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Indiana University –
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Cover image: Cover image of the fruit of *Tabernaemontana arborea* (Apocynaceae) was taken by Paul Pickhardt near the Bladen River in southern Belize.

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The Association of College and University Biology Educators (ACUBE) focuses on undergraduate and graduate biology education. Members of ACUBE share their ideas, concerns, and course innovations; present their work at the annual meeting; publish their work in *Bioscene*, our peer reviewed journal; and participate in the friendly collegiality of the organization.

The objectives of ACUBE are:

1. To further the teaching of the biological sciences at the college and other levels of educational experience;
2. To bring to light common problems involving biological curricula at the college level and by the free interchange of ideas; endeavor to resolve these problems;
3. To encourage active participation in biological research by teachers and students in the belief that such participation is an invaluable adjunct to effective teaching; and
4. To create a voice which will be effective in bringing the collective views of college and university teachers in the biological sciences to the attention of college and civil government administrations.

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ARTICLES

Presenting Global Warming and Evolution as Public Health Issues to Encourage Acceptance of Scientific Evidence

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Abstract: Although evidence supporting anthropogenic global warming and evolution by natural selection is considerable, the public does not embrace these concepts. The current study explores the hypothesis that individuals will become more receptive to scientific viewpoints if evidence for evolution and implications of global warming are presented as issues of public health. Non-science majors, nursing students, and freshman biology majors from two similar institutions answered pre- and post-test survey questions addressing the autism-vaccine connection, public health issues related to global warming, and public health issues associated with evolution by natural selection. Pretest questions elicited simple yes/no responses, whereas post-test questions were presented with relevant public health-related information and required students to articulate specific rationales. Student responses were categorized as either “evidence-based” or “non-evidence-based.” Only the natural selection question produced post-test responses that were significantly different from pretest responses. There were significantly more post-test “evidence-based” responses to the natural selection question in all three student groups. Results indicate that the presentation of controversial topics, particularly evolution, in the context of public health could be used to encourage public acceptance of scientific viewpoints.

Key words: Global warming, evolution, autism, public health

INTRODUCTION

The Pew Research Center for the People and the Press (PRCPP) is an independent opinion research group that studies attitudes toward the press, politics, and public policy issues. In collaboration with the American Association for the Advancement of Science (AAAS), the PRCPP conducted a phone survey of 2,001 adults from April 28 to May 12, 2009 to assess public perceptions of specific scientific issues. On the issue of global warming, 11% of those surveyed claim there is no evidence that the earth is warming. While 85% acknowledge the warming trend, only 49% agree that the warming is due to human activity. Thirty-six percent of the surveyed adults believe that the warming is part of a natural cycle. Regarding the topic of evolution, 31% of those surveyed reject the concept outright. While 61% acknowledge the evolution of living organisms, only 32% agree that evolution is due to the process of natural selection. Twenty-two percent of the surveyed adults believe that evolution is guided by a “supreme being.” Although public perceptions of certain issues seem incongruent with scientific evidence, the public, in general, seems to respect the scientific process. Eighty-four percent of those surveyed believe that science has produced knowledge that benefits society. When asked for specific examples, 52% cite advances in public health, including the development of vaccines. When

asked directly whether vaccination of children should be required, 69% of those surveyed answer in the affirmative (PRCPP, 2009). Clearly, the public is very supportive of healthcare-related science. Perhaps they would be more likely to accept evidence-based explanations of more controversial scientific issues if those issues were presented in the context of public health.

In the last decade, an anti-vaccine movement has received considerable media attention (Judelsohn, 2007). Included in the movement are those who blame the MMR (mumps-measles-rubella) vaccine for an apparent autism epidemic. Autism is a neurological disorder, typically diagnosed early in life, involving severe deficits in social skills and behavior (Novella, 2007). In the 1990s, the number of autism diagnoses increased from between one and three cases per 10,000 to between 30 and 60 cases per 10,000 (Rutter, 2005). During the same time period, the number of vaccines routinely given to children also increased. This led some to assume causation from correlation (Novella, 2007). A published study by Andrew Wakefield and colleagues (1998) suggested a connection between the MMR vaccine and autism. Although the study was small, it received a great deal of media attention. Subsequent to the Wakefield publication, many follow-up studies have been performed, but none of them have demonstrated a link between the vaccine and the

developmental disorder (Taylor et al., 1999; Dales et al., 2001; Madsen et al., 2002; Honda et al., 2005; Hornig et al., 2008). In 2004, 10 of Wakefield's co-authors on the 1998 paper withdrew their support for its conclusions. Furthermore, the editors of *Lancet*, the medical journal in which the paper was published, also withdrew their endorsement of the paper, citing a conflict of interest for Wakefield. Specifically, at the time of the paper's publication, Wakefield was conducting research for a group of parents of autistic children who were planning to sue MMR vaccine producers for damages (Murch, 2004). Britain's General Medical Council investigated Wakefield and ruled that he acted "dishonestly and irresponsibly" in doing his research, prompting the editors of *Lancet* to issue a full retraction of the 1998 paper (*Lancet*, 2010). According to epidemiologists, the autism "epidemic" of the past 10-15 years is best explained by changes in the way the disorder is diagnosed. It is now referred to as "autism spectrum disorder" and includes milder developmental disorders that had not been previously diagnosed as autism (Taylor, 2006). The issue of autism, and its purported association with certain vaccinations, is obviously a matter of public health.

While there is no shortage of opinion in the debate on whether the earth is warming and, if so, whether that warming is due to human activity, the issue of global warming and the role that humans play in the process is rarely presented as a public health concern. However, since the causes and potential consequences of increased global temperature are scientific issues, conclusions regarding those issues should be based on the best available empirically-collected data. The data, peer-reviewed and published in scientific journals, suggest that global warming is a fact (Dowdeswell, 2006; Overpeck et al., 2006), and the warming is most likely due to human activity (Sarmiento and Wofsy, 1999; Jordan, 2007). Published research indicates that the most likely cause of climate change is an acceleration of the greenhouse effect, with more solar energy being retained than is radiated back into space (Jordan, 2007). The acceleration is almost certainly a result of the increased production of greenhouse gases (primarily carbon dioxide) associated with the burning of fossil fuels (Sarmiento and Gruber, 2002; Epstein, 2004). Potential repercussions of increased global warming have also been addressed in the primary literature. A complete melting of the Greenland ice sheet would result in a sea level rise of approximately 22 feet (Church et al., 2001). Changes in the "oceanic conveyor belt," which governs both surface and deep water currents, could affect major regional climates. Consequently, current temperate areas could become much cooler (Stocker et al., 2001). Finally, climate change may produce profound consequences for public health. Warming trends can expand the geographic distribution of

infectious agents, and extreme weather events can spawn clusters of disease outbreaks. Diseases carried by mosquitoes are particularly sensitive to weather conditions. Warmer temperatures increase the insects' reproductive activity, protect their eggs and larvae from cold stress, and increase the rate at which pathogens mature within them. Extended droughts can devastate populations of insect predators (amphibians, dragonflies), and subsequent floods can contaminate clean water supplies and create new mosquito breeding sites, further encouraging transmission of diseases like malaria, dengue fever, and West Nile virus (Epstein, 2004).

Like global warming, the concept of evolution by natural selection is controversial in the eyes of the public. Furthermore, like global warming, the issue of evolution is rarely addressed as a matter of public health. There are many myths regarding the theory of evolution (i.e. it's just a theory, people come from monkeys, intelligent design is science, etc.). In some cases, the myths are perpetuated because evolution is misinterpreted or misrepresented by high school teachers, religious leaders, and the media (Smith and Sullivan, 2007). The theory of evolution is a fundamental, unifying theme in the sciences. Evidence supporting the theory is robust and widely accepted. There are literally thousands of research studies published over the last century and a half, the conclusions of which support it. The mechanism that drives the evolutionary process is best described by Charles Darwin's theory of evolution by natural selection. The concept of natural selection is based on the idea that individual organisms within populations vary in terms of physical characteristics. Due to the traits they express, some individuals will be better adapted to their local environments. Consequently, better adapted individuals will survive longer and will produce more offspring. The offspring will inherit adaptive traits, and the frequency of those traits will increase in the population. Evolutionary theory provides a framework within which many diverse concepts, including issues of public health, are integrated and explained. Since the 1940s, we have been fighting bacterial infections with antibiotics, toxins that destroy specific components of bacterial cells. Unfortunately, many bacterial strains have become resistant to the antibiotics that were toxic to them in the past. This is a classic example of natural selection. There is variation within any bacterial population. Some individuals will be slightly more resistant to treatment than others. Antibiotics (especially when overused or used inappropriately) will kill most, but not all, individuals in the bacterial population. Consequently, the most resistant bacteria will survive and reproduce, and the "resistance" characteristic will become more prevalent (Ewald, 1994). Effects of natural selection can also be seen in human populations. Sickle-cell disease is a genetic

disorder that affects red blood cells. People suffering from sickle-cell disease have difficulty transporting oxygen through the circulatory system. In the United States, sickle-cell disease is much more common in African Americans than in the general population. Roughly 10% of all African Americans are carriers of the sickle-cell trait. Why? In tropical Africa, where malaria is a major cause of death, it is actually advantageous to be a carrier of the sickle-cell trait. The abnormal red blood cells do not make good hosts for malaria-inducing microorganisms. Therefore, Africans who carry the sickle-cell trait are more likely to survive and reproduce, ensuring that the sickle-cell condition is passed to future generations (Allison, 2004; Harris and Malyango, 2005).

The public, in general, believes that science benefits society, particularly in the arena of healthcare. Even though disproportionate media coverage has been given to the anti-vaccine movement, public support of childhood vaccination continues. However, although the evidence supporting anthropogenic global warming is more than ample, and the evidence supporting evolution by natural selection is overwhelming, the general public has yet to fully embrace these concepts. The current study explores the hypothesis that individuals will become more receptive to scientific viewpoints if the evidence for evolution and the implications of global warming are presented as issues of public health.

METHODS

In accord with official guidelines regarding research and educational practices involving human participants, this study was classified as “exempt from review” by the Institutional Review Boards of Davis & Elkins College (D&E) and Lenoir-Rhyne University (LR).

Student Profile

During the fall semester of 2009 and the spring semester of 2010, a total of 227 students, 69 from D&E and 158 from LR, participated in the study. Both institutions are small, private, liberal arts colleges located in the southeastern United States. Students were enrolled in either Basic Biology for non-science majors (n=87), Microbiology for allied health majors (n=77), or Principles of Biology II for science majors (n=63). At both institutions, Basic Biology has no prerequisites, Microbiology has a two-semester sequence of human anatomy and physiology as a prerequisite, and Principles of Biology II has Principles of Biology I as a prerequisite. Basic Biology students at both institutions were non-science majors, a majority of whom were underclassmen. Microbiology students at both institutions were almost exclusively nursing or pre-nursing majors, while Principles of Biology II students at both institutions were second-semester freshman biology majors. The courses were taught very similarly at the two institutions. Author MLM

developed all three courses at D&E before moving on to LR. Authors LBM and SKS took over teaching the three courses at D&E, using syllabi, PowerPoint slides, and exams from previous semesters to follow the format established by MLM.

Pretest

Each course, at both institutions, incorporated three lecture exams, plus a final exam. Spacing between exams was fairly consistent between courses and institutions. Survey questions used for this study were attached to the exams. Completion of the survey questions was voluntary and had no effect on students' exam grades. As part of their first exam, early in the fall semester of 2009 or the spring semester of 2010, students answered the following Yes/No questions regarding autism, global warming, and natural selection: Do you believe that the MMR (mumps-measles-rubella) vaccine is responsible for the significant increase in diagnosed cases of autism over the last 10-15 years? Do you believe that global climate change, if left unchecked, will have devastating effects on human populations? Do you believe that Charles Darwin's theory of evolution by natural selection adequately explains how living organisms change over time? The autism question served as a positive control, as it obviously deals with an issue of public health. Authors SKS and MLM categorized the student responses from both institutions as either “evidence-based” or “non-evidence-based.” “Evidence-based” answers were deemed consistent with current scientific information. An answer of “No” to the question regarding a potential link between autism and the MMR vaccine was considered “evidence-based.” “Yes” answers to the questions regarding the impact of global warming on human populations and natural selection as an adequate explanation for biological change over time were also considered “evidence-based.”

Post-test

Attached to subsequent exams, the same questions were presented separately to students in the three classes. Autism was addressed in a survey attached to the second exam, global warming was addressed with the third exam, and evolution was addressed at the time of the final. Of the three topics highlighted by the current study, evolution by natural selection was the only one covered (to varying degrees) in each of the three classes. In these later presentations, the survey questions were preceded by paragraphs summarizing relevant scientific data. For the global warming and evolution questions, the presented data were specifically related to public health. Students were asked to justify their Yes/No responses to the questions by answering “Why?” Totals of 214, 216, and 214 students provided complete answers to the autism, global warming, and natural selection questions, respectively. Authors SKS and MLM evaluated the student responses from

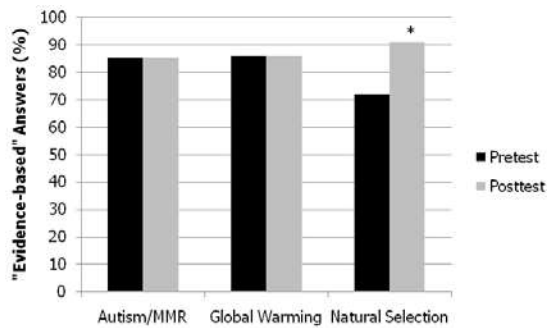


Fig. 1. Percentages of “evidence-based” responses by Basic Biology students (*Significantly different from pretest, $P < 0.05$).

both institutions. As in the pretest, Yes/No responses were categorized as either “evidence-based” or “non-evidence-based.” It is possible that students could provide an “evidence-based” response for the “wrong” reason. For example, an individual might agree that the global climate is changing (an “evidence-based” response), but his/her conclusion might be based solely on the opinion of a popular political candidate (anecdotal evidence). Therefore, “evidence-based” rationales were subcategorized as being based on the evidence presented in the survey, based on evidence that was not presented in the survey, based on anecdote, or based on misinterpretation. Remaining miscellaneous “evidence-based” rationales were subcategorized as “other.” “Non-evidence-based” rationales were subcategorized as being based on anecdote or based on misinterpretation. Remaining miscellaneous “non-evidence-based” rationales were subcategorized as “other.”

Statistics

In an effort to ensure inter-rater reliability, Cohen's Kappa coefficient (κ) was calculated for the categorical evaluation of student rationales. $\kappa > 0.75$ was considered reliable (Portney and Watkins, 2000). Differences between the two institutions (pretest and post-test responses) were determined via analysis of variance (ANOVA). Furthermore, for each of the three classes, differences between pretest and post-test responses to the three survey questions were tested by univariate, repeated measures ANOVA. $P < 0.05$ was considered statistically significant.

RESULTS

Pretest “evidence-based” responses are presented in Figures 1-3. These figures represent combined responses from both institutions. No significant differences were found between the two institutions or among the three classes. In each class, at least three quarters of participating students (75-86%) selected the “evidence-based” responses for the autism and global warming pretest questions, whereas about two thirds of participating students (61-72%) in each class selected the “evidence-based” response for the natural selection pretest question.

There was one significant difference within one of the groups. The Principles of Biology class from D&E had a significantly higher percentage of “evidence-based” responses than the corresponding LR class (87% vs. 63%). The exact reason for this difference is unclear. While both classes consisted of second-semester freshman biology majors, it should be noted that the D&E class ($n=15$) was considerably smaller than the corresponding class at LR ($n=48$).

Post-test “evidence-based” responses are also presented in Figures 1-3. Again, no significant differences were found between the two institutions or between the three classes. In each class, at least 80% of participating students provided “evidence-based” responses for the autism, global warming, and natural selection post-test questions. Only the natural selection question produced post-test responses that were significantly different from pretest responses. There were significantly more post-test “evidence-based” responses to the natural selection question in all three classes.

Student rationales for post-test responses are presented in Tables 1 and 2. The data are presented as a percentages of the total number of students (all three classes combined) providing “evidence-based” (Table 1) and “non-evidence-based” (Table 2) responses to each question. Examples of representative rationales are provided. Inter-rater reliability (κ) was calculated as 0.89, 0.84, and 0.83 for the autism, global warming, and natural selection rationales, respectively. No significant differences were found between the three classes. Academic background and interest in science aside, non-science majors, freshman biology majors, and nursing students provided “evidence-based” responses to the three questions with roughly the same frequency and rationalized their choices in much the same way. Furthermore, each question elicited “evidence-based” responses with about the same frequency and with very similar rationales.

As indicated by Table 1, 60% of participating students justified a post-test “No” to the autism question by citing the evidence that had been presented to them. Another 16% cited evidence that

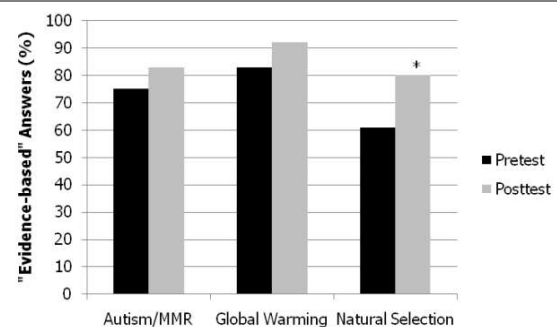


Fig. 2. Percentages of “evidence-based” responses by Microbiology students (*Significantly different from pretest, $P < 0.05$).

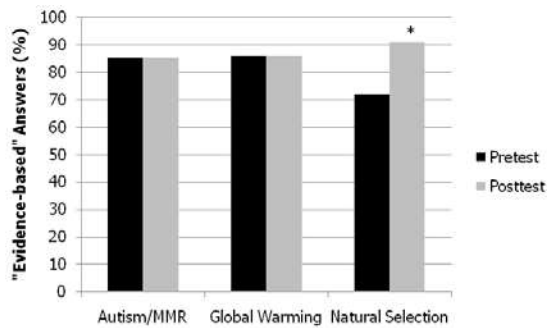


Fig. 3. Percentages of “evidence-based” responses by Principles of Biology students. *Significantly different from pretest ($P < 0.05$).

was not included in the survey as a rationale. Of this other evidence, genetic factors were cited most frequently as likely causes of autism. A few students elected to describe personal experiences, or anecdotes. Others simply misinterpreted the question, providing rationales that directly conflicted with their “No” responses. As indicated by Table 2, a small percentage of participating students misinterpreted the autism question, answering “Yes” while giving a conflicting rationale. Some students justified a “Yes” response by claiming that all vaccines are either unnecessary or harmful, and a few others resorted to anecdote.

As indicated by Table 1, 57% of participating students justified a post-test “Yes” to the global warming question by citing the evidence that had been presented to them. Another 20% cited evidence that had not been included in the survey as a rationale. Of this other evidence, melting ice caps and rising sea levels were cited most frequently as likely consequences of climate change that could devastate human populations. To justify a post-test “No” to the global warming question, some participating students stated that humans will be able to successfully adapt to climate change. Others justified a “No” response by claiming that the current

warming trend is simply part of a natural cycle. A very small percentage of the surveyed students provided anecdotal responses.

As indicated by Table 1, 57% of participating students justified a post-test “Yes” to the natural selection question by citing the evidence that had been presented to them. Another 18% cited evidence that had not been included in the survey as a rationale. Of this other evidence, teleological reasoning was offered most frequently as an explanation for adaptation. To justify a post-test “No” to the natural selection question, some participating students referred to anecdotal evidence, and a few others cited a conflict between Christianity and Darwin’s theory.

DISCUSSION

As stated in the introduction, the current study explores the overall hypothesis that individuals will become more receptive to scientific viewpoints if evidence is presented in the context of public health. The autism question was, essentially, a positive control. Regardless of one’s opinion on the connection between autism and the MMR vaccine, it is clearly a public health issue. A large majority of students (85% of Basic Biology, 75% of Microbiology, and 84% of Principles of Biology) answered “No” to the pretest question regarding autism, indicating they do not believe there is a connection between the MMR vaccine and the developmental disorder. A summary of the Wakefield study and its aftermath preceded the autism question on the post-test. Knowledge of the conflict of interest accusation, the withdrawal of support by Wakefield’s co-authors, and the failure of other studies to replicate his data, did not significantly affect student responses (Figures 1-3). As indicated earlier, the autism question clearly represents a public health issue and requires no “framing” as such.

Table 1. Percentages of “evidence-based” post-test rationales and representative examples.

	Autism/MMR	Global Warming	Natural Selection
Based on evidence presented in survey	60% ; “The original study cannot be supported by subsequent studies.”	57% ; “Warmer temperatures increase the disease-carrying abilities of certain insects.”	57% ; “It explains why individuals with advantageous traits survive and pass the traits on to their offspring.”
Based on evidence not presented in survey	16% ; “The only link between the two is the sudden spike in autism cases occurring after routine vaccinations.”	20% ; “Due to the warmer climate, ice caps are melting, dumping fresh water into our oceans.”	18% ; “There is evidence in the fossil record, embryological structures, and comparative DNA.”
Based on anecdote	2% ; “I had the MMR vaccine, and I didn’t get autism.”	2% ; “Every time I tune in to the Discovery Channel, they seem to be talking about global warming.”	3% ; “Working in forestry, I have witnessed the products of natural selection.”
Based on misinterpretation	2% ; “If the vaccine is supposed to help with autism, then it couldn’t cause autism.”	1% ; “The paragraph addresses a few of the positive effects of climate change. However, the negatives outweigh the positives.”	3% ; “It’s just a theory. Those pathogens probably had the resistant gene from the beginning.”
Other	4%	5%	5%

Table 2. Percentages of “non-evidence-based” post-test rationales and representative examples.

	Autism/MMR	Global Warming	Natural Selection
Based on anecdote	3%; “I have always heard that a vaccine is linked to autism.”	2%; “I listen to information. I just don’t always believe the facts I hear.”	5%; “The fossil record isn’t nearly as complete as scientists would like you to believe.”
Based on misinterpretation	5%; “If they withdrew because of a conflict of interest, red flags go up.”	1%; “Effects from the Earth are going to impact human populations.”	1%; “Bacteria have become resistant to antibiotics because they have been overused.”
Other	8%; “In general, I think that vaccines can be harmful.” “If autism rates went up after vaccines were given, there must be a connection.”	12%; “The current warming trend is just part of the natural climate cycle.” “Humans will be able to adapt to the changing climate.”	8%; “As a Christian, I cannot accept the theory of evolution.” “I believe that factors other than natural selection are more important for adaptation.”

One specific aim of the current study was to explore the hypothesis that individuals will become more receptive to the current scientific consensus on global warming if the implications of climatic changes are presented as issues of public health. Consistent with the PRCPP national poll, roughly 85% of all participating students acknowledge that the earth is warming. Eighty-six percent of Basic Biology, 83% of Microbiology, and 76% of Principles of Biology students answered “Yes” to the pretest question regarding global warming, indicating they do believe that unchecked climate change will have devastating effects on human populations. A summary of potential climate change-related consequences for public health preceded the global warming question on the post-test. Knowledge of an expanded distribution of infectious agents, weather-related disease outbreaks, and contaminated clean water supplies did not significantly affect student responses (Figures 1-3). Apparently, the presentation of global warming as a public health issue is not sufficient to change the perceptions of global warming deniers. It is interesting to note that a small number (roughly 3%) of participating students justified a “No” response to the global warming question by claiming that the current warming trend is simply part of a natural cycle. This is in stark contrast to the 36% of surveyed adults in the national poll who believe that the warming is part of a natural cycle. Deniers of anthropogenic global warming have suggested that solar cycles might be responsible for the warming process. However, published data refute this hypothesis (Ramaswamy et al., 2001; North et al., 2004). There is also speculation that natural cycles of the earth itself might be responsible for the change in global temperature. The El Niño Southern Oscillation might play a role, but there is no convincing evidence to support it (Stocker et al., 2001).

Another specific aim of the current study was to explore the hypothesis that individuals will become more receptive to the current scientific consensus on evolution if the evidence for natural selection is presented as an issue of public health. Sixty-one percent of surveyed adults in the PRCPP national poll acknowledge the evolution of living organisms, while

only 32% agree that evolution is due to the process of natural selection. In the current study, 72% of Basic Biology, 61% of Microbiology, and 69% of Principles of Biology students answered “Yes” to the pretest question regarding natural selection, indicating they do believe that Darwin’s theory adequately explains how living organisms change over time. Public health-related examples of natural selection preceded the natural selection question on the post-test. Knowledge of the evolution of antibiotic resistance and the population genetics of sickle-cell trait expression significantly affected student responses (Figures 1-3). Most students (57%) rationalized a “Yes” response to the natural selection question by citing the public health-related information that had been presented in the survey. Some students (18%) cited other evidence for evolution by natural selection, including the fossil record, homologous anatomical structures, and DNA sequencing. It is interesting to note that teleological reasoning was offered quite frequently as an explanation for biological adaptation. A teleological 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. Natural selection, to individuals with this perspective, is a process by which nature selects individuals who are in need to become beneficiaries of helpful changes (Greene, 1990). Previous research has demonstrated that even upper level biology majors can fall into a teleological mode of thinking (Stover and Mabry, 2007).

Both global warming and evolution are matters of science, and conclusions regarding these matters must be based on empirical evidence. The intent of our study was to emphasize the aspects of evolution and global warming that are relevant to human health in an attempt to capitalize on the public’s respect for healthcare-related science. On the topic of global warming, it appears that our efforts to emphasize public health did not have an impact on students’ ability or willingness to draw an evidence-based conclusion about this issue. A large majority of the surveyed students were already convinced that global warming is real, that it is a result of human activity, and that, if left unchecked, it will have devastating

consequences on human populations. In terms of evolution, our approach seemed to be much more effective. There were significantly more post-test “evidence-based” responses to the natural selection question in all three classes, even after subtracting responses with “misinterpretation” rationales. While it is possible that other explanations exist for this increase, including coverage of evolutionary topics in each of the three classes, presentation of the issue with a public health perspective is a possible reason for the difference we saw. The majority of “evidence-based” rationales were related to antibiotic resistance and other public health concerns. Thus, these results suggest that, by presenting evidence in the context of public health, it may be possible to convince “antievolutionists” or those who doubt the relevance of natural selection in the evolution of organisms that there is merit in the scientific viewpoint. Given that the public health perspective did not influence the frequency of “evidence-based” post-test responses to the global warming question, however, more research is needed to determine the number and range of issues for which one might successfully use the public health perspective strategy for getting students to see the merit of scientific evidence.

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Inquiry-based Investigation in Biology Laboratories: Does Neem Provide Bioprotection Against Bean Beetles?

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Abstract: We developed an inquiry-based biology laboratory exercise in which undergraduate students designed experiments addressing whether material from the neem tree (*Azadirachta indica*) altered bean beetle (*Callosobruchus maculatus*) movements and oviposition. Students were introduced to the bean beetle life cycle, experimental design, data collection, and reporting practices. At the end of the semester students exhibited increases in specific areas such as self-confidence in science process skills related to the design and implementation of experiments, as well as scientific reasoning skills.

Key words: Bean beetles; neem; inquiry skills; experiment design; biology; instructional strategies; inquiry based learning

INTRODUCTION

Inquiry-based teaching methods reportedly inspire students to develop curiosity, investigative abilities, and teamwork skills. The inquiry-based method provides students with opportunities to actively engage in problem solving rather than simply applying memorized concepts to preconceived experiments (Rehorek, 2004). In inquiry-based studies, students usually work in teams to explore an issue and develop a scientific question that is solved by applying the scientific method. These activities allow students to learn by active, rather than passive, teaching methods. In the final step, students present the experimental rationale, design, and results to their peers, and respond to feedback and questions. This active form of learning is thought to enhance depth of understanding; studies have shown that students taught using an inquiry-based method score significantly higher on exams than those taught using the so-called cookbook method (Luckie, 2004; Rissing, 2009). Because of the positive impact of inquiry-based approaches on student learning, these approaches are recommended to be foundational to national changes in the undergraduate biology curriculum (AAAS, 2011).

Inquiry-based instruction, like many approaches in science teaching, is not without its challenges. Kirschner et al. (2006) contend that learning in a minimally guided environment is less effective than direct instructional guidance and maintain that changes in long-term memory are required for effective learning and that only guided instruction results in such changes. According to Kirschner et al., a guided-inquiry approach, in which students are presented with the scientific question, are tasked to

develop an experiment to test the question, and are then led as a class to an effective experimental design through leading questions, provides a more structured inquiry process than a truly open-ended inquiry. Furthermore, our experience and that of others supports the idea that undergraduate students may be capable of learning scientific content knowledge, but have little to no experience in the actual scientific process (Campbell et al., 2012), thus advocating for a guided inquiry-based approach.

As affiliates of the Bean Beetle Curriculum Development Workshop supported by the National Science Foundation (NSF), two of the authors of this study participated in a training workshop in which groundwork was laid for the development of a guided inquiry-based learning exercise using neem (*Azadirachta indica*) and bean beetles (*Callosobruchus maculatus*). The goal of the above learning exercise would be to help undergraduate students improve their understanding of the nature of science and their scientific reasoning skills. Upon our return to our home institutions, we shared our newfound knowledge with peers and formed a team to implement our guided inquiry-based activities over the course of one academic year. As part of the process we formally assessed students in the courses that included the exercise, the primary purpose being to evaluate the effectiveness of the approach. The exercise reported here can be easily adapted to students of different levels, does not require costly equipment, and results in important student gains in scientific reasoning skills and self-confidence in science process skills.



Fig. 1. Female bean beetle on bean.

Bean Beetles

Callosobruchus maculatus is an agricultural pest insect of Africa and Asia that presently ranges throughout the tropical and subtropical world (Figure 1). The larvae of this species feed and develop exclusively within the seeds of legumes (Fabaceae); hence the name bean beetle. The sexually dimorphic adults do not require food or water and spend their one to two week adult lifespan mating and laying eggs on beans. Generation times are as short as three to four weeks in a 30°C incubator. Bean beetles are widely used in research in evolutionary ecology, host-parasite relations, and sexual selection (Messina and Fox, 2011; Messina and Jones, 2011; Tuda, 2011; also see Blumer and Beck, 2011), and the bean beetle is gaining popularity as a model organism for inquiry-based undergraduate laboratory activities in ecology, evolution, animal behavior, and physiology (Blumer and Beck, 2011).

Bean beetle infestation affects stored beans causing losses in food resources and infestation is especially problematic in developing countries where beans are the main source of nutrients for the population. For example, in some parts of Africa, over 90% of stored cowpeas (*Vigna unguiculata*) are infested by bean beetles (Sallam, 2008). Therefore, preventing beetles from laying eggs on the beans while maintaining the quality of beans has been of great interest to researchers and economists.

Neem

Azadirachta indica, or the neem tree, is native to Southeast Asia where parts of the plant have found varied uses, including use as medicine, food, dental hygiene products, and as an insect repellent (Lowery and Isman, 1994; Ruckin, 1992). The active insect-repelling ingredient in the neem tree is believed to be azadirachtin, a chemical found in the highest concentration in the leaves, fruit, and seeds. Azadirachtin is considered harmless to humans (Miller and Uetz, 1998; HDRA, 1998), and neem, as well as neem products, is widely available to people whose food supplies are threatened by insects.

Although neem is widely reported as a bioprotectant, to our knowledge no scientific studies have systematically addressed the following

questions: (1) Is bean beetle behavior, e.g., movement patterns, altered by powdered neem leaves? (2) Does neem extract or powder prevent female bean beetles from laying eggs on beans? (3) If neem extract does in fact prevent egg laying, are other neem products such as neem oil as effective? (4) If eggs are laid on neem-treated beans, is the viability of the eggs affected? (5) At what concentration, if any, is the neem product maximally effective? Using a guided inquiry-based approach in an undergraduate biology lab, the experiments described here were used to preliminarily address these questions.

METHODS

Participants

The laboratory experimental protocol and the student survey methods were approved by the Institutional Review Board of Arkansas State University (#125182-1) and classified as exempt by the Institutional Review Board of Emory University. Participants included students from three sections of a sophomore-level cell biology course, (n=18, n=17, n=2), students from one section of a senior-level cell biology course (n=25; taught by the same instructor as the one teaching the sophomore-level course), and students from a sophomore-level Psychology as Science and a Profession course taught by a different instructor (n=13). The numbers provided reflect only the subsamples of students who completed the online assessments. Additionally, another subsample of these students (n=10) participated in a focus group session at the end of the semester. Due to the small number of students in each course, we combined the data from all of the courses for analysis.

Laboratory Approach

Prior to the first lab, students (n=75, representing several lab sections) took on-line pretests assessing their self-confidence in science process skills, understanding of the nature of science, and scientific reasoning skills. Students were also given material to read that provided a brief background on neem, bean beetles, and experimental design (Blumer and Beck, 2011). Each instructor gave a short pre-lab presentation on bean beetles, neem, and the methods of studying bean beetle behavior and reproduction. Students were informed that they would be gathering new information, and that the effect of neem on bean beetles had not been tested scientifically. Students were tasked with formulating one or more hypotheses that could be tested during the semester and with drafting an experiment to test the hypothesis. Additionally, students were asked to predict the outcomes for their experiments, identify and list variables and controls, and list the types of data they would need to collect to determine whether their predictions were supported.

The students' experimental objectives for this activity were:

- To determine whether the presence of neem acutely alters bean beetle movement patterns
- To determine whether the presence of neem deters oviposition (egg laying) by female bean beetles
- To test the effect of neem on egg viability

The materials needed for this exercise per student group were: male and female bean beetles (a minimum of three of each sex; initial stock cultures are available from Carolina Biological), neem leaf powder or neem oil (Organneem LLC), spray bottles and liquid detergent (if using neem oil), a magnifier or dissecting microscope, cardboard, mung or other desirable dry beans, such as black-eye peas and adzuki beans (~40 g per group; these may be purchased from local food stores), white adhesive tape, sorting brushes (Drosophila sorting brush, Carolina Biological Supply Company), plastic zipper bags, permanent markers, a digital balance, and petri dishes [3 large (150 mm) and 1 small (35 mm) per group]. An incubator (28°C), although optional, is recommended. Three to four weeks before beginning the activity, bean beetles must be cultured for sufficient numbers to be available; for detailed instructions and sample student results from the weekly activities see: *Bioprotection from Beetles: Investigating the Untapped Secrets of the Neem Tree (Azadirachta indica)*, available at <http://www.beanbeetles.org/protocols/bioprotection>.

Briefly, although experiments varied, during the first week of the laboratory exercises the students were generally instructed on how to prepare plates to observe bean beetle avoidance behavior. Then students were divided into groups, asked to propose specific experiments, and agree on a final experimental approach. Groups were given 20 minutes to outline their basic methods before discussing their proposed experiment with course instructors to ensure no two groups had proposed the same experiment. Once each experiment and its methods were approved, each group gave a brief presentation to their classmates for additional feedback.

Each group was then provided with three male and three female bean beetles placed in the center in a small culture dish (35 mm) within a large cell culture dish (100 mm). The large dish was divided into two to four equivalent regions depending on each group's experimental design, and each region was filled with beans, with type again depending on each design. Neem was introduced to the beans in one or more regions of each plate and avoidance behavior was observed and recorded: student groups divided themselves into observers for each region, timer, and recorder, and beetle movement between regions was determined. Beetles, eggs and neem treatments in each region were transferred to fresh dishes, and placed in the incubator until the next lab session. During week two, students addressed whether neem

influenced oviposition in the plates prepared the week previous by observing each bean for the presence and number of beetle eggs. During subsequent weeks, students tested the effect of neem on egg viability by counting and recording the number of emergent beetles.

Examples of experiments proposed included testing: (a) neem oil on varied bean types (pinto, lima, kidney), (b) varied neem oil application methods (neem oil applied to beans by spraying vs. beans soaked directly in neem oil), (c) the presence of filter paper vs. its absence under the beans, (d) neem oil vs. powdered neem leaves, (e) various concentrations of neem oil, and (f) neem leaf powder on various bean types (mung, pinto, black-eyed peas). Students in the upper level class presented their overall findings regarding their experiment to their peers, and reported the acceptance or rejection of their hypotheses. In the lower-level classes, students discussed their experiments and results then presented their data and interpretations within a group lab report which included descriptive statistics.

The duration of the activities can vary widely depending on the approach taken and, after the second week, these activities may be conducted concurrently with other lab exercises.

Student Assessments

We assessed the effect of inquiry-based laboratory courses incorporating the bean beetle exercise on self-confidence in process skills related to the design and implementation of experiments (Champagne, 1989), understanding of the nature of science (Murcia and Schibeci, 1999), and scientific reasoning skills of the students (Lawson et al., 2000). The student self-confidence assessment consisted of 12 statements scored on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). It addressed students' self-perceived confidence in a variety of domains including, but not limited to, their ability to answer a scientific question through experimentation, to assess methodologies, to read and understand articles and graphs on science, and to describe natural phenomena. The nature of science assessment was composed of 15 statements covering topics on experimental design, personal beliefs and attitudes about science, ethics, and professionalism that students evaluated as either correct, incorrect, or 'don't know'. Finally, the scientific reasoning assessment presented three different scientific scenarios in which students predicted outcomes and provided a rationale for their predictions. Students were given these pre-tests at the beginning of the semester. They were then given the same questions as post-tests at the end of the semester. The pre-tests also surveyed students on their previous university-level laboratory courses and on basic demographic information (i.e., gender, year in school, race/ethnicity).

Statistical Methods and Software

To determine if student self-confidence, understanding of the nature of science, and scientific reasoning skills improved over the semester, we compared pre-test scores with post-test scores using Wilcoxon signed rank tests. In addition, we determined if any of the demographic variables or past experience in previous university-level laboratory courses influenced learning gains (post-test score minus pre-test score) for each assessment with generalized linear models that included pre-test score as a covariate. Finally, we examined the relationship between student performance on the three assessments with Spearman rank correlations independently for pre-test scores, post-test scores, and learning gains. All analyses were carried out using SPSS 20 with statistical significance at $P < 0.05$.

RESULTS

Laboratory Approach

To the students' surprise, the overarching hypothesis that neem provides bioprotection against bean beetles was not supported. Most of the experiments designed and executed by the student groups did not reveal any consistent or striking difference between the compartments that contained beans treated with neem and untreated beans in deterring or attracting the bean beetles (data not shown). The experiments likewise did not reveal an influence of neem on oviposition behavior (data not shown). However, mung beans exposed to 0.75 g of neem powder showed some possible deterrent to movement that could be explored further (Figure 2). Also, after failed attempts to expose beetles to beans coated with oil, students realized that properties of the oil itself were a deterrent simply because the beetles would get stuck in the oil. Students determined that to use the oil, beans needed to be soaked and allowed to dry, or needed to be sprayed and the remaining residue removed. Beyond this, our students did not systematically study the application of neem oil, although this method of neem application may be more promising as a bioprotectant than the method of applying neem as a powder.

It should be noted that our undergraduate students had no prior compulsory statistical training;

for this reason we allowed them to calculate and report totals and percentages pooled from the entire class, which were then presented descriptively. If one were to adapt this exercise for more advanced students, Chi-Square tests for the frequency data are recommended.

Student Assessments

A comparison of pre-test and post-test data showed a significant increase in self-confidence in science process skills and in scientific reasoning skills, but not in an understanding of the nature of science (Table 1). Further pre- vs. post-test analysis of the individual statements comprising the overall confidence assessment revealed student-perceived gains in areas such as stating a testable hypothesis, providing scientific explanations for natural processes, assessing methodologies, designing experiments, describing natural phenomena, challenging authority, and providing an instance of how scientific discovery has affected society. However, they did not express increased confidence in their ability to read science, to understand science, or to interpret scientific articles and graphs.

For all three assessments, learning gains were significantly negatively related to pre-test scores. In other words, students who performed better on the pre-test showed lower gains than students who had lower scores on the pre-test. Gains in self-confidence were unrelated to previous experience in laboratory courses and demographic variables. In contrast, gains in scientific reasoning skills were significantly greater for students who had *not* previously designed experiments in their university-level laboratory courses ($P=0.021$) and for students who had taken more university-level laboratory courses ($P=0.008$). Overall, students did not show an increase in their understanding of the nature of science, as scores decreased for some students and increased for other students. Scores were significantly more likely to decrease for male students ($P=0.014$), for students who had taken more university-level laboratory courses ($P=0.041$), and students who were not seniors ($P=0.013$). However, these changes in student understanding of the nature of science should be interpreted with caution, as the assessment showed

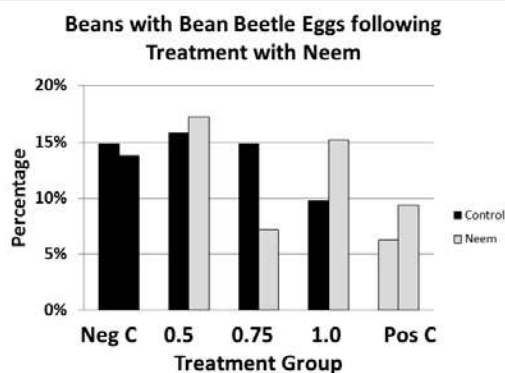


Fig. 2. Sample student-generated graph showing percentages of beans with eggs following exposure of beans to various amounts of neem powder. Beetles were placed in partitioned dishes with no neem powder on beans in either side of the partition (Neg C); varied amounts of neem powder on beans on one side of the partition (0.5, 0.75, 1.0 g) and no neem on the other side; or 1.0 g neem on beans on both sides of the partition (Pos C).

Table 1. Student learning gains in inquiry-based laboratory courses. Values are means \pm SE.

Measure	Pre-test	Post-test	Wilcoxon Signed-Rank
Self-confidence	3.22 \pm 0.10	3.72 \pm 0.11	-5.198**
Nature of Science	0.66 \pm 0.02	0.65 \pm 0.02	-0.452
Scientific Reasoning	0.47 \pm 0.03	0.53 \pm 0.03	-2.011*

Note: Self-confidence was measured on a 5-point Likert scale with 5 being the most confident. Values for nature of science and scientific reasoning are the proportion of correct answers. * $P < 0.05$, ** $P < 0.01$

low internal reliability (Cronbach's $\alpha = 0.51$), suggesting that it might not be a good instrument for measuring student understanding of the nature of science.

As might be expected, pre-test scores were significantly positively correlated for all three assessments ($P < 0.05$ in all cases). Similarly, post-test scores were significantly positively correlated ($P < 0.03$) with the exception of the correlation between self-confidence and understanding of the nature of science ($P = 0.21$). Interestingly, gains in the three assessments were not significantly correlated ($P > 0.35$ in all cases). However, Beck and Blumer (2012) found a similar result for the relationship between self-confidence and scientific reasoning skills using the same instruments.

DISCUSSION

Although none of the neem concentrations tested here had a measurable and direct effect on bean beetle deterrence, oviposition, or adult emergence, we found that the inquiry-based activity was constructive for students in several ways. For instance, students who participated in the focus group reported that the inquiry-based lab was more interesting, yet more challenging, than traditional "cookbook" labs performed in the course during the same semester. These students also shared that they were surprised when no significant differences in attraction or repulsion of bean beetles by neem occurred. They stated that they expected the instructors had known that neem would be a deterrent and were surprised to learn that the experimental outcomes were indeed completely unknown, and thus perhaps more realistic. Focus group students also commented that the exercise was beneficial in that they learned to postulate hypotheses as they creatively designed experiments. They felt comfortable presenting their ideas to peers for feedback, and believed that their critical thinking skills were enhanced as they critiqued others' ideas. Students took ownership of their experimental designs, leading to the completion of data collection and the writing of lab reports; thus increasing the students' opportunity to strengthen their scientific writing abilities. Furthermore, through their lab reports, all students were exposed to accepted scientific reporting practices using their own data.

Whereas our activity was conceived as guided inquiry-based, most existing university science lab activities accommodate the traditional approach.

Considering the growing body of studies showing the benefits of inquiry-based instruction, and given the recommended national changes in the undergraduate biology curriculum (AAAS, 2011), institutions may feel the need to convert some traditional, so-called "cookbook" labs, to inquiry-based ones (Volkman and Abell, 2003). A limitation of the present study is that we did not compare a traditional activity using bean beetles to this inquiry-based lab to determine which method improved their learning. However, based on our own experiences in teaching both types of labs, we prefer to offer inquiry based labs once students have learned some basic skills from traditional labs so that they may more constructively devote the full lab period to discussing and designing experiments using inquiry-based methods.

It was not surprising that our students with more lab experience, as well as our upper class-level students, scored better on assessments of scientific reasoning. It was also not surprising that our students reported gains in self-confidence in science, because other studies have reported gains in student confidence in communicating science using inquiry-based approaches (Brickman et al., 2009). However, it would be interesting to further explore the meaning behind some of the other student assessment data. For instance, why were gains greater for students with less lab experience? And why weren't gains in self-confidence in science process skills correlated with gains in scientific reasoning skills?

In conclusion, although unanswered questions remain, our experience supports the idea that bean beetles are an organism amenable to use in biology laboratories. We contend that using bean beetles as a model organism allows for the exploration of various scientific questions. Bean beetles are well suited for creating inquiry-based learning opportunities, especially in departments that have limited resources. Furthermore, we conclude that this laboratory exercise using neem fully engages students in the construction of experimental designs and in collaborating with other students. The laboratory exercise described here has the potential to be adapted for use in both high school and college biology departments and can provide a positive and effective learning experience for students.

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Engaging Biology Undergraduates in the Scientific Process Through Writing a Theoretical Research Proposal

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Abstract: It has been suggested that research experiences are an important element that should be included in all undergraduate Biology curricula. This is a difficult suggestion to accommodate due to issues with cost, space and time. We addressed this challenge through development of a capstone project in which Biology majors work in groups to develop novel theoretical research proposals with guidance from a faculty mentor. Though students are not directly working at the bench, they are being mentored in aspects of the scientific process such as synthesizing information from the literature, asking novel research questions, constructing logical aims, designing experiments and writing scientifically. Since this project began, we have mentored 417 students in proposal writing and have assessed their experiences through pre- and post-surveys. Students have made gains in several areas, but most notably in their ability to pose novel questions and develop an experimental plan, and in the number of professional relationships they have with faculty members. Most faculty feel positively about mentoring these projects. In our view, this approach allows programs to engage a large number of students in the scientific process, and could be adapted for use in a variety of different university or college environments.

Key words: undergraduates, capstone, Biology, proposal, grant, research, writing, experimental design.

INTRODUCTION

Reports from the National Research Council (NRC) and American Association for the Advancement of Science (AAAS) have made suggestions indicating how Biology undergraduate education should be reformed to meet the changing needs of students (National Research Council 2003; Woodin, Carter et al. 2010; American Association for the Advancement of Science 2011). A common theme has emerged from these studies, suggesting that students should be given opportunities to engage in scientific research (Lewis et al. 2003; Woodin et al. 2010). Indeed, a number of studies have demonstrated the benefits of undergraduate research, including personal and professional gains such as increased confidence, ability to think like a scientist, and gains in communication and organizational skills (Seymour et al. 2004; Hunter et al. 2009; Junge et al. 2010; Laursen et al. 2010; Lopatto 2006; Lopatto 2007). While some institutions can provide opportunities for all Biology majors to conduct independent research, this is a challenge at many institutions due to issues of space, cost and availability of faculty mentors. As a result, many programs need to employ creative approaches to allow students to experience research.

In developing approaches to provide students with a genuine research experience, it is essential to reflect on the types of skills students gain through research. Based on several studies that have evaluated the benefits of undergraduate research, the best supported benefits include an increase in self-confidence, understanding of science and the research process, ability to apply knowledge and skills,

communication skills, and ability to work independently (Laursen et al. 2010; Lopatto 2004; Russell et al. 2007; Seymour et al. 2004). While data generation and analysis are certainly critical parts of science, they are not the only things that scientists do. In fact, scientists devote a good deal of their time to designing novel research questions, devising well controlled experimental strategies to address these questions, and writing proposals to secure funding for their research. In light of this, we developed a year-long proposal writing project to engage Biology majors in developing theoretical research proposals similar to the research plan component of an NIH grant, with guidance from a faculty mentor. One benefit of using this type of approach is that it does not require costly equipment, reagents or lab space.

While the use of a research proposal as a training tool for undergraduate students is not novel, an assessment of what students learn from this type of approach has not been carefully documented in the literature (Wolfson et al. 1996; Hunter 1998; Rammelsberg 1999; Oh et al. 2005; Schepmann & Hughes 2006; Blair et al. 2007; Colabroy 2011). In fact, a recent article reviewing the literature on writing-to-learn in science education has called for evaluating the impact of writing-to-learn practices (Reynolds et al. 2012). Here, we detail the structure of the proposal writing project we utilized to teach our students and provide data from assessments conducted to evaluate this project over a three year period.

Institutional Background

Drexel University is a private, urban, comprehensive research university. The Biology

Table 1. Timeline of theoretical research proposal related activities in the capstone course series.

Student Timeline	Week	Instructor Timeline
	1	Lecture on guidelines, designing a research question and doing a careful literature search.
	3	Lecture on managing references.
Mini-proposals due	5	Lecture on research ethics. Grade proposals.
	6	Match student groups with mentors.
Expanded mini-proposals due	10	Grade proposals. Review feedback from mentors and students.
	11	Lecture on specific aims and scientific writing. Address any group issues.
Specific aims due	13	Grade specific aims. Meet with individual student groups to discuss progress.
Background due	16	Grade background sections.
Abstract, background and specific aims due	20	Grade proposals. Review feedback from mentors and students.
	21	Lecture on experimental design. Address any group issues.
Experimental design due	23	Grade experimental design.
Draft of complete proposal due	26	Grade proposals.
Final proposal due	28	Grade final proposals and choose award winners.*

*The top three proposals are selected after review by both course instructors, and students from these groups earn a small prize at a ceremony for the senior students and their faculty mentors.

Department is part of the College of Arts and Sciences, and is currently home to 770 undergraduate Biology majors. At present, there are 15 tenure-track, research intensive faculty in the department, and 8 full-time teaching faculty.

Drexel employs the quarter system, with four 10-week terms per year. Most students take at least four courses per term. The quarter system is one approach in place to support Drexel's cooperative education (co-op) program. Students who choose to participate in co-op benefit from at least six months of full-time professional employment. Notably, only about 52% of all Biology majors participate in the co-op program.

METHODS

Course Structure

The proposal writing project is completed as part of the Seminar in Biological Sciences course series, which is a 3-course sequence (10 weeks per term) intended for senior undergraduate Biology majors. Each course in the sequence is worth two credits. In each of the three courses of the Seminar in Biological Sciences series, the class meets once a week for 110 minutes. Course sessions include lectures on project related topics (see Table 1), scientific seminars, career panels, and small group discussions (not shown). The courses in the Seminar in Biological Sciences series are directed by the authors, who serve as "course instructors." These instructors run the

day-to-day aspects of the courses, instruct students about the basics of proposal design, grade assignments, and manage group issues.

Project Description

This project requires students to identify a novel research question of interest supported by relevant and current background information, and develop a proposal that justifies the research question, establishes aims to address that question, and describes specifically how those aims will be addressed experimentally. These proposals are written in self-selected teams of five students, with support from faculty mentors. We have chosen to use a group approach to allow students to benefit from collaborative group study (Oh et al. 2005; Petress 2004). Note that "faculty mentors" are distinct from course instructors, though both course instructors also serve as faculty mentors each year. Faculty mentors meet with student groups on a regular basis outside of class (usually once a week) to provide feedback and guidance on proposal development.

This project is intended to challenge students to further develop skills that they have obtained throughout their undergraduate career and to acquire additional skills (see Table 2). In class, students are given lectures on researching the literature, developing research questions, managing references, planning ethical experiments, designing specific aims, writing scientifically, and devising sound experimental strategies. Students are also provided

Table 2. Learning outcomes for the capstone research project.

Through the development of a theoretical research proposal, students will:
1. Demonstrate a strong understanding of biological concepts
2. Improve their critical thinking and problem solving skills
3. Gain experience with critically reading and reviewing the scientific literature in a specific area of interest
4. Further develop and enrich their skills in scientific written communication
5. Begin to learn about grant writing
6. Exercise their time management skills in planning and submitting each stage of the proposal
7. Build on their abilities to work as effective team members
8. Develop a relationship with a faculty mentor who will oversee group progress and provide helpful insight into the field of interest

with detailed descriptions of project-related assignments, and with the overall learning goals for the project.

The timeline of assignments and course instructor responsibilities with regards to the project are outlined in Table 1. In brief, the first 10 weeks are initially focused on identifying topics of interest. Project selection and matching of faculty mentors with specific groups are based upon “mini-proposal” submissions. Each group submits three mini-proposals that each include a novel research question supported by brief background and justification sections sufficient to allow a reader to understand the relevance and context of the question. Students are permitted to choose any biological topic of interest as the focus for these proposals. Course instructors choose one of these proposals for further development based on extent of initial proposal development, quality and originality of the ideas, and suitability of matching with faculty mentor interests. Course instructors then match selected proposals with faculty mentors. Working with their mentors, student groups then refine their research question, identify additional sources to support their ideas, and begin to expand their background section to support their research question. The second 10 weeks are focused on continuing to expand the background and justification of the proposal and devising three specific aims to address the overall research question. The last 10 weeks are focused on experimental design. The final submission includes an abstract, background section, research question, justification, brief description of specific aims, experimental design section, and at least 20 references.

As has been discussed elsewhere, it is essential to ensure consistency in grading when evaluating assignments of this type (Oh et al. 2005). As a result, we have developed rubrics to aid in our evaluation of student assignments. In addition, while each assignment is graded by one of the two instructors, all graded assignments are discussed by both instructors to further ensure consistency in grading, similar to what has been previously described (Oh et al. 2005).

Assessing Student Outcomes

From the 2009-10 academic year through the 2011-12 academic year, the project was assessed using a pretest/posttest student self-assessment design. Embedded in both pre- and post-project surveys were the same series of questions about the project. Most of these questions utilized a 5-point Likert scale to assess student comfort level with project related skill sets. All Likert scale options were defined with written labels to clarify each choice. An

additional question asking about the number of faculty whom students felt understood their career goals used multiple choice responses. In the 2010-11 academic year, a Likert scale question was added to both the pre and post-project surveys regarding student comfort level with understanding laboratory techniques described in the literature. In addition, a multiple choice question was added to the post-project survey in 2011 to clarify the role that this project played in increasing the number of faculty that students believe understand their career goals.

Surveys were posted on the course learning management system. While the surveys were anonymous, it was possible to observe whether a student completed the survey. Students who had not completed the survey were contacted by email to encourage compliance. Of all possible students who could have responded, 88% complied with submitting the pre-project survey (270 out of 307 students who engaged in the project between the 2009-10 and 2011-12 academic years), and 89% of students complied with submitting the post-project survey (274 out of 307 possible students).

Assessing The Faculty Experience

Faculty were asked to complete a survey on their experiences with mentoring these projects. All faculty who had ever served as mentors for this project were surveyed once in 2012. This survey primarily used multiple choice questions with choices directed at addressing specific issues, including number of mentored groups, whether faculty benefited from interacting with these student groups, overall experience with the student groups, how this project has affected the number of students the faculty member interacted with, and whether the faculty felt that students met project learning goals. Faculty were also given the opportunity to provide additional comments. The survey was developed using Qualtrics (www.qualtrics.com). Responses were anonymous. Of all mentors engaged in the project in the 2011-12 academic year, 67% complied with completing the survey.

RESULTS

Since the 2008-9 academic year, 417 students have participated in this project in 81 distinct groups, and 21 faculty have served as mentors. Of the faculty involved, 13 have served as mentors for all four years that the project has run. Additional faculty who began mentoring in subsequent years have also mentored consistently. Only one faculty member stopped participating in this project as a result of leaving the university.

Table 3. Faculty perceptions of the benefits and negative aspects of mentoring student groups.

Benefit or Negative Aspect	% Response
I find it rewarding to teach students	75%
I find it rewarding to work closely with students	67%
I find it rewarding to work closely with students on this type of intellectual project	75%
I enjoyed talking with undergraduates about an area of research that was of interest to me	50%
Working with my student groups made me aware of a paper relevant to my research that I had not previously seen	8%
Working with my student groups was intellectually stimulating	67%
I developed new teaching strategies as a result of my interactions with a student group	8%
I enjoyed mentoring the students about career related issues in addition to mentoring them about their project	42%
The time investment was high	8%

When developing the project, we felt that it was important to allow students to choose the focus area for their own work to encourage student engagement, as has been described (Lewis et al. 2003). As a result, our student projects are quite varied in topic, for example, understanding viruses, basic cell biology, aspects of epigenetics, the underlying mechanisms of disease, organismal physiology, evolution, and effects of environmental changes on ecosystems. One

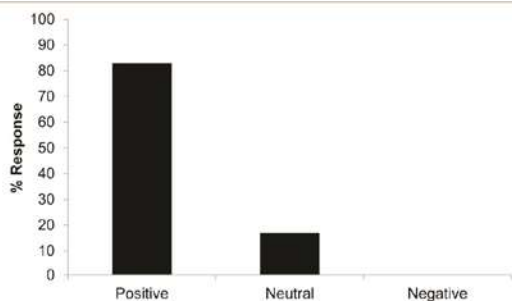


Fig. 1 . Faculty perception of their overall experience with mentoring student groups. Faculty indicated their average overall experience working with student proposal writing groups using a Likert scale ranging from 1 (Very Positive) to 5 (Very Negative). Data are reported as the percentage of faculty who chose positive, neutral or negative responses.

challenge this approach raises is that it sometimes requires faculty to mentor groups on topics outside their area of expertise. Of note, faculty who responded to the survey generally had a positive experience (Figure 1), despite the time and effort required. The majority of responding faculty found it rewarding and intellectually stimulating to interact with students in this way, and few found the time

investment to be high (Table 3).

One additional benefit of this approach is that it provides students with another mentor with whom to discuss career related issues. A number of mentors indicated that they enjoyed this aspect of working with student groups (Table 3). As well, the number of students who feel as though they have at least one faculty member who knows their career goals increased by 14.7% by the end of the project (Figure 2A). Because it is possible that this change in student relationships with faculty could be due to factors outside of the senior project, on the 2011 and 2012 surveys we asked students whether the project was the reason why more faculty know them well. A majority (62%) reported that this was at least one of the reasons for the increased connection with faculty (data not shown). As well, the majority of faculty surveyed indicated that they have made more connections with senior undergraduates as a result of this project (Figure 2B).

In considering what students have learned through the use of this project, we asked students to self-assess their comfort level with intended project learning outcomes (Table 4). While students exhibited learning gains in all areas studied, the greatest gains were seen in their ability to design and develop an experimental research plan, and to propose a novel research question. Statistically significant gains were also seen in scientific writing, reading the scientific literature and conducting a literature search in Biology. At the end of the project, of the assessed outcomes, students were most comfortable with conducting a literature search in Biology, reading the Biology primary literature, scientific writing, and working as part of a group.

Table 4. Mean responses of student comfort level \pm SD with important aspects of the proposal writing project.

	Mean Scores Pre-Project	Mean Scores Post-Project
Ability to work as part of a group	4.02 \pm 0.07	4.12 \pm 0.12
Conducting a literature search in biology	4.02 \pm 0.23	4.45 \pm 0.07*
Reading the biological primary literature	3.91 \pm 0.16	4.28 \pm 0.15*
Understanding techniques described in the biological literature [#]	3.81 \pm 0.10	3.87 \pm 0.22
Analyzing and synthesizing information in multiple primary research articles	3.74 \pm 0.08	4.07 \pm 0.21
Scientific writing	3.87 \pm 0.10	4.25 \pm 0.03*
Proposing a novel research question	3.31 \pm 0.18	3.76 \pm 0.02*
Designing and developing an experimental research plan	3.32 \pm 0.12	3.80 \pm 0.03*

Data were collected from pre and post project surveys from 2009-2012. Responses were on a scale of 1 (very uncomfortable) to 5 (very comfortable). [#]This question was added to the survey in 2010. *Two sample t-test, $p < 0.05$.

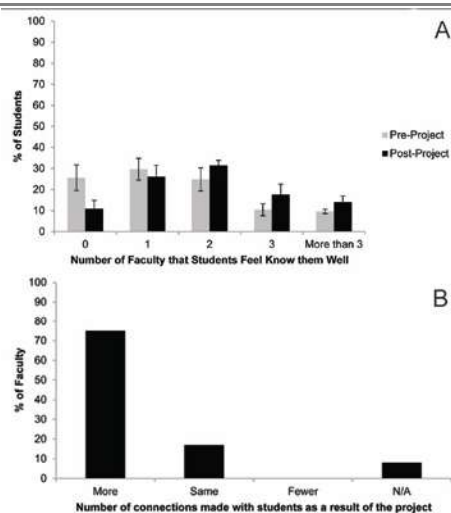


Fig. 2. Connections made between senior undergraduate students and faculty. (A) Students were asked to report the number of faculty that knew them well and understand their career goals on pre and post-project surveys given from 2009-2011. (B) Faculty reported the relative increase or decrease in number of connections they made with senior undergraduates since the inception of the project.

The majority of faculty agreed that students made gains with conducting a literature search, reading the literature, analyzing and synthesizing information from multiple articles, scientific writing, proposing a novel research question and designing and developing an experimental research plan (Table 5). Interestingly, while a majority of faculty indicated that they thought students gained knowledge in understanding techniques in the literature, there was no significant change to the students' perception of their comfort with this skill.

DISCUSSION

Through the implementation of this project, we have been successful in providing 417 students with a type of research experience that has been generally well received by both faculty and students. Notably, with the number of department faculty we have, space limitations, and costs, we would not have been

able to accommodate this number of students in traditional undergraduate research experiences. While students do not engage in bench work through this project, they certainly engage in scientific thought processes, namely designing novel research questions, justifying their ideas logically, and devising experimental aims to address their research question. Thus, we have provided all of our graduating Biology majors with an opportunity to engage in a type of research experience through this project.

Students gained comfort with a variety of skills through this project. The skills with the most gains included the ability to propose a novel research question and the ability to design and develop an experimental research plan. Because these skills are not formally taught elsewhere in the curriculum, it is not surprising that students felt least comfortable with these skills at the beginning of the project. Importantly, though, this project allows students to gain competence in these areas. The skill sets in which students had the highest confidence level at the end of the project included the ability to conduct a literature search in Biology, read the Biology primary literature, write scientifically, and work as part of a group. Because these skills are taught in a variety of contexts throughout the Drexel Biology curriculum, it is not surprising that students ended the project feeling most comfortable with these skills. What is notable is that despite learning about these skill sets elsewhere in the curriculum, this project still had an effect on student learning in these areas.

The areas where students had the least gains were in their ability to work as part of a group, and in their ability to understand techniques described in the literature. Because Biology majors engage in group work extensively throughout their undergraduate career, this is a skill set that students have experience with prior to the project. Therefore, it is not surprising that students do not appear to make significant additional gains as a result of this project. However, the finding that students do not make

Table 5. Faculty perceptions of student learning gains. Faculty were asked to select the learning gains in which they saw student improvement as a result of the project, from this list.

Skill	% Response
Ability to work as part of a group	33%
Conducting a literature search in biology	83%
Reading the biological primary literature	75%
Understanding techniques described in the biological literature	83%
Analyzing and synthesizing information in multiple primary research articles	75%
Scientific writing	75%
Proposing a novel research question	75%
Designing and developing an experimental research plan	83%
Professional networking	8%
Creative thinking	58%
Critical thinking	58%
Ethical reasoning	8%
Self-directed learning	58%

Table 6. Suggestions for establishing this project.

<u>Mentoring</u>	<i>Approach:</i> <ul style="list-style-type: none">• Supply mentors that provide feedback on proposal development. <i>Benefits:</i> <ul style="list-style-type: none">• Regular meetings with mentors enable significant progress.• Provides another opportunity for student:faculty connections. <i>Strategies that Work:</i> <ul style="list-style-type: none">• Allow mentors to focus solely on discussing proposal content and development.• Establish guidelines for effective interactions with mentors.• Ask mentors to evaluate their groups once per term, allowing instructors to address emerging issues.
<u>Group Work</u>	<i>Approach:</i> <ul style="list-style-type: none">• Have students work together in groups of five students. <i>Benefits:</i> <ul style="list-style-type: none">• Group work has cognitive and affective benefits (Petress, 2004).• Larger numbers of students can be mentored by using this approach. <i>Strategies that Work:</i> <ul style="list-style-type: none">• Consider group size (Petress, 2004). Larger groups have more issues with group dynamics. Smaller groups may need additional mentoring to complete the project effectively.• Ask students to consider common issues of incompatibility during group formation, such as: times they are available to work together, group work style, and topics of interest.• Ask students to evaluate the efforts of their group members once per term, allowing instructors to address emerging issues.
<u>Grading</u>	<i>Approach:</i> <ul style="list-style-type: none">• Establish a system in which assignments meeting stated requirements earn a grade in the A range. <i>Benefits:</i> <ul style="list-style-type: none">• Emphasizes a focus on the quality of the product generated instead of on numeric grades.• Acknowledges student effort.• Avoids discouraging groups that struggle with the difficult process of grant writing. <i>Strategies that Work:</i> <ul style="list-style-type: none">• Use a four-point scale: Unsatisfactory – does not meet requirements; Good- has significant issues with the writing, logic and/or scientific approach; Very Good – has an issue with one of these elements; Excellent – excels in all aspects of proposal writing.• Though most students earn grades in the A range, a majority become exceptionally invested, going beyond expectations for the project.

significant gains in their ability to understand techniques was a surprising result. As course instructors and mentors who have worked closely with a number of student groups, we have both seen firsthand that students learn a lot about experimental approaches through this project. Our faculty colleagues seem to agree, in that 83% reported that they believed students made gains in their ability to understand techniques (Table 5). One possible explanation for this student outcome may be that it is a metacognitive issue. Students' initial perception, that they are at least comfortable with understanding techniques, may change as they are asked to make use of these techniques in their aims and experimental design. By the end of the project, we believe students have gained skills in their ability to understand techniques, but by acquiring these skills, they gain a much clearer perspective of what they know and do not know. Another possibility is that the students' perception of their understanding of techniques does not change throughout the year because of a belief that the only way to learn techniques is by gaining hands-on experience. We may be able to better understand this outcome by asking one or more follow-up questions about their understanding of techniques on a future survey.

It also came as a surprise to us that so many students felt as though no faculty knew them well at the beginning of the senior year (Figure 2A). This is problematic from a programmatic perspective, because the success of a program depends on students' ability to find employment or to enroll in a professional school program. If students do not have a faculty member that they can confidently ask for a reference, it is unclear whether they will be successful in achieving these goals. While it is undoubtedly important that students make an effort to develop relationships with faculty, a program must also provide opportunities for students to work closely with faculty. This is a challenge in programs that have a medium to high student:faculty ratio. These data suggest that this project is one mechanism that can help to address this challenge. By the end of the senior year, the number of students reporting that no faculty member knew them well declined significantly, and the majority of students indicated that this project was at least one of the reasons why that was the case.

While we describe the use of this project in the Biology Department at Drexel, we believe the format of this project could be used in a variety of departments and institutions. Though Drexel is on the quarter system, this project took place over 30 weeks,

and could be adapted for use in a semester school by adjusting to two 15-week terms. The format of a proposal utilizing a research question and specific aims is certainly not specific to Biology. As a result, this format should be generalizable to use in other disciplines. We have found that there are some factors that are useful to consider when implementing this type of project, and we outline these in Table 6. Most importantly, over the past four years we have observed a high level of engagement from students participating in this project. It is common to see students talking enthusiastically about their project with their peers and the faculty, and we believe this level of engagement is one of the best aspects of this project.

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Using Castration Surgery in Male Rats to Demonstrate the Physiological Effects of Testosterone on Seminal Vesicle Anatomy in an Undergraduate Laboratory Setting

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Abstract: Rats can be used as a model organism to teach physiological concepts in a laboratory setting. This article describes a two-part laboratory that introduces students to hypothesis testing, experimental design, the appropriate use of controls and surgical techniques. Students perform both a castration and sham-control surgery on male rats and test the effects of reduced testosterone due to castration on the weight and histology of seminal vesicles. After performing the surgeries and collecting the data, students learn histological techniques, as well as empirical data collection, analysis and interpretation. Demonstrating the effects of testosterone through castration surgery bridges concepts learned in a traditional physiology class setting with data gleaned from research in a laboratory. Overall, the male castration surgery provides students with hands-on skills and an understanding of the work done by scientific researchers and health care professionals.

Key words: castration, physiology, seminal vesicles, testosterone, rat

INTRODUCTION

During their undergraduate studies in Biology, it is invaluable for students to gain hands-on experience in laboratory situations that they will carry with them into their postgraduate careers. Human physiology laboratory activities should give students hands-on demonstrations of different body systems at work and emphasize the interplay and interdependence of the body's organ systems. When combined with in-class discussions, engaging a student in research and laboratory activities aids in development of scientific processing skills, promotes conceptual understanding, and increases motivation and retention, especially in STEM-focused students (Lewis et al., 2003; Burrowes & Nazario, 2008). Primary reform efforts in undergraduate STEM education have focused on a conceptual shift to learner-centered and applied, hands-on learning (Fairweather, 2008; Mestre, 2008). In this vein it is important to present students with the opportunity not only to follow the "scientific method" but also to involve them in a research experience that will enhance understanding and long-term retention of scientific concepts. We therefore developed a two-part lab in an effort to expose students to the practical experiences of performing surgery using an animal model, to learn histological techniques and to collect empirical data. We use this lab exercise in Biology 4640: Physiology Laboratory, an upper-level lab course intended for junior and senior Biology, Biochemistry and Chemistry majors at the University of Detroit Mercy.

In this course, students participate in a laboratory research project designed to involve students in a hypothesis-driven activity that will generate data regarding the effects of testosterone exposure on male accessory sex organ anatomy. In addition to hearing a pre-laboratory lecture on reproductive anatomy and physiology, students generate hypotheses, learn surgical techniques, are introduced to the use of appropriate scientific controls, practice data interpretation, and evaluate data statistically. Students use male rats (*Rattus norvegicus*) as a model organism and perform both a castration and sham-control surgery. This lab teaches that the physiologic workings and products of the endocrine system influence almost every organ system of the body. Specifically, students learn that the hormone testosterone has a substantial impact on the anatomy and physiology of the seminal vesicles.

It has long been understood that testosterone production by Leydig (interstitial) cells in the testes helps to regulate growth and maintenance of secondary sex organs. Leydig cells produce approximately 95% of a male's testosterone. Testosterone and testosterone derivatives regulate growth and development of all male reproductive organs (e.g., penis, seminal vesicles and prostate glands). During development, increases in the production of testosterone plays a major role in the maturation, physical growth and function of the male reproductive organs (Kandeel et al., 2001). The seminal vesicles contain pseudostratified columnar epithelium and consist of secretory cells that produce an alkaline seminal fluid rich in fructose, fibrinogen,

vitamin C and prostaglandins (Burkitt et al., 1993). Fluid produced in the seminal vesicles typically forms more than half of the seminal volume and is necessary for the formation of the sperm coagulum, the regulation of sperm motility and the suppression of immune function in the female genital tract (Freud, 1933, Higgins et al., 1976; Kandeel et al., 2001; Rudolph & Starnes, 1954). It has been reported in primary literature that when the effects of testosterone are blocked or when the testes are removed and testosterone is not produced in male animals, a significant decrease in seminal vesicle weight follows and the seminal vesicles display abnormal histology (Rudolph & Starnes, 1954; Karri et al., 2004).

The rat serves a useful animal model of the male reproductive system that can be manipulated to induce the loss of, or mimic a failure to produce, the male hormone testosterone. Additionally castration will demonstrate the effects of testosterone loss on the growth and maintenance of accessory sex organs. Freud (1933) stated that the seminal vesicles make a good model for studying the effects of testosterone because they are easy to prepare histologically and they respond rapidly to castration. Castration surgeries on female rats have been performed in other undergraduate labs (Kirkpatrick, 2009), supporting the idea that learning and performing small animal surgical techniques is ideal for undergraduate physiological lab courses that seek to give a hypothesis-driven research experience. The male castration surgery is relatively simple and the completion of a recovery surgery provides students not only with hands-on skills but also with an understanding of the work done by scientific researchers or health care professionals.

One week following the castration surgeries, students sacrifice the rats and weigh them, remove and weigh the seminal vesicles and prepare the seminal vesicles for histological evaluation in order to determine any testosterone-deletion effects. Post-fixation, the students embed, section and stain the seminal vesicle tissue from both castrated and sham-treated control rats. The second week of lab provides students with the opportunity to practice data collection, data interpretation and hypothesis testing using a real animal model of hormone action. As a final exercise in scientific data interpretation, students generate research posters in order to provide the opportunity to solidify background knowledge, use primary research references, and place collected data in the arena of reproductive scientific inquiry. Overall, this laboratory research activity provides exposure to biological practices such as animal surgery and care, tissue fixation, histology, tissue staining, hands-on hypothesis testing, statistical analysis and the interpretation and scientific presentation of data.

MATERIALS AND METHODS

Presurgical Preparation:

Male Sprague Dawley CD rats (*Rattus norvegicus*) weighing between 125 and 136 grams were obtained from Charles Rivers Laboratories International, Inc. (Wilmington, Massachusetts). The rats were housed in groups of four in the animal care facility at the University of Detroit Mercy, and were fed rodent chow and given water *ad lib* (IACUC approved by UDM Animal Care and Use Committee; July 2011). Before the lab began, all instruments were sterilized in an autoclave and wrapped in paper. Prior to surgery, laboratory benches were sanitized and prepared with an absorbent liner at the surgery site. Each laboratory bench was stocked with 70% ethanol and sterile cotton pads, a 50-milliliter beaker with a cotton pad or gauze strips at the bottom soaked in ether (ether cone) and a covered bottle of ether as ether evaporates quickly. Each group of students also had access to a pair of electric clippers. Students were provided gloves when they entered the lab and were advised to wipe their surgical equipment with 70% ethanol. Surgical tools consisted of scissors, forceps, straight hemostats, silk suture and size 18 surgical needles. A recovery cage was also set up in a quiet area with a light mounted above it to provide warmth to the recovering rats.

Student Exercise:

Students are initially given a lecture on male reproductive anatomy and physiology that includes information on the effects of androgens. The use of appropriate experimental controls and the generation of hypotheses and expectations based on background information from both textbooks and primary literature is also explained. Given the appropriate background information, students are then required to generate a working hypothesis on what anatomical changes they predict they will occur in the seminal vesicles after castration. Students are also informed about the proper surgical techniques, anesthesia, post-surgical care and husbandry. The surgery, data collection and histological analysis take two to three laboratory sessions (or weeks) depending on the histology preparation. To conserve time, the teaching assistants and professor may complete the tissue embedding and sectioning.

Student Lab Week 1:

Anesthesiology:

Ether is used to anesthetize rats for castration surgery because it can be easily administered and regulated. The specific action of ether is unknown; however, there is experimental evidence suggesting that ether reduces the number of phospholipid interactions. Ether has been shown to decrease excitability of muscles and neurons by inhibiting the sodium conductance responsible for depolarization during an action potential and may therefore modulate consciousness (Inoue & Frank, 1965).

Anesthetics that could replace ether in this exercise include halothane, nitrous oxide, isoflurane, barbiturates, and opioid derivatives.

Prior to anesthetizing the rats, cotton soaked with ether was placed on the bottom of a glass desiccator (25 cm in diameter and 13 cm in depth) and the cover of the desiccator was sealed by placing a thin film of Vaseline around the lip. Rats are not introduced to the desiccator for ten minutes following the addition of ether to the desiccator so that the desiccator could become saturated with ether vapors. After this time period, a rat was quickly transferred to the ether chamber after removing it from its cage. The lid to the desiccator was reapplied quickly so that very little ether vapors were released. Students test the level of anesthesia by examining the rat's breathing and by using a toe pinch. A rat that has reached an appropriate plane of anesthesia should be breathing slowly. More importantly, it should show with no response to a toe pinch. Forceps are used in this exercise to test the rat's "readiness" by gently pinching its toes. If the rat does not respond by pulling (withdrawing) its leg in response to the pinch, the rat has reached a level of anesthesia appropriate for surgery.

The rat is then transferred to the prepared laboratory bench and its nose is placed in an ether cone. During the entire surgical procedure, anesthesia should be maintained by a student who has been appointed as the anesthesiologist. Breathing and the level of anesthesia should be closely monitored by the anesthesiologist. The student should ensure that the gauze in the ether cone is continually saturated with ether. Furthermore the student should adjust the cone, move the cone further away from the nose or remove the cone entirely, if the rat's breathing becomes very shallow until breathing returns to normal. If the rat stops breathing, it may be resuscitated using a six inch piece of aquarium tubing cut at a 45 degree angle at one end. The angled end of the tubing is placed over the rat's nose and the anesthesiologist breathes into the opposite end of the tubing in short, rapid puffs. The student's should apply gentle pressure on each side of the abdomen with their thumb and fingers to prevent air from entering the rat's stomach. The thumb and fingers should then be placed on either side of the chest and the chest gently massaged between intervals of puffing. Throughout the surgery, breathing should be shallow, the eyes should be clear pink (not cloudy) and the rat's feet should be flesh tone (not blue).

Male Castration:

Students are advised to put on gloves and to use 70% ethanol to wipe surgical equipment. The testes and surrounding area are shaved using electric clippers. The incision areas are prepared by wiping 70% ethanol over the shaved skin of the scrotum. The male gonads (testes) rest in the perineum. The perineum is the portion of the pelvic cavity that is

isolated by a muscular diaphragm, which consists of the levator ani and coccygeus muscle. The testis, epididymis and lower spermatic cord (crematic muscle, vas deferens, testicular artery and pampiniform plexus) are contained in a pouch of skin called the scrotum. The testes are mobile organs; therefore, prior to shaving fur and making the initial incision on the rat's scrotum, the testes should be gently pushed into the scrotum. Students will make their initial incision with scissors; scalpels can cause unnecessary damage when pressing down on an organ. The incision should be straight (caudal to cranial) and about 3 to 4 cm in length. Each testis is surrounded by the tunica vaginalis and several layers of fascia. Using forceps, the testis is freed from the scrotum. A ligature is then tied tightly around the spermatic cord. The ligature should be at least 2 cm from the testes, which leaves enough room to cut through the spermatic cord with scissors. The loose ends of the ligature are then trimmed to 0.5 cm in length. Care should be taken not to trim too closely to the knot, so that it will not slip. The ligature should occlude the vasculature of the spermatic cord, thereby preventing blood loss. The incision is closed with three to four interrupted over-and-over sutures (Serag-Weissner, 2006). Next the procedure is repeated to remove the other testis in each experimental rat.

Following the first surgery, the students switch roles such that the anesthesiologist becomes the surgeon. A sham-control surgery is performed in which the control rat undergoes the initial cutaneous incisions described above, but does not have its testes removed. The incision is closed with sutures as described earlier. As a control animal, its gonads will remain undamaged and intact. This control condition will eliminate any question of variability in data collected that may be attributed to the surgical procedure, and not by the removal of sex hormones produced by the gonads.

Postsurgical Procedure:

After completion of the surgery, students punch ear marks to identify the castrated and control rats for follow-up experiments. The unconscious rats are placed in the recovery cage, making sure that it is under the warming lamp. The lamp provides low-level heat that facilitates the expulsion of ether from the rat, hastening its revival. Recovery from surgery typically takes approximately 20 to 30 minutes. Once conscious, the rats are relocated into a cage with clean litter and an ample supply of water (needed for replacement of lost blood volume) and food. Students are required to check on their rats throughout the next week.

Student Lab Week 2:

Removal of Seminal Vesicles:

One week after the castration and control surgeries, both the control and castrated rats are euthanized by overdose of ether and subsequent

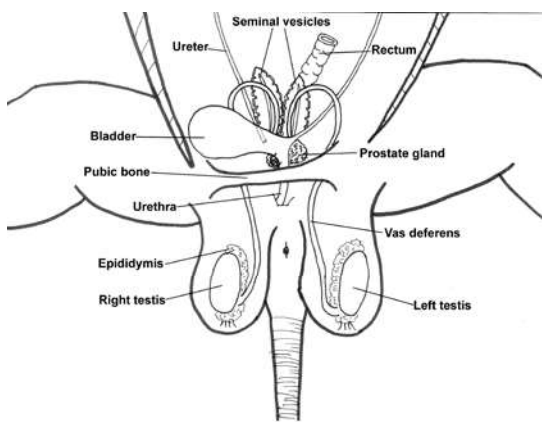


Fig. 1. Anatomy of the urinogenital system in male rats. Photo credit: Elizabeth Grabowski.

cervical dislocation (AVMA, 2013) and the body weights of both rats are obtained. An abdominal incision is made and the seminal vesicles, located on each side of the bladder, are identified and exposed (Figure 1). To determine if sex hormones affect the seminal vesicle anatomy, the students remove the seminal vesicles and weigh them. Seminal vesicle weight is expressed as a percent of total body weight to emphasize data standardization. We typically have students remove the seminal vesicles from control rats first as they are much larger than in the castrated rats. This makes locating the seminal vesicles in the castrated rats less challenging.

Histological Preparation:

The seminal vesicles from the control and castrated rats are then placed into Bouin's fixative (Sigma-Aldrich) in separate containers overnight and prepared for paraffin embedding. Histological preparation and staining is then completed using Bancroft and Stevens (1990) as a guide. The following morning, the tissues are placed in an ethanol series: 75%, 80%, 95% and 100% for 45 minutes each. The tissues are then placed in two changes of 100% ethanol for 60 minutes each. Following this, the seminal vesicles are placed into two changes of xylene for 60 minutes. Seminal vesicles then undergo three changes in paraffin for 60 minutes each (Bancroft & Stevens, 1990).

Embedding the tissue begins with selecting a mold that corresponds to the size of seminal vesicle tissue, leaving a margin of 2 mm around the tissue. A small amount of hot paraffin is poured into the mold and, using forceps, the seminal vesicle tissue is transferred into the mold (cut side down). The mold is then transferred to a cold plate and the tissue is centered within the paraffin wax. A tissue cassette is then placed on top of the mold as a support and hot paraffin is added to the mold, covering the cassette. The mold and cassette are kept cold, and the paraffin will solidify within about 30 minutes.

A microtome with a fresh blade is then used to cut 10 μ m sections. These sections are transferred to a warm water bath ($\sim 37^\circ\text{C}$) and the sections are then

floated onto the surface of a clean glass slide marked as either control or castrated seminal vesicle. Slides, with paraffin sections, are then placed on a hot plate or warming block ($\sim 65^\circ\text{C}$) for 20 minutes in order to melt the wax to the glass. Slides can then be stored at room temperature until stained.

Hematoxylin and Eosin Staining:

The processed and sectioned seminal vesicle tissue is then stained to give contrast to the tissue so that the seminal vesicle tissue from control and castrated rats may be compared. We use a series of Coplan jars for paraffin removal and Hematoxylin and Eosin staining. First the slides are deparaffinized by putting them through two changes of xylene for 10 minutes each. Following this, the sections are rehydrated in 2 changes of 100% ethanol for 5 minutes each, then 95% and 70% ethanol 2 minutes each. The slides with the tissue sections are then placed briefly in distilled water. Harris' Hematoxylin is the first stain used and the slides are placed in the solution for 8 minutes, followed by washing for 5 minutes in distilled water. Tissues are then placed in acid alcohol for 30 seconds for differentiation and washed with distilled water for 1 minute. The water is blotted with blotting paper and the slides are placed in the counterstain Eosin for 30 seconds to 1 minute. Following the counterstain, tissue is then dehydrated using two changes of 95% and 100% ethanol for 5 minutes each. Finally slides are cleared using two changes of xylene, 5 minutes each and mounted using a xylene-based mounting medium such as Permount (Fisher Scientific) and a coverslip. The coverslip should be angled and allowed to fall gently, so that the Permount may spread evenly beneath the coverslip and bubbles may be avoided (Bancroft & Stevens, 1990; Kiernan, 2008).

RESULTS

While removing and weighing the seminal vesicles, students notice that the castrated rats have much smaller seminal vesicles. Students then compare the weights of control versus castrated seminal vesicles as a function of body size (weight of seminal vesicles/weight of rat $\times 100$), which allows for comparison of rats of different weights. Students in each laboratory section are instructed to share data with their classmates. Figure 2 is similar to a figure that students create for their posters. It demonstrates that there is a significant difference ($p < 0.0001$; $t = 6.720$) in the percent weights (mean \pm standard error) of the seminal vesicles between control ($0.17 \pm 0.02\%$) and castrated rats ($0.05 \pm 0.01\%$). Further, students perform a histological evaluation of the seminal vesicles. This evaluation typically demonstrates that control seminal vesicles are composed of columnar or pseudostratified columnar epithelium that consists of secretory cells arranged in folds surrounded by smooth muscle. A normal (control) seminal vesicle typically has an irregular

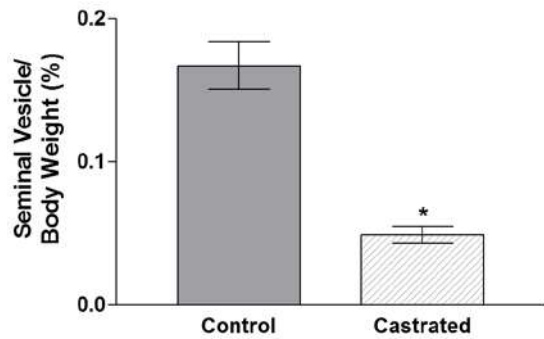


Fig. 2. One week after castration, seminal vesicles were removed from both castrated and control rats and weighed. Percent seminal vesicle weight (mean \pm S.E.) as a function of overall body weight was calculated for both control and castrated male rats (N=15). One week post-surgery, the seminal vesicles of castrated rats were significantly smaller than control rats. * indicates $p < 0.0001$.

lumen, giving it a honeycombed appearance (Fig. 3A). In contrast, students notice that in castrated rats, the seminal vesicles are regressed and show abnormal histology. The seminal vesicle epithelium in castrated rats exhibits atrophy and is not organized into glandular folds, which inhibits secretion of seminal fluid (Fig. 3B). Because students prepare all of their own histological samples, after staining, students can trade coded (or unlabeled) slides with another group of students in order to reduce bias during analysis.

Laboratory Evaluation:

To evaluate learning in the BIO 4640 Physiology Laboratory, we compared overall student grades for the Physiology lecture course (BIO 4630) of Biology majors who took the course concurrently with the laboratory with Biology majors who did not enroll in the lab portion of this course (IRB protocol #1314-08). We found that Biology majors who take and complete the laboratory portion of this course have a higher overall grade in the Physiology lecture when the laboratory and lecture are taken concurrently ($p > 0.05$; t-test; N=35). The grade for students who are enrolled in the lab averaged 82.5% (B) while those who did not take the lab course averaged 79.5% (B-).

DISCUSSION

This laboratory teaches students that testosterone, produced by the Leydig cells of the testes, is physiologically important for the development and maintenance of the seminal vesicles. Using seminal vesicles to demonstrate the importance of testosterone is advantageous for this lab exercise because seminal vesicles are easy to prepare histologically and the secretory cells of the seminal vesicle respond quickly to castration (Frey, 1933; Burkitt et al., 1993). Within a week, students notice that there is a significant decrease in seminal vesicle weight in the castrated rats and that the castrated rats display abnormal seminal vesicle histology (Figures 2 and 3). Mean seminal vesicle

weight expressed as a percentage of total body mass (seminal vesicle weight/body weight \times 100) decreases by 0.12% one week post-castration.

Further, when the Hematoxylin- and Eosin-stained seminal vesicle tissue is prepared and examined by the students, it is evident that the control tissue has a large number of folds of pseudostratified epithelium or secretory tissue. The castrated rats' epithelium was regressed with distinctly fewer, less prominent folds.

The students enrolled in this laboratory gain a first-hand understanding of male reproductively physiology and how the hormone testosterone affects the structure and functioning of the seminal vesicles. Biology majors enrolled in the lab concurrently with the lecture had higher overall grades in the lecture course than students who did not take the laboratory. While we did not see statistically significant results from this preliminary analysis, we believe that this laboratory exercise greatly increases knowledge of reproductive physiology for those students participating in both the lecture and lab. Moreover, student data will continue to be collected and a larger sample size could ultimately yield a significant difference between students enrolled in both lecture and lab and those that are enrolled only in the lecture.

This lab exercise examining the effects of castration on the seminal vesicles has been taught for several years at the University of Detroit Mercy. Although we have not in the past collected quantitative data on each laboratory exercise offered throughout the semester, during end of the term course evaluations students often rate this course very highly (4.85 out of 5). When providing written feedback about the castration lab module, students generally have positive comments about what that lab taught them. Some comments that we have received from students following the completion of this lab were: "A tough class, but it was fun, interesting and an excellent complement to Physiology lecture. This class introduced me to my first live surgery, which is such an awesome experience." "I particularly enjoyed the rat surgery lab. I felt it helped me understand how

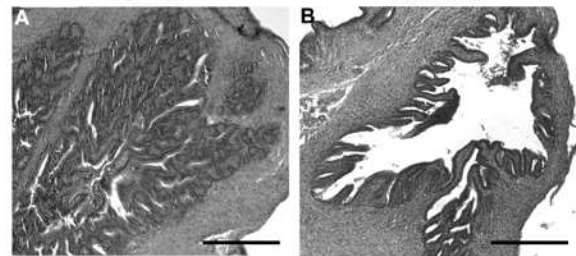


Fig. 3. Hematoxylin and Eosin stained seminal vesicle tissue from control (A) and castrated (B) male rats, obtained one week after the castration and sham-control surgeries. Seminal vesicles are composed of pseudostratified columnar glandular epithelium that is organized into folded mucosa (A). Castration surgery and the subsequent loss of testosterone caused a regression of seminal vesicle epithelium and abnormal histology (B). Scale bar in A = 300 μ m and scale bar in B = 200 μ m.

testosterone functioned within the body; it also helped expand and clarify the knowledge I had about the reproductive system in general.” “The Rat Reproduction lab was intriguing and rewarding for aspiring medical professionals. It made personal the tie between solid research techniques, the comprehension of reproductive physiology, and clinical proficiency.” “I want to be a Physician Assistant, and the rat surgery lab made me feel like a doctor. We got to anesthetize and do surgery on our rats. Dissecting something that has already died is interesting, but doing surgery on live rats, successful ones at that is unlike an experiment I have ever done in my life actually. Loved this lab!” The feedback from this lab has been very positive and we have students in the hallways telling us they are looking forward to enrolling in this lab so that they can perform the rat surgeries. Overall, students gain an enhanced understanding and appreciation for animal research.

This laboratory module is an important component of Physiology Lab because it requires students to generate scientific hypotheses regarding the physiological effects of testosterone. Along with the generation of hypotheses, students are introduced to the appropriate use of scientific controls, and to the collection and evaluation of data. We believe that students gain hands-on experience in this laboratory that they will carry with them into their postgraduate careers. Many of our students are focused on gaining acceptance into Dental or Medical School or a Physician Assistant Program. Few of our students actually think about postgraduate programs such as an M.S. or Ph.D.; however, the number of student pursuing these degrees has recently increased and some students who have completed this laboratory course have chosen to pursue research as a career. This lab module provides active participation in research that may help with retention of STEM-focused students in research fields. Students who complete the male castration surgery gain hands-on skills and an understanding and appreciation of the work done by scientific researchers and health care professionals.

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PERSPECTIVES

Connecting Students to Content: Student-Generated Questions

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Abstract: Students learn best by being actively engaged in the learning process. This essay describes a teaching technique where students generate their own questions about a course topic. This occurs at the beginning of each new section of a course. The instructor works with the class to answer the students' own questions throughout that section of the course and, via discussion and research, students become better connected and more motivated to learn the content as the course continues. This technique has been used successfully in several different biology courses including anatomy, physiology, environmental biology and introductory biology. Try it. You might like it!

Key words: student-generated questions; course content; student engagement; active learning

One of the biggest challenges of teaching any biology course is to get students to see the relevance, the connections, and the applications of course content using their previous knowledge from other courses and from everyday learning experiences. When students can see and understand these connections, their motivation to learn and add to their stored knowledge is enhanced. (Barkley, 2010)

Another challenging aspect of active student learning is to promote vocal student discussions and question/answer sessions in class. Many students feel uncomfortable talking in a group or contributing to these discussions. But if a specific compelling statement or topic is discussed, especially if they generated it themselves, students may "come out of their shell" and contribute their ideas and benefit their learning directly (Ambrose et al., 2010).

More learner-centered instruction and less teacher-centered instruction is another somewhat recent movement that has been shown to increase student learning and motivation to learn in many classrooms. Students are invited to have more input in planning the direction and content discussed in class. Sometimes they are asked during the first week of class to help decide the weight of assignment

grades and even the basic content of exams. The more connections and engagement they have, the better they will learn new information. Studies have shown that more student ownership of the course and its content result in better retention and better application of information after the course (Weimer, 2002; Blumberg, 2009).

To try to better connect students to the content of many of my courses and meet some of these challenges, I use the following teaching method. When I start a new topic, I ask students to generate their own questions about the topic. A topic is usually a different body system in anatomy and physiology or a new text chapter in environmental biology. I give them 10 minutes to talk with their neighbor, open their text or do a quick Google search on their laptop or smartphone about the upcoming topic that the class will explore in the next several weeks. I use prompts to get them started like asking about rumors, myths, or stories they have heard about or ads they have seen on TV or the internet. I mention a few new terms or diseases they may have heard of to get them thinking. What have they heard about this topic in other classes, in the cafeteria, on the street, or at their relative's house about this topic?

Table 1. Cardiovascular/Heart Questions

Effects of aerobic training on heart health? How much training for how long?
Mitral valve transplants? Are pig valves really used? How?
Artificial valves and blood thinners? Why? What do blood thinners do? Effects of "thin blood"?
Why do some people have higher susceptibility to high BP? What do BP medications actually do?
Heart murmur – genetic or can it get worse with age?
Cold hands/cold feet – poor circulation? Long term effects?
Hole in one's heart – surgery or not?
Do taller people's hearts work harder?
How does my heart work continuously and not fatigue?
Why can young people have heart attacks?
Heart attack vs. stroke?
Heartworm? In people or just dogs? Why?
Tingly feeling when foot or arm falls asleep?

Table 2. Respiratory Questions

Why do lungs fill with fluid when sick? Pneumonia?
Why does my throat feel tight when you exercise?
Is there a better way to breathe when running – through the nose or through the mouth?
Is asthma genetic? What happens during asthma attack? Sports induced asthma?
How does an inhaler work?
Why do lungs collapse?
Why do swimmers hyperventilate before certain swimming events?
How do oxygen tents work? NFL and NBA players using them – benefits? Problems?
Does taking protein supplement affect lungs?
Can I still exercise with a respiratory illness?
Breathing oxygen-carrying liquid into lungs? Possible? Problems?
Popping noises when exhaling when congested?
How long after quit smoking do lungs improve? Will lungs always be damaged?
Why do lungs burn when running outside in cold?

Are there diseases related to this topic or everyday questions they would like to learn more about? I ask them to write at least two questions first. Then they look at their neighbor's questions to see if they had any common interests. Finally, I make a list of questions on the board as they ask them.

Sometimes during this question-recording time, class discussions erupt about where students heard certain information or comments like “that same thing happened to me.” Genuine looks of interest come over many faces as these questions emerge. Truthfully, despite over 20 years of teaching these courses, many new interesting questions arise each semester for each topic, ones that I would have never thought to ask or include in the class activities for that topic. Some questions are simple and some come from very individual experiences. Some students almost seem relieved that, finally, they get to pose their own question – not just something that the instructor thinks is important! I collect all the written questions from each student and make a large list for that topic. I keep this list available during my talks, after student presentations and in labs. I try to remember to have the class help me answer a few of them each day, especially when the specific information for that day connects directly to several questions on the list.

I teach a majors physiology course, a non-majors general education A&P course and an elective, cadaver-based, human anatomy course. In all three courses, I have successfully started each new topic/system by having students generate a list of their questions for which they would like to learn answers. Questions and answers become parts of exam questions for that topic. Many times, questions from the list are posed to four or five students at the end of a class period. They find answers, working individually or in small groups, and bring them back to the next class period for everyone to learn. Having different groups of students find answers to the same questions sometimes produces controversy or added depth to the discussion of answers in the subsequent class period. When groups present different answers to the same question, this adds intrigue and increases students' motivation to find out more and check the credibility of the sources of both sets of answers. This immerses students into the process of science even more, as they practice their abilities to be skeptical at all times – an important characteristic of being an active scientific citizen.

I prepare for these answer sessions by having electronic images or websites available that show details of the disease in question, or pros and cons of a specific treatment or concept. During the review

Table 3. Muscle Questions

Pulled muscles? How do they fix themselves? Repair process? Can muscles be retrained after surgery?
Muscular Dystrophy – Cure in future? Why do they have increased bronchitis, pneumonia easier?
Slow twitch ↔ Fast twitch conversion? How do I know if I have slow or fast twitch fibers?
Muscle strength limits? Muscle size limits?
Able to transplant muscles like organs?
Lifting causes microscopic tears – able to use stem cells to make muscle repair bigger and faster?
How does electric stimulus machine cause muscle to contract? Benefits? Problems?
Irregular huge strength at times of danger?
Most important nutrients for healthy muscles?
Calcium deficiency affect sliding filament theory?
Why do they feel like jello after done running?
How do people lose muscle over time? Why?
Why is it easier for some people to build muscle than others?
Is protein safe to take?
Barry Bonds – “the cream” and “the clear”?
Differences between muscles in men vs. women?
Can muscles be retrained after surgery?

Table 4. Cancer Questions

What factors can speed up or slow down treatment effects besides medications?

Cancer killed by Vitamin B17?

Do things I eat or chemicals/hormones added to food cause cancer?

Does it skip generations?

Why are nerve endings so active right before death?

Do cell phones cause cancer?

Why do some forms of cancer spread faster than others? How does it spread? And how fast?

How do I help someone going through treatment? Exercise, healthy diet?

Why do some people with same cancer respond differently to same treatment?

Two people could smoke entire life but one dies of cancer, the other not. Why?

Which water bottles give you cancer?

session for the topic before an exam, I review the list of student questions and ask them for the answers that they remember. Sometimes we get questions for which we cannot find adequate, well-documented answers. Students learn that many questions in science and everyday life do not have good answers yet. Some find this hard to believe and others keep trying to find a better answer. I encourage students to constantly ask questions, to be curious, to stop and find answers when they can. Science and understanding the world around us is driven by asking questions, finding answers and satisfying oneself about the application of new answers in everyday life. I have included several actual lists of questions from several commonly explored topics in my courses (Tables 1-4) to show the variety and unexpected nature of questions students have asked.

I have successfully used this method in my anatomy and physiology courses because students are interested in their own bodies and in how diseases affect them, their relatives or friends. Can this method work in other biology courses... in a cell biology course, a microbiology course or an introductory biology course? Yes, I am confident that it can. I have used it successfully in several environmental biology courses. Topics like drinking water, ground water pollution, storm water runoff, land use, air and soil pollution, and invasive species are all topics that most students have heard of or witnessed personally that help them generate questions. With the use of specific prompts as noted earlier, and giving students time to look through their textbooks, talk to their classmates or search for basic information, they can successfully frame a solid question or two. Many times, as questions start being

asked, this stimulates thinking and prompts other students to ask related questions.

Overall, this method greatly helps connect students to a topic and its applications to everyday life. In my experience, I think students possibly learn more as they wait for the answers to their questions to be discussed. This stronger connection to the topic can also help them remember it better. One of the aspects of how students learn effectively is by connecting new or current information to previously learned information (Barkley, 2010). This helps build a bigger, broader, overall “mind map” for that topic and its applications. I encourage other biological educators to try this method in their courses. It has helped to better connect my students to course content, increased their motivation to learn, and given me the opportunity to learn more along with my students.

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REVIEWS

Alice's Adventures in Molecular Biology

Review by Barbara Hass Jacobus

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Alice's Adventures in Molecular Biology by Arieh & Roberta Ben-Naim seeks to educate readers about the flow of cellular information from DNA to RNA to protein and protein folding through the fictitious experiences of college student Alice in Professor Holmes' molecular biology course. Intended for the lay reader, the story presumes one is familiar with the chemistry of water, as discussed in the authors' previous book, *Alice's Adventures in Water-Land*. That presumption would make the concepts more challenging for readers unfamiliar with that work or with water chemistry.

While *Alice's Adventures in Molecular Biology* is scientifically sound, the reader will find little adventure and no plot in the storyline. The story is merely a series of molecular biology lectures written in prose form. Each chapter opens with college student Alice, clearly the top student in Professor Holmes' class, showing up early for each lecture, engaged in the class, and periodically seeking further tutoring and clarification in Professor Holmes' lab from Professor Holmes and from his virtual simulations starring a monkey character named Kofeau. The authors attempt to interject humor through a real version of Kofeau that Professor Holmes brings to class, however only the students see the humor in Kofeau's antics. While the prose style makes some of the content more readable, in the end

it does not do a better job than many of the familiar non-majors textbooks in explaining the concepts. Illustrations are included as figures, but are seldom directly referenced or explained in the story or the captions, and often do not even appear on the same page as the associated text, a serious flaw in the book. Sadly, there is very little character development to envelop the reader into the story and no "Harry Potter" adventure woven around molecular biology, but simply vain attempts to grab the reader's attention merely by telling us that Alice is excited to attend lecture and thinks about it every waking moment. One wonders how Alice is doing in her other courses, or how the other students manage to pass Professor Holmes' course without the benefit of the Kofeau simulations.

I applaud the efforts of the authors to make science more accessible to the lay person. However, if you are looking for adventure rather than another textbook, you will have to look elsewhere.

BOOK DETAILS

BEN-NAIM, A. AND R. BEN-NAIM. 2013. *Alice's Adventures in Molecular Biology*. World Scientific Publishing Co., Singapore. 172p.
ISBN: 978-981-4417-24-2 (Hard Cover)
ISBN: 978-981-4417-25-9 (Soft Cover)

Bioscene: Journal of College Biology Teaching

Submission Guidelines

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:** Course and curriculum development, innovative and workable teaching strategies that include **some type of assessment** of the impact of those strategies on student learning.
- **Innovations:** Laboratory and field studies that work, innovative and money-saving techniques for the lab or classroom. These do not ordinarily include assessment of the techniques' effectiveness on student learning.
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- **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

II. Preparation of Articles, Innovations and Perspectives

Submissions can vary in length, but articles should be between 1500 and 5000 words in length. This includes references and tables, 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. Topics designated as acceptable as articles are described above. The formats for all submissions are as follows:

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- B. **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. Articles describing some type of research should 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. Articles describing a laboratory or class exercise that works should be broken into sections following the introduction as procedure, assessment, and discussion.

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:

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

Two Authors:

"... assay was performed as described previously (Roffner & Danzig, 2004).

Multiple Authors:

“...similar results have been reported previously (Baehr et al., 1999).

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DEBURH, L.E. 1991. Using *Lemna* to study geometric population growth. *American Biology Teacher* 53(4): 229-32.

(b) 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.

(2) Books-

BOSSEL, H. 1994. *Modeling and Simulation*. A.K. Peters, London. 504p.

(3) 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.

(4) Web sites-

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

For references with more than five authors, note the first five authors followed by et al.

D. Tables

Tables should be submitted as individual electronic files in Word (2003+) or RTF format. 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.

E. Figures

Figures should be submitted as high resolution (≥ 300 dpi) individual electronic files, either TIFF or JPEG. Placement of figures should be indicated within the body of the manuscript. Figures only include graphs and/or images. Figures consisting entirely of text will not be allowed and should be submitted as tables. All figures should be accompanied by a descriptive legend using the following format:

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

III. Letters to the Editor

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.

IV. Other Submissions

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.

V. Manuscript Submissions

All manuscripts are to be sent to the editor electronically. *Authors must clearly designate which type of article they are submitting (see Section I) or their manuscript will not be considered for publication.* Emails should include information such as 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. Email will be the primary method of communication with the editors of *Bioscene*.

Communicating authors will receive confirmation of the submission within three days. 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 necessarily blind unless requested by an author. If the article has a number of high resolution graphics, separate emails to the editor may be required. The editors recommend that authors complete and remit the [Bioscene Author Checklist](#) with their submission in order to expedite the review process.

VI. Editorial Review and Acceptance

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- **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. Further revisions should be made within six months if called for. Manuscripts requiring revision that are submitted after six months will be treated as a new submission. Should manuscripts requiring revision be resubmitted without corrections, the associate editors will return the article until the requested revisions have been made. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. Time from acceptance to publication may take between twelve and eighteen months.

VII. Revision Checklist

Manuscripts will be returned to authors for not following through on the following:

- A. Send a copy of the revised article back to the associate editor, along with an email stating how reviewers' concerns were addressed.
- B. Make sure that references are formatted appropriately.
- C. Make sure that recommended changes have been made.
- D. Figures and legends sent separately, but placement in manuscript should be clearly delimited.

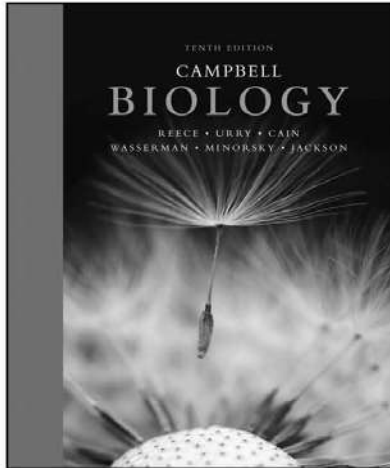
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