn Five Flags – Downtown Dubuque
450 Main St.
563-556-2000
$62 +tax per night
Ask for rooms held for Davis

Best Western Midway Hotel
3100 Dodge St.
563- 557-8000
$65 +tax per night
Ask for rooms for Loras College Biology Teachers
Reservations need to be made by Sept. 17, 2007

Hampton Inn
3434 Dodge St. (Hy 20 W)
563-690-2005
$84 = tax per night
Ask for rooms held for Davis

Heartland Hotel
4025 Dodge St. Hy 20 W
563-582-3752
$55 + tax per night
Ask for rooms for Loras College Biology Teachers

Call for Resolutions

The Steering Committee of ACUBE requests that the membership submit resolutions for consideration at the 2007 Annual meeting to the Chair of the Resolutions Committee. Submit proposed resolutions to:
Sister Marya Czech, Dept. of Biology, Lourdes College, 6832 Convent Blvd. Sylvania, OH 43560,
Email: MCZECH@lourdes.edu
Phone: 419-824-3687

Book Review

The Reluctant Mr. Darwin: An Intimate Portrait of Charles Darwin and the Making of His Theory of Evolution. David Quammen. W.W. Norton & Co., New York.2006. 304 pp. Hardback – ISBN: 0-393-05981-2. $22.95.

As part of the landed gentry, Charles Darwin's family lived a sedate and sophisticated life in a large Georgian house in Shrewsbury. Darwin's father, a successful doctor and capitalist, had a large library, especially rich in natural history; a greenhouse was just off the morning room, and Darwin's mother kept fancy pigeons. After what is often described as an unremarkable childhood, Darwin left for Edinburgh to study medicine at the age of sixteen, but was appalled by the body trade and especially the brutality of surgery without anesthesia. After he abandoned that career, his father told him, "You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family." Darwin's next plan was to prepare himself for ordination at Cambridge and become a parson-naturalist.

But then it happened. In 1831, Darwin received an invitation to accompany Captain Fitzroy on the second *Beagle* expedition. Darwin wrote in his *Autobiography* that before leaving he "did not then in the least doubt the strict and literal truth of every word in the Bible." After nearly five years of collection, observation, and seasickness, he returned to England, and David Quammen's new biography *The Reluctant Mr. Darwin* begins with this return.

When considering the number of existing biographies of Darwin, one may wonder what is left to say. However, Quammen's biography, while not revisionist, is noteworthy for several reasons. At 250 pages, it is concise and manageable, especially compared to Adrian Desmond and James Moore's 800 pages or Janet Browne's 1000-page treatment. Also, more than a biography of the man, Quammen's lucid and engaging book is the history of an idea — the "marvelous and shocking and grim" idea of natural selection. Quammen provides just enough biographical detail to convey the birth of this idea in the context of a great deal of hesitation and reluctance on Darwin's part.

With his characteristic flair for metaphor, Quammen entitles the first chapter "The Fabric Falls," and writes that for two years after the *Beagle* voyage, Darwin "lived a strange double life, like a spy in the corridors of the British scientific establishment, which at that time was closely attuned to Anglican orthodoxy and grounded in the tradition of natural theology." In 1837, an important breakthrough occurred when John Gould examined the bird specimens from the Galápagos Archipelago. Darwin had thought that one group represented an assortment of wrens, grosbeaks, orioles, and finches, but they were all finches, thirteen species, closely related but distinct, and all unknown to science. Also, three distinct species of mockingbird were nestled in the collection, and, unlike the finches, the mockingbirds had been carefully tagged. Each species inhabited a different island.

Another breakthrough occurred in 1844, when Joseph Hooker examined the old plant specimens from the *Beagle* and found that their island-by-island diversity contradicted the preconceived notions of species radiating from a center. Darwin wrote, "At last gleams of light have come & I am almost convinced (quite contrary to opinion I started with) that species are not (it is like confessing a murder) immutable." Quammen writes that this was a daring admission, "cast in sheepish understatement and contradicting one of the fundamental tenets of British natural theology." At that time, Darwin completed a 189-page draft of his species theory, tucked it away, and seemed to stop.

In speculating on the reasons for what is referred to as "Darwin's Delay," Quammen continues to examine the tensions between Darwin's class and status and the political implications of his work. As a gentleman and patriarch, Darwin was part of the establishment working in a political climate in which Church and government feared the Chartists and street agitators bolstered by Lamarckism and other such subversive ideas. As the law of the land, Christianity helped to keep the lower orders in check; anything that challenged the Church was seditious. Darwin was not only afraid to publish, he wanted no part of this class warfare. The evolutionary radicals in the public arena were not his kind of people.

In 1846, Darwin began to dissect barnacles, and because of his reputation and vast network of contacts, he was able to obtain them from all over the world. In contrast to his former belief regarding the rarity of variation, he discovered that barnacles were highly variable, and Quammen writes, "Here they were, the minor differences on which natural selection works." After almost eight years of barnacle work, his volumes won the Royal Medal for Natural Science, providing even more scientific esteem and credibility from the establishment.

Darwin had sixteen years to refine the ideas he had outlined in 1842 and drafted in 1844. He had fathered nine children, buried two, and published eight books. Why not publish? Instead, he started to breed pigeons.

Quammen compares Darwin to a kiwi, a bird that lays a disproportionately large egg. Not only was it large, but Darwin postponed and delayed and then published only when forced to do so. When Alfred Russel Wallace independently developed the idea of evolution by natural selection, Quammen writes that Darwin responded with surprise, nausea, and despair. In 1858, the Darwin-Wallace material was read before the Linnean Society and published in the society's *Journal of Proceedings* two months later — and triggered no immediate reaction. In 1859, just ten months after the Wallace scare, Darwin published *Origins*, writing, "I am *infinitely* pleased & proud at the appearance of my child."

The idea of descent of species from common ancestors became widely accepted soon after *Origins*, but natural selection did not. Natural selection as the differential reproductive success resulting from small, undirected variations served as the chief mechanism of adaptation and divergence — but it lacked purpose or design and challenged not the existence of a Divine force, but the godliness of humans. The coinage of such words and phrases as "agnosticism" by Thomas Huxley and "survival of the fittest" by Herbert Spencer indicates what a profound shift was taking place in intellectual and scientific circles.

Quammen calls *Origins* one of the most influential books ever written, provoking the most cataclysmic change in human thinking in four hundred years. He regularly discusses the incompatibility of Darwinian evolution and Christianity, writing that scientific insight and religious dogma "had never come more directly into conflict." In his introduction, he notes 2004 Gallup poll results revealing that 45 percent of Americans interviewed were creationists and 38 percent theistic evolutionists. Only 13 percent were materialistic evolutionists, and these results remained virtually unchanged over the course of a generation. Quammen writes that such results represent "an extreme level of skepticism and willful antipathy," but perhaps we can use Darwin's reluctance and delay to better understand this contemporary unwillingness to accept such a well-established scientific discovery.

Nancy Cervetti
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Avila University
Kansas City, MO 64145

Letters to the Editor

Cover Art for December Issue

In your December issue of *Bioscene* I was given credit for naming the two house sparrows pictured on the cover. Higher on the branch there is also a female house finch. Both are very common in cities and towns and they provide us with viewing pleasure throughout the year.

John Rushin,
Department of Biology
Missouri Western State University
St. Joseph, MO 64507

Editorial

At the 2002 ACUBE annual meeting, my colleague Dr. Greg Fitch and I gave a presentation about an assessment plan that our department was developing. One of the issues that arose in the discussion was how to assess understanding about evolution by means of natural selection. I had recently given an examination in our first year survey class where 3/4 of the class embraced Lamarckian thinking despite much class time devoted to evolution. This was at the height of the intelligent design assault on public school science curricula. A senior member of the audience said that he had been wrestling with the topic for over 30 years and that if we figured out a way to deal with it, let him know. While it was comforting to know that we were not alone, it was frustrating that the centerpiece of modern biology continues to be a black hole for much of the student population.

Stover and Mabry (2007) address this problem (p 10, this *Bioscene*) relying on an historical and multi-faceted approach to tackle the misperceptions that students have going into the course. They conclude that teleological thinking is more readily embraced by college level students and that repeated exposure to evolutionary thinking, including the historical development of the concept, is the remedy to understanding modern biology.

It is clear that for biology educators this will be an on-going struggle for years to come. Popular culture and even non-science educators bring together Lamarck, Social Darwinism, and Darwinism in a mixture that seems to linger in students' minds far longer than the voyage of the *Beagle* and the writings of its naturalist. Even biology educators use teleological language to drive home concepts other than evolution. Individuals (including this author) describe acquired immune responses in goal-oriented language. Articles in popular science magazines describe fertilization in terms of an argument and rapprochement between two individuals, the sperm and the egg. While this drives home the concept being discussed, it also reinforces teleological thought.

Is it hopeless? Certainly not! The solution for us as educators is to: (1) continue to discuss the problem; (2) continue to test methods of addressing the problem; and (3) continue to develop assessment strategies to see if students are learning. It is clear that one of the weaknesses of the Darwinian paradigm that creationists have exploited is that Darwinism is buried within much of our survey course content. Pick up a typical college biology textbook and you'll see that evolution by natural selection is acknowledged in the introductory chapter and then buried between cells, genes, and surveys of organisms. Lamarck is part of the history of the development of biological thought and so students link the two; bringing long-necked giraffes and Galapagos finches together in a comfortable synthesis that remains long after grades are posted.

If Darwinian theory is the cornerstone of modern biology, then it needs to be brought up continually in textbooks and in lecture. Stover and Mabry offer one approach to coverage of this topic. Others must be proposed and discussed. An excellent opportunity will be during this year's meeting of ACUBE at Loras College in Dubuque, Iowa, this October. Also, this journal welcomes articles describing successful and unsuccessful attempts at teaching this concept.

Finally, because the buzzword in higher education right now is "assessment," effective assessment methods of learning must be developed. I know that I can teach evolution as well as design assignments and exam questions that require students to memorize bits and facts about natural selection. However, effective assessment that leads to classroom change and student learning will take considerable effort. Again, I think this is a matter that bears repeated conversation about what works.

I know that creationists will continue to challenge the teaching of evolution. I also know that not struggling with this problem in education will embolden creationists and their offshoots. In fact, their latest assaults involve going to legislations and public school boards and promoting what is now called "academic freedom" legislation. In order to deal with this, the general public must be informed about what evolution and natural selection are. Since many in the general public now hold college degrees and have experienced at least one college science course, it is our duty to make sure these educated members of society understand what good science is and that teleological thinking is not good science.

Stephen S. Daggett
Bioscene editor

Association of College and University Biology Educators
51st Annual Meeting

Loras College, Dubuque, Iowa
Thursday, October 4 – Saturday, October 6, 2007

Call for Presentations
Conference Theme: Learning by Doing – Integrating Teaching and Research in the Biology Classroom

One of the most significant developments in science education in recent years has been the integration of research activities into the science classroom. Examples range from the addition of a short investigative module in a traditional lab, to semester-long class projects in which students contribute to original research intended for publication. The benefits of this approach to student learning, motivation and understanding of the scientific process have been well documented. However, open-ended, investigative projects can present many challenges to an instructor.

We invite you to submit a paper, poster or workshop on ways that you have combined the skills and approaches of the research scientist into the teaching laboratory and classroom. Do you have a research system or approach that is particularly engaging and motivating for students? How have you modified your courses to include research-rich activities? What types of projects have you found to be most effective in promoting student learning? What methods have you used to assess investigative projects? Please plan to share your experiences in the classroom and learn from others at the meeting.

Proposal Submission: All presentation proposals should be submitted via email to the program chair, Pres Martin (email address - pmartin@hamline.edu). An electronic version of the proposal form can be downloaded from the ACUBE web site – ACUBE.org/meeting/proposal. Alternatively, send the following information in an email to pmartin@hamline.edu.

Presenter: Please provide name, address, phone number and email address.
(Also provide name, address, phone and email of any co-presenters)

Proposal Title:
Presentation type (indicate one): Poster, 45 minute paper, or 90 minute workshop
Equipment needed: All rooms are equipped to connect a laptop computer to an LCD projector. Please list any other computer or AV equipment needs, and any special room requirements (multiple computer workstations, wet lab, etc.)

Abstract: Attach a 200-250 word abstract of the presentation to the email.

Proposal Deadline: The deadline for proposals is **July 15, 2007**. Please submit proposals as early as possible to assure that you will get your choice of presentation format. If space for papers or workshops is filled, you may be asked to use a different format for your presentation.

ACUBE

Association of College and University Biology Educators

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MAJOR INTERESTS

- ☐ 1. Biology
- ☐ 2. Botany
- ☐ 3. Zoology
- ☐ 4. Microbiology
- ☐ 5. Pre-professional
- ☐ 6. Teacher Education
- ☐ 7. Other ____________

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