

Bioscene

Journal of College Biology Teaching



Volume 37(1)

May 2011

Bioscene

Journal of College
Biology Teaching

Volume 37(1) May 2011

ISSN 1539-2422

A Peer-Reviewed Journal of the

Association of College
and University Biology Educators

Editor-in-Chief:

James W. Clack
Indiana University –
Purdue University

An archive of all publications of the
Association of College and University
Biology Educators (ACUBE) can be
found at <http://acube.org/>

Bioscene is published in May (online)
and December (online and in paper
format). Please submit manuscripts
according to the guidelines for
consideration.



Cover image: Cover image was
taken by James Clack of an *Alligator
mississippiensis*, found in the
Everglades National Park in Florida,
USA.

CONTENTS

Editorial & Governance Information	2
Articles	3
Bridges or Barriers: Analysis of Logodiversity in College Biology Textbooks ..3 <i>Rebecca S. Burton</i>	
The Experimental Design Ability Test (EDAT)	8
<i>Karen Sirum and Jennifer Humburg</i>	
Innovations	17
Use of the Frog Heart Preparation to Teach Students about the Spontaneous Mechanical Activity of the Vena Cava	17
<i>Brent J.F. Hill, Ian Goodman, and William M. Moran</i>	
Creating Cost-Effective DNA Size Standards for Use in Teaching and Research Laboratories	23
<i>Jeff Shultz</i>	
Perspectives	26
The Biology Major Capstone Experience: Measurements of Accountability ..26 <i>Thomas A. Davis</i>	
Editorial	29
Studying and Grades: When Less is More and More is Less.....	29
<i>James W. Clack</i>	
Submission Guidelines.....	31

Bioscene: Journal of College Biology Teaching

Volume 36 (2) • December 2010

A Publication of the Association of College and University Biology Educators

Bioscene Editors

James W. Clack, Editor-In-Chief,
Division of Science
Indiana University – Purdue University
4601 Central Ave., Columbus, IN 47203
Telephone: 812-348-7266
FAX: 812-348-7370
Email: jclack@iupui.edu

Janice Bonner, Associate Editor (Articles),
College of Notre Dame, MD.

Karen Sirum, Associate Editor (Viewpoints &
Innovations), Bowling Green State University, OH.

Editorial Board

James Bier, Mercy College
Neval Erturk, Converse College
Greg Fitch, Avila University
Anjali Gray, Lourdes College
Wendy Heck Grillo, North Carolina Central University
Barbara Hass Jacobus, Indiana University – Purdue
University
Carol Maillet, Brescia University
Irina Makarevitch, Hamline University
Dave Matthes, University of Minnesota
Paul Pickhardt, Lakeland College
Carol Sanders, Park University
Chad Scholes, Rockhurst University
Conrad Toepfer, Brescia University
Aggie Vanderpool, Lincoln Memorial University
Kristen Walton, Missouri Western State University
Don Williams, Park University
Robert Yost, Indiana University – Purdue University

ACUBE Mission Statement

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.

ACUBE Governance

Laura Salem, Rockhurst University, President
Tom Davis, Loras College, Executive Secretary/Treasurer
Debbie Meuler, Cardinal Stritch University, Secretary
Tara Maginnis, University of Portland, President-Elect
Aggy Vanderpool, Lincoln Memorial University, Local Arrangements - 2011
Neval Erturk, Converse College, Program Chair - 2011
Chiron Graves, Eastern Michigan University, member
Cori Fata-Hartley, Michigan State University, member
Karen Sirum, Bowling Green University, member
Kristen Walton, Missouri Western State University, member
Greg Smith, Lakeland College, member
Conrad Toepfer, Brescia University, past-President

ARTICLES

Bridges or Barriers: Analysis of Logodiversity in College Biology Textbooks

Rebecca S. Burton

Department of Biology, Alverno College, Milwaukee, WI 53234-3922

Email: rebecca.burton@alverno.edu

Abstract: When selecting a textbook, college instructors must weigh a variety of factors. One is whether the text is written at a level that is accessible to one's students. An important factor in this is how many technical words are used. I developed an index to calculate logodiversity, a term I coined that reflects the number of technical words and the usage frequency of those words. The college-level animal behavior textbooks I examined varied greatly in their logodiversity. A fairly reliable substitute for the more time-consuming calculation of logodiversity is the ratio of pages in the glossary to the number of pages in the text as a whole.

Key words: textbook, readability, jargon, logodiversity

*Such an educated feller
His thoughts just came in herds
He astonished all the cowboys
With his jaw-breakin' words.*

-The Zebra Dun

Specialized language separates members of groups from non-members. Cultures, age groups, and people from different geographic regions often use knowledge of particular jargon or slang to distinguish those who belong from those who do not. Most of us have probably been in situations where we've been excluded from conversations because we did not know the specialized vocabulary of a subculture. As we stand outside the circle, group members glory in their use of their own language. We are left to figure out the meaning, wait for an interpretation, or wander off to join another group.

As jargon proliferates, science becomes more like a foreign language (Montgomery 2004). Indeed, we probably all have heard students in our biology courses make similar statements. Given enough time and practice, many students are able to join the biology in-group, but the struggle may exclude some students who would otherwise have been successful scientists.

When does the teaching of specialized science vocabulary cease to be a bridge to the world of science and instead become a barrier that prevents students from joining the profession—or even the conversation? If we are to make effective decisions about how to present material, we need to decide how much specialized vocabulary to use. We might decide “on the fly” how to say things in the classroom—even offering several wordings for the same concept—but these discussions are ephemeral. Our

textbook selection is a decision that lasts throughout the school term.

Informally reviewing a textbook may not be enough to determine readability. High school biology teachers generally are able to distinguish between more and less readable biology textbooks, but tend to underestimate how much a difficult text must be simplified in order to make it more readable (Wright and Spiegel 1984). Several readability indices have been designed for evaluating textbooks quantitatively. Most (*e.g.* Coleman-Liau, EFLAW, Flesch-Kincaid, Fog, Fry, and Raygor) are based on length of sentences and words (either characters or syllables). Armbruster *et al.* (1985) demonstrated that passages designed to score as more readable on these scales can actually become more difficult to understand because shortened sentences often lack connecting words that help students understand the relationships between facts. Johnson and Otto (1982) found that making sentences shorter and simpler did not make college biology textbooks easier for high school seniors to understand. So many readability indices may not be applicable to science textbooks.

A major challenge in reading biology texts is the number of discipline-specific words. Shorter words are not necessarily any easier to understand because either the word itself (*e.g.* lek), the scientific use of the word (theory), or the concept behind the word (fitness) will be new to a student with little science background. Therefore, the use of technical words

may be a critical factor in biology textbooks' readability.

Some textbooks introduce new terms often, even if the word is used only once. Other books tend to avoid technical words unless they will be repeated often. In attempting to quantify this variable, I coined my own jargon, *logodiversity*: the measure of the use of specialized vocabulary.

There are potential advantages to high textbook logodiversity. Introducing students to the rich and complex language of biology can facilitate their acceptance into a community of professional biologists and solidify their self-images as biologists. Students who are comfortable with the lexicon of biology will probably make a more professional impression in many communication areas, from interviews to papers to presentations. A broad technical vocabulary can also improve students' future reading comprehension, particularly as they read the primary literature. Similarly, students with a strong command of biology terms might also improve their performance on entrance exams for graduate and professional programs.

On the other hand, a study in general business courses found that when textbooks were less readable, courses had fewer A and B grades, lower average grades, and more students withdrawing from the course (Spinks & Wells, 1993). A related disadvantage to high logodiversity is that the students who are most likely to be challenged by it include people who would increase the diversity of our field. Students who are the first in their families to attend college, socio-economically disadvantaged students, those for whom English is not the primary language, and those with learning differences related to communication are likely to find concepts even more difficult to master when they are confronted with a multitude of new terms. These students also are more likely to believe that they will never belong to the in-group. Certainly faculty can spend extra time teaching the new vocabulary, but this may occur at the cost of instruction in the central concepts of biology.

These concerns led me to ask whether there is much variation in logodiversity among textbooks and whether there were a simple way to quantify it. Being able to ascertain quickly the logodiversity of a textbook before adopting it might lead to more informed textbook choices.

MATERIALS AND METHODS

Using a search engine, I located 100 on-line syllabi of animal behavior courses that listed textbooks in 2004, taken in the order identified. I continued my analysis using the six most common textbooks that had indices. For each word in the glossary, I counted the number of times the word occurred in the index.

I analyzed these data using a modification of the Shannon-Wiener Index of Diversity, which is used to quantify species diversity in natural communities. It is based on both the number of species (richness) and the evenness of the community. In other words, the index is sensitive to whether there are comparable numbers of individuals in each of the species as opposed to there being a few common species and many rare ones. The Shannon-Wiener index of diversity is calculated as:

$$H' = - \sum_{i=1}^s p_i \log_e p_i$$

Where H' = The Shannon-Wiener index of diversity

s = Number of species in a community

p_i = Proportion of the community of i th species.

I adapted this so that:

s = number of words in glossary

p_i = proportion in index of i th word.

and calculated logodiversity as:

$$(s^2/H')/1000$$

The value of the Shannon-Wiener index of diversity increases with both the number of species and the evenness of their proportion in the community. Logodiversity values *increase* with number of specialized words (s) and *decrease* with evenness in word occurrence. Logodiversity values are *lower* when a text uses only those specialized words that are used often. Logodiversity values are *higher* when many specialized words are used, especially if each word is rarely used.

I also analyzed the relationship between the value of the logodiversity index and other measures of logodiversity that were easier to calculate.

RESULTS

Nine textbooks accounted for 89% of the textbooks used in undergraduate animal behavior courses (Fig. 1). Six of the nine most commonly used textbooks identified in the survey had glossaries. Therefore, I continued my analysis on these six.

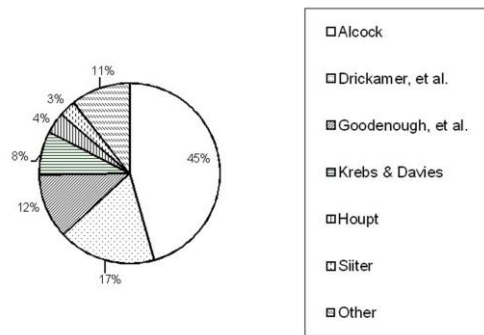


Fig. 1. Use of textbooks in college animal behavior courses (listed in descending order) as found in a survey of online syllabi in 2004.

The books differed greatly in their inclusion of technical terms (Table 1). The total number of words in glossaries ranged from 120 to 375. The logodiversity index values ranged from 3.44 to 29.5, nearly an order of magnitude of difference. A comparison of texts with high and low logodiversity reveals that high logodiversity was due not only to the number of words in the glossary, but also to the large number of words used only once or twice in the high logodiversity example (Fig. 2).

These results indicate that it may be important to examine textbooks for their use of language. However, calculating logodiversity is prohibitively time consuming. Therefore, I tested a variety of other measures to see which would correlate most closely to logodiversity. Two measures that were strongly correlated with the logodiversity score were the total number of words in the glossary (Fig. 3; $R^2 = 0.9772$) and the ratio of pages in the glossary to pages in the body of the text (Fig. 4; $R^2 = 0.9112$). In the latter measure, a textbook with a nonstandard layout (Slater) was an outlier and excluded from the analysis. There was no correlation between logodiversity of a textbook and how many courses were using it ($R^2 = 0.11$).

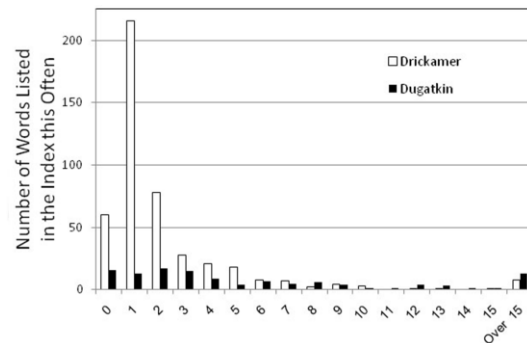


Fig. 2. Evenness of terms used in textbooks with the highest and lowest logodiversity values.

DISCUSSION

When selecting a textbook, biology instructors have many characteristics to evaluate including the book's general approach, topics, pedagogical aids, cost, and artwork. Logodiversity may also be an important factor to consider, though my findings indicate that is not currently a common consideration.

Animal behavior textbooks in this study differed greatly in their use of technical terms. Blystone (1987) contends that some authors use new terms in textbooks "like seasoning to whet the appetite of fellow professionals" to demonstrate that the book reflects current research, and that this practice makes textbooks less effective for student use. Whether one agrees with this view or not, recognizing the level of logodiversity may assist instructors in selecting a book that is consistent with their own goals. Recognizing that the logodiversity of a textbook is not an optimal match for the course or students is a critical first step in providing students with appropriate assistance.

The measures used in this study may not be a perfect reflection of actual use of terms in the books. There may have been differences among authors on their judgment of which words should be included in a glossary. This could have caused me to over- or under-estimate logodiversity. Inclusion of words in

Table 1. Measures of technical vocabulary in six textbooks. Numbers in parentheses reflect words that were defined in the glossary but not listed in the index.

Author(s) & Edition	Number of Words in Glossary	Total Number of Pages	Glossary/Text Page Ratio	Logodiversity Index Score
Alcock 7 th	123 (24)	453	0.0123	3.92
Drickamer <i>et al.</i> 5 th	397 (60)	422	0.0315	29.5
Dugatkin 1 st	100 (16)	675	0.0067	3.44
Maier 1 st	357 (18)	569	0.0364	26.11
Siiter 1 st	146 (90)	392	0.0251	13.81
Slater 1 st	119 (92)	233	0.0571	10.65

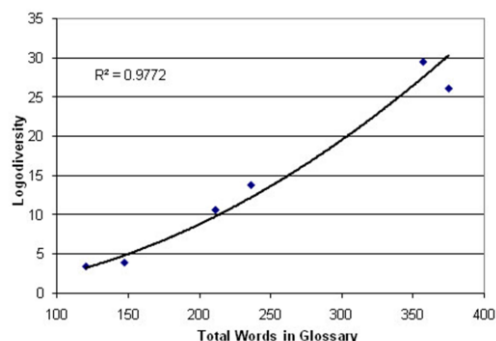


Fig. 3. Correlation between the total number of words in the glossary and the logodiversity for six animal behavior textbooks.

the index is likely to have been automated and therefore less likely to be a source of spurious differences among the textbooks.

Even if the logodiversity index were a perfect measure of the use of technical terms in textbooks, it is not a practical method for evaluating textbooks due to the time required for analysis. However, two other methods yield very similar results. The total number of words in the glossary provides very similar results to the logodiversity index score but still requires some time to measure. A very simple measurement is the ratio of pages in the index to the total number of pages in the body of the textbook (excluding index and glossary). Either of these should be sufficient for most faculty, who will be making decisions based on several criteria and may wish to know merely whether the logodiversity is high, low, or moderate.

IMPLICATIONS FOR TEACHING

The *preparation* of students may result in different optimal textbook logodiversity levels. Some college students are well-versed in the language of biology before arriving at college, while others have had little exposure to any science. Students who are returning to formal education after a long absence may have lost science language skills. The placement of a course in the curricular sequence will also

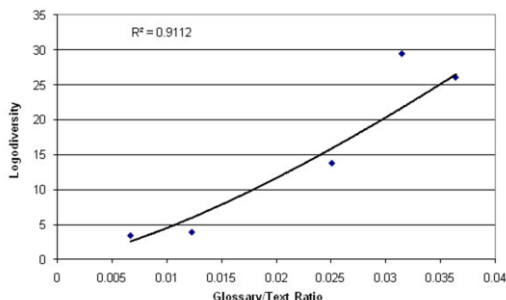


Fig. 4. Correlation between the ratio of pages in the glossary to pages in the text and the logodiversity for five animal behavior textbooks.

influence the level of vocabulary that students can manage. The students may also have difficulties if they are English language learners or have learning differences related to communication.

The *goals* of students may also result in different optimal textbook logodiversity levels. Those planning to attend graduate or professional schools need a more sophisticated science vocabulary in order to transition easily to the next level of their education.

In practice, courses are likely to include students with different goals and levels of preparation. When using a textbook with low logodiversity, using supplemental readings from the primary literature may increase our students' working vocabulary. This allows us to concentrate on smaller sets of words while still giving students a more accessible textbook for the majority of their learning.

Whether we use a textbook with high or low logodiversity, all students benefit from learning strategies for coping with unfamiliar words. If we scaffold their reading, we can expect them to understand more than they would if we merely assigned readings. For example, we might provide vocabulary resources before the reading or teach our students how to use glossaries effectively. We can help them to use context cues and word roots for figuring out the meanings of words on their own. Worksheets and reflection questions can assist students in assessing whether they have understood the concepts and vocabulary or whether they need to review the reading.

FUTURE QUESTIONS

Several questions remain unanswered. For example, does logodiversity capture how students experience readability of textbooks? Do other aspects of textbook design significantly assist or impede our students in their understanding of textbooks? Does increased logodiversity actually lead to greater vocabulary comprehension or provide students with a larger working vocabulary? Does possession of a larger specialized vocabulary increase interest, entrance, or performance in a field?

As we consider the best possible textbooks for our courses, we can easily determine their relative logodiversity. Depending on the needs of our students, we may prefer a higher or lower logodiversity. Identifying this level will help us to determine how we can best assist our students in using the textbook effectively.

ACKNOWLEDGEMENTS

I thank Dawn C. Balistreri for careful and ruthless editing. I also benefitted from the perspectives of those who attended a workshop on this topic at the 2007 ACUBE meeting.

REFERENCES

- ARMBRUSTER, B.B., OSBORN, J.H., AND A.L. DAVISON. 1985. Readability formulas may be dangerous to your textbook. *Educational Leadership* 42(7): 18-20.
- BLYSTONE, R. V. 1987. College introductory biology textbooks: an important communicative tool. *American Biology Teacher* 49(7): 418-25.
- JOHNSON, L.L. AND W. OTTO. 1982. Effect of alterations in prose style on the readability of college texts. *Journal of Educational Research* 75(4): 222-29.
- MONTGOMERY, S. 2004. Of towers, walls, and fields: perspectives on language in science. *Science* 303: 1333-1335.
- SPINKS, N. AND B. WELLS. 1993. Readability: a textbook selection criterion. *Journal of Education for Business* 69(2): 83-88.
- WRIGHT, J. D. AND D. L. SPIEGEL. 1984. How important is textbook readability to biology teachers? *American Biology Teacher* 46(4): 221-25.

The Experimental Design Ability Test (EDAT)

Karen Sirum and Jennifer Humburg

Dept. of Biological Sciences, 202 Life Sciences Building, Bowling Green State University, Bowling Green, OH 43403

Email: ksirum@bgsu.edu

Abstract: Higher education goals include helping students develop evidence based reasoning skills; therefore, scientific thinking skills such as those required to understand the design of a basic experiment are important. The Experimental Design Ability Test (EDAT) measures students' understanding of the criteria for good experimental design through their open-ended response to a prompt grounded in an everyday life science problem. Using a straightforward scoring rubric to analyze student responses, the EDAT provides for consistent and rapid evaluation. Minimal student and classroom time is required to administer the EDAT and it can be used in a pre-/posttest format to measure gains. Significantly, the EDAT is content and terminology independent, and requires minimal quantitative skills. Our findings indicate that the EDAT is sensitive to improvements in experimental design ability, as only students in our sample who participated in a redesigned introductory biology course that included explicit instruction and experiences using the scientific method, made significant gains in their experimental design ability.

Key Words: Scientific Thinking Skills, Science Reasoning, Experimental Design, Assessment, Pretest and Posttest

INTRODUCTION

At the national level, science organizations have expressed their support for science education initiatives that promote scientific literacy (American Association for the Advancement of Science, 1989 and 2011; National Research Council, 1995; National Science Foundation, 1996; Osborne, 2010). A scientifically literate person is one who is able to evaluate the quality of scientific information, pose and evaluate arguments based on facts, and apply this information appropriately (National Research Council, 1996). We set out to design an assessment instrument that would allow us to determine whether we were providing such a learning environment for undergraduate non-science majors in a redesigned introductory biology course. We devised an assessment instrument called the Experimental Design Ability Test (EDAT) and we investigated the test's sensitivity by evaluating students' ability to design an experiment at the beginning and end of the course.

The EDAT requires that students explain how they would go about determining whether they would accept a claim about a product in an open-ended question format. First students have to recognize that an experiment *can* be done to evaluate the plausibility of the specified claim. Then they guide us through their thinking process in the design of such an experiment. Students need to demonstrate their understanding of the importance of controlling variables, larger sample sizes, reproducibility, and of the limitations to the generalization of their conclusions. However, the EDAT is content

independent and does not require students to use specific terms such as independent or dependent variables and it has a minimal requirement for quantitative skills. Compared to a multiple-choice test, this format gives insight into a student's thought processes instead of simply the end result of their thinking. It demands that students think through the process of designing an experiment in their own minds without being cued in on what the correct answer might be from the options provided in a multiple-choice test (Lederman, 1998). The EDAT only requires 10-12 minutes for students to complete, and scoring is straightforward using our specific scoring rubric, requiring one hour for the instructor to score 40 tests.

METHODS

The Experimental Design Ability Test (EDAT) was administered in a pre- and posttest format to students enrolled in multiple sections of a non-majors introductory biology course. Sections of the course, including those using non-lecture based teaching strategies and student-designed labs (Experimental Groups) and those using traditional lecture and descriptive labs (Traditional Groups), were assessed with the EDAT. In Experimental Groups, interactive engagement teaching strategies were used which involved challenging students with a variety of problem based, interactive, and group learning activities, and incorporating Socratic discussions (Klionsky, 2004; Knight and Wood, 2005). In addition, in Experimental Groups the traditional lab component was replaced by lab activities that involved student-designed experiments, some based

Pretest: Advertisements for an herbal product, ginseng, claim that it promotes endurance. To determine if the claim is fraudulent and prior to accepting this claim, what type of evidence would you like to see? Provide details of an investigative design.

Posttest: The claim has been made that women may be able to achieve significant improvements in memory by taking iron supplements. To determine if the claim is fraudulent and prior to accepting this claim, what type of evidence would you like to see? Provide details of an investigative design.

Fig. 1. EDAT pre- and posttest student prompts. Students were provided a sheet of paper with the prompt at the top and told to use as much writing space and time as they need.

on the “desk-top” biology labs of Handelsman *et al.* (2002). These sections of the course met 3 times a week: once a week for 2 hours and twice a week for 75 minutes. The maximum enrollment was 25 students. In Experimental Groups 1-3, the instructor integrated lab group learning activities, discussions, and group problem solving, while lecturing was limited to approximately 15 minutes maximum per class. Students completed web-based readings and take home reading quizzes to prepare for class (Klionsky, 2004). In contrast, Experimental Group 4 fully incorporated the same lab experiences as Experimental Groups 1-3 (see below) but the main pedagogical strategy was lecturing with occasional (approximately once per week) implementation of some of the active learning activities used in Experimental Groups 1-3.

The lab activities for students in Experimental Groups 1-4 involve first presenting students with a problem and some background information. Students are then asked to propose a hypothesis and design an

experiment to test their hypothesis regarding the problem in a PreLab homework assignment (North Carolina State University, 2004). Two such examples of these types of lab experiences are the “Moldy Bread” and “Mutation and Selection” lab activities found in Handelsman *et al.* (2002). In groups and with the entire class, students discuss, critique, and modify their experimental design, and then perform their experiments in pairs. Individually, students submit a written lab report, using as a guide a lab report rubric that we abbreviated and modified based on that described in LabWrite (North Carolina State University, 2004; Appendix). These lab reports, a maximum of 3 pages including figures and tables, include a student’s hypothesis, methods with description of treatment and control groups and variables, results, discussion, brief conclusions, and references. The lab report is then critiqued by the instructor and returned to students with comments and with a marked copy of the rubric, indicating the student’s level of achievement and the number of points earned in each section of the lab report. Students complete six PreLab assignments, perform six experiments and write six lab reports throughout the semester, in addition to other activities. Through the student-designed experiments, an emphasis is placed on helping students learn to be precise in their interpretation of their data and thorough in their explanation of the limitations of their experimental designs and conclusions. A student’s combined average on these lab assignments comprises one third of their overall course grade. These groups are referred to as “Experimental” because they utilized new science teaching strategies for our institution.

In the Traditional sections of the course, students attended 50-minute lectures three times a week and

Table 1. Characteristics of the introductory non-majors biology course sections in this study.

Section	Section Characteristics							
	Term	# Enrolled*	N EDAT	% Freshmen	% Female	Instructor**	Lab Method†	Lecture Method†
Exp. 1	Sp '07	21	21	57%	57%	A	S-D	AL
Exp. 2	F '07	25	24	100%	80%	A	S-D	AL
Exp. 3	F '07	22	21	23%	64%	A	S-D	AL
Exp. 4	F '07	24	22	100%	58%	B	S-D	Trad. + AL
Trad. 1	F '07	15	12	8%	62%	C	Trad.	Trad.
Trad. 2	F '07	21	20	100%	56%	C	Trad.	Trad.
Trad. 3	F '07	123	76	40%	66%	C	Trad.	Trad.
Trad. 4	Sp '08	119	71	48%	52%	B	Trad.	Trad.

Exp. = Experimental Groups. Trad. = Traditional Groups.

% Freshman & % Female are tabulated from the sample of students that participated in assessments.

Term is the year of either the Spring (Sp) or Fall (F) semester for that course section.

*Indicates number of students enrolled in course, which is different from sample number, N.

** Course sections were taught by three different instructors indicated by A, B, or C.

† Lab teaching strategy is either S-D (Student-Designed labs) or Trad. (Traditional descriptive lab). Lecture teaching strategy is AL (Active Learning/Interactive Engagement), Trad. (Traditional lecture), or Trad. + AL (a combination of both).

participated in traditional descriptive labs once a week for a 2- hour time period. In the Traditional lab, students receive credit for completing lab worksheets, tests and quizzes, and an end-of-semester PowerPoint presentation based on one of their lab activities. A student's scores on these assessments comprise one third of their course grade. Two of the Traditional sections of the class had enrollments similar to the Experimental Groups (maximum 25 students), while two of the Traditional sections were large lecture sections with up to 140 students and with multiple 30-student sections for the lab taught by various graduate Teaching Assistants (See Table 1).

The EDAT pretest was administered during the first week of the semester in each of the participating sections. Students were given as much time as they needed to complete their responses; almost all students finished in 10-12 minutes. Grade points were not awarded to the students for participation in the pretest. We have found that students are often eager to do their best at the beginning of the semester and motivation is high. Students were informed that we were gauging their abilities in biology to gain a better understanding of where they were and how we could help them be successful in this course. EDAT pretest scores and the EDAT scoring rubric were not shared with students at any time and students were not told in advance that a similar posttest would be administered later in the semester.

The EDAT posttest was administered during the week prior to the last week of class in the Experimental Groups. Students were told several days in advance that they were having a quiz based on the scientific thinking skills they learned and that their effort on the quiz would count for approximately 3% of a student's grade in the course. In the Traditional Groups, the EDAT posttest was also administered during the week prior to final exams. Students were also told in advance that they were having a quiz based on scientific thinking skills and that they could earn bonus points towards their course grade (not more than 1% of the course total) for their degree of effort on the EDAT. Given the different instructors and course formats, we were not able to control the weight given to the EDAT towards a student's grade in the different sections of the course. Again, students were given as much time as they needed to complete their responses, typically 10-

12 minutes. Note that all three of the course instructors and the laboratory Teaching Assistants had equal knowledge of the EDAT pre- and posttest prompts and scoring rubric.

Only EDAT scores for students that participated in both the pre- and posttest are reported and were used in statistical analysis. The data did not fit a normal distribution; therefore, a nonparametric test, the One-sample Wilcoxon sign rank test, was used for analysis. Individual student scores were paired in the Wilcoxon test. Statistical analysis of results was performed using Minitab 15 Statistical Software (2008). Correlation analyses (Spearman's rank correlation) were performed using STATISTICA (2008).

RESULTS AND DISCUSSION

Criteria for a Scientific Thinking Test

We wanted to measure changes in students' scientific thinking in terms of their ability to design experiments, and we wanted to be able to use an assessment instrument with the following six criteria:

1. Not time consuming to administer to students in the classroom,
2. Based on a practical challenge from an "everyday life" problem to increase student buy-in and effort,
3. Requiring minimal student quantitative skills,
3. Open-ended to reveal student's thinking (*i.e.*, not multiple choice),
4. Easy to score consistently, and
6. Providing a quantitative measure.

Therefore, we designed the Experimental Design Ability Test (EDAT). Students were given a specific prompt asking them to come up with an investigative design to test a claim (based on Ommundsen, 2005; Fig. 1). We chose the wording of the prompt to avoid leading the students or directing their response as much as possible and we avoided using multiple-choice questions because they may provide unintended corrective feedback to the students.

The open-ended student responses were then scored using a rubric that we designed for the purpose of simplification and clarification of the criteria for a good experimental design (Allen and Tanner, 2006; Moskal, 2000; North Carolina State University, 2004; University of Michigan-Dearborn School of Education, 2002). Ten criteria were selected for good basic experimental design (Fig. 2) and each student's score reflects the number of criteria correctly included in their answer, with a maximum score of 10. Note that the order of the listed criteria was designed to reflect increasingly difficult items for students to include in their EDAT response such that, for example, the tenth point is more challenging for the student to include than the first point. Work is in progress to confirm this order

Table 2. Determination of inter-rater reliability value for EDAT scores: Pearson's coefficient.

EDAT Inter-rater Reliability		
	$r = 0.835$	$p < 0.001$
	<i>M</i>	<i>SD</i>
Rater 1	5.16	2.54
Rater 2	5.56	2.31

EDAT Scoring Rubric (7/2010)

- ___ 1. Recognition that an experiment can be done to test the claim (vs. simply reading the product label).
- ___ 2. Identification of what variable is manipulated (independent variable is ginseng vs. something else).
- ___ 3. Identification of what variable is measured (dependent variable is endurance vs. something else).
- ___ 4. Description of how dependent variable is measured (e.g., how far subjects run will be measure of endurance).
- ___ 5. Realization that there is one other variable that must be held constant (vs. no mention).
- ___ 6. Understanding of the placebo effect (subjects do not know if they were given ginseng or a sugar pill).
- ___ 7. Realization that there are many variables that must be held constant (vs. only one or no mention).
- ___ 8. Understanding that the larger the sample size or # of subjects, the better the data.
- ___ 9. Understanding that the experiment needs to be repeated.
- ___ 10. Awareness that one can never prove a hypothesis, that one can never be 100% sure, that there might be another experiment that could be done that would disprove the hypothesis, that there are possible sources of error, that there are limits to generalizing the conclusions (credit for any of these).

Fig. 2. EDAT scoring rubric used to score students responses to the edat prompts. This rubric should not be shared with students. Each item that is included in the student's response is checked and the checks are tallied for a student's total EDAT score with a maximum of 10 points.

(manuscript in preparation). Of significance is the fact that the EDAT scoring rubric allows students to demonstrate understanding of experimental design without having to use any specialized vocabulary or terms such as "independent/dependent variable" or "control", and without requiring substantial quantitative skills. The EDAT can be used with both science majors (manuscript in preparation) and non-majors at all levels.

Using the rubric, students' EDAT responses were independently scored by two raters, and then scores were compared for inter-rater reliability. Each rater was able to score approximately 40 EDAT responses in an hour and the inter rater reliability was determined to have a Pearson's Correlation Coefficient of 0.83 (Table 2). Note that at time of scoring, raters did not know the identity of the course section of each student response.

Changes in Students' Experimental Design Ability

To investigate the utility of the EDAT, we administered it to multiple sections of the same introductory non-majors biology course that focused on the molecular and cellular basis of life at our large undergraduate and graduate degree granting public university (~19,000 undergraduate students) over four 16-week semesters.

Three different teaching strategies were used in various sections of the course, each of which included a 3-credit lecture and 1-credit laboratory component: some sections fully used interactive engagement, non-lecture-based teaching strategies as well as student-designed labs (Experimental Groups 1-3, Table 1); one section had a combination of mainly traditional lecturing with some active learning activities but did not fully incorporate the student-designed labs (Experimental Group 4, Table 1); and some sections consisted of traditional lecture and traditional descriptive lab teaching methods (Traditional Groups 1-4, Table 1).

Three different instructors taught these different groups (Table 1). One instructor taught both the lecture and the lab sections of Experimental Groups 1-3. Another instructor taught the Experimental Group 4 lecture sessions and a biology graduate student teaching assistant (TA) who was trained for instruction of the student-designed laboratories, taught the lab sessions of this group. The same instructor for Experimental Group 4 also taught Traditional Group 4 with various other TAs teaching the multiple 30-student lab sections. A third instructor taught the Traditional Groups 1-3, again with various TAs teaching the lab sessions (Table 1). Note that Traditional Group 1 was an honors section of the course restricted to students with a minimum university grade point average (GPA) of 3.5.

It is important to understand that the purpose of this report is NOT to compare two teaching strategies or different instructors *per se*, but rather to use the existing differences in teaching strategies to test the utility and significance of the EDAT. The intent of the Experimental Groups was to help develop students' scientific thinking skills; specific student learning activities were incorporated into both the lecture and lab portion of the course to this end. Therefore, it is reasonable to predict that these sections of the course will show gains in EDAT scores, thus serving as one form of validation for the EDAT instrument. While it is natural to compare the various sections of the course to identify those factors contributing to the differences in EDAT scores, there are confounding variables that limit the interpretation of data to this end. Further analysis of the many course section differences, and analysis of varied teaching strategies used, is the subject of ongoing investigation and will be published separately.

We analyzed the utility of the EDAT by administering it to non-major introductory biology students enrolled in both Experimental and Traditional Groups at the beginning of the 16-week

Table 3. The means and standard deviations of pre- and post-test EDAT scores for each course section.

Section	Mean EDAT Scores			
	Pretest		Posttest	
	Mean	SD	Mean	SD
Exp. 1 n = 21	4.67	1.74	6.52	0.93
Exp. 2 n = 24	3.29	1.73	7.21	1.64
Exp. 3 n = 21	3.14	1.91	6.95	1.32
Exp. 4 n = 22	3.33	1.88	5.77	1.51
Trad. 1 n = 12	3.33	1.92	3.50	1.24
Trad. 2 n = 20	3.30	1.76	3.05	1.43
Trad. 3 n = 76	3.00	1.76	3.42	1.81
Trad. 4 n = 71	3.66	2.07	3.61	1.69

semester and again at the end. While the basic format of the EDAT from pretest to posttest does not change, and the requirements to answer the question are the same for both, in this data set, the specific details of the question posed to the student was varied pretest to posttest so that the prompt seemed different to the students (Fig. 1). We have subsequently used the pretest prompt also as the posttest prompt with other classes and observe results similar to that reported here, indicating that the differences in the two prompts is not sufficient to account for differences in EDAT pre- and posttest scores (manuscript in preparation).

After scoring the pre- and posttest EDAT responses, we found that the average EDAT pretest scores for the Experimental and Traditional Groups were 3.6 (SD=1.8) and 3.3 (SD=1.9) respectively (Table 3 & Figure 3) indicating that for both groups, students' experimental design abilities are very similar at the beginning of the semester. The average EDAT posttest scores for the Experimental and Traditional Groups were 6.6 (SD=1.35) and 4.0 (SD=1.5) respectively (Table 3 & Figure 3). Statistical analysis of these EDAT scores indicates that all of the sections that incorporated student-designed experiments in the laboratory sessions (Experimental Groups 1-4) made statistically

Table 4. Determination of significant gains in EDAT scores for each participating introductory non-majors biology course section: results from Wilcoxon Sign Rank test.

Section	EDAT Change from Pre- to Posttest			
	Mean	SD	Median	P
Exp. 1 n = 21	2.28	2.03	2.5	< 0.001 *
Exp. 2 n = 24	3.92	2.28	3.5	< 0.001 *
Exp. 3 n = 21	3.81	2.16	4.0	< 0.001 *
Exp. 4 n = 22	2.55	1.99	2.5	< 0.001 *
Trad. 1 n = 12	0.17	2.25	0.0	0.894
Trad. 2 n = 20	-0.25	1.77	0.0	0.570
Trad. 3 n = 76	0.42	2.09	0.5	0.063
Trad. 4 n = 71	-0.06	1.87	0.0	0.768

* $p < 0.05$

significant gains ($p < 0.001$), while the sections with traditional labs (Traditional Groups 1-4) did not make gains (Table 4) indicating that something about the students' experience in the Experimental Groups facilitated the development of experimental design ability compared to the Traditional Groups. This can also be seen when looking at the distribution of the number of students with scores from 1-10 on the EDAT pre- and posttest for both Experimental and Traditional Groups (Figs. 4 & 5). Students who were exposed to experiences that required them to design their own experiments and analyze and reason with data made greater gains in their ability to design experiments as measured by the EDAT compared to their peers who were exposed to traditional lecture and laboratory teaching methods.

Although the goal of the research reported in this paper is not a controlled experiment to assess the effectiveness of an instructional method, the differences in instructional methods used in the Experimental and Traditional Groups gave us an opportunity to assess experimental design ability in students who either were or were not exposed to student-designed experiment experiences. While these data do not rule out other differences between the two groups that may influence performance on the EDAT, the data do show that the EDAT can be used to rate students' scientific thinking ability in terms of their understanding and application of the fundamental concepts of experimental design. Halpern (2003) found similar results when using a standardized thinking skills tests to assess the effectiveness of critical thinking instruction and found that students who were taught with specific thinking instruction outperformed those who were not taught in this manner. Our findings are supportive of the effectiveness of our instrument, the EDAT, in measuring basic experimental design ability, as students who had an opportunity to use and practice experimental design were the same students who made gains in their EDAT scores.

The reliability of the EDAT can be demonstrated by the fact that all of the sections that incorporated student-designed experiments made statistically significant gains in EDAT scores. The validity of this assessment has been established thus far through scoring the EDAT responses with a scoring rubric that consists of a list of the elements that make a good experimental design (Fig. 2), thereby establishing face or qualitative validation. If further validation is necessary, this could be accomplished through the use of other measures of experimental design ability. In this regard, we could not use students' scores on their lab reports as a direct report of their change in experimental design ability since lab reports also require conceptual understanding of

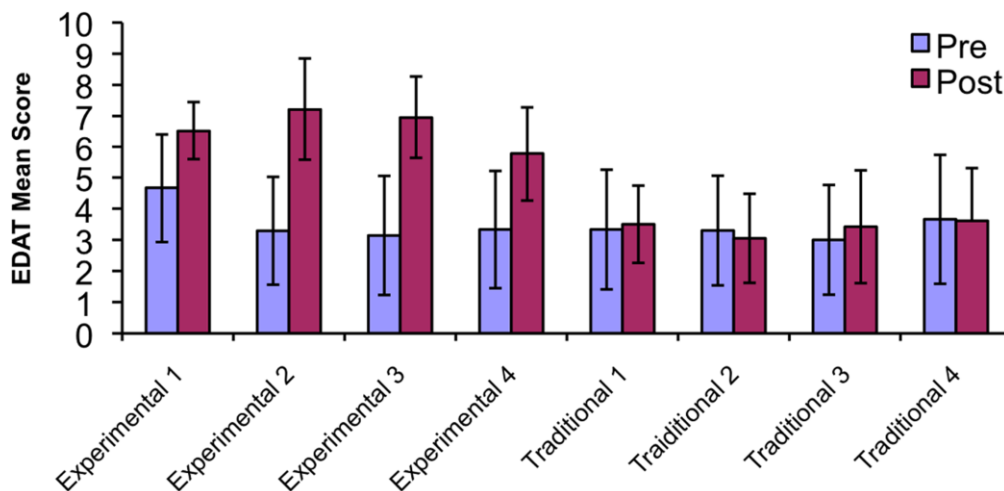


Fig. 3. Pre- and post- EDAT score means +/- standard deviation for each participating introductory non-majors biology course section. Gains in average EDAT scores for the experimental groups are statistically significant ($p < 0.001$) as determined by the one-sample Wilcoxon Sign Rank test. Traditional groups did not make statistically significant gains (See Tables 3 and 4).

the biological concepts being explored. Early labs were conceptually simpler than those the students performed later in the semester so a student's change in lab report scores would not necessarily reflect changes in their experimental design ability.

In our analysis, we had a total of three instructors. One instructor (C in Table 1) taught only Traditional Groups 1-3, another instructor (B, Table 1) taught Experimental Group 4 and Traditional Group 4, and a third instructor (A, Table 1) taught

only Experimental Groups 1-3. We observe increases in EDAT scores for two different instructors. Experimental Groups 1-4, with either instructor A or B, all incorporated the student-designed experiments and all made statistically significant gains in the EDAT ($p < 0.001$). Instructor B also taught Traditional Group 4 without the student-designed experiments and this group's average EDAT score virtually remained the same over the course (pre=3.66, post=3.61; Fig. 3). This example points

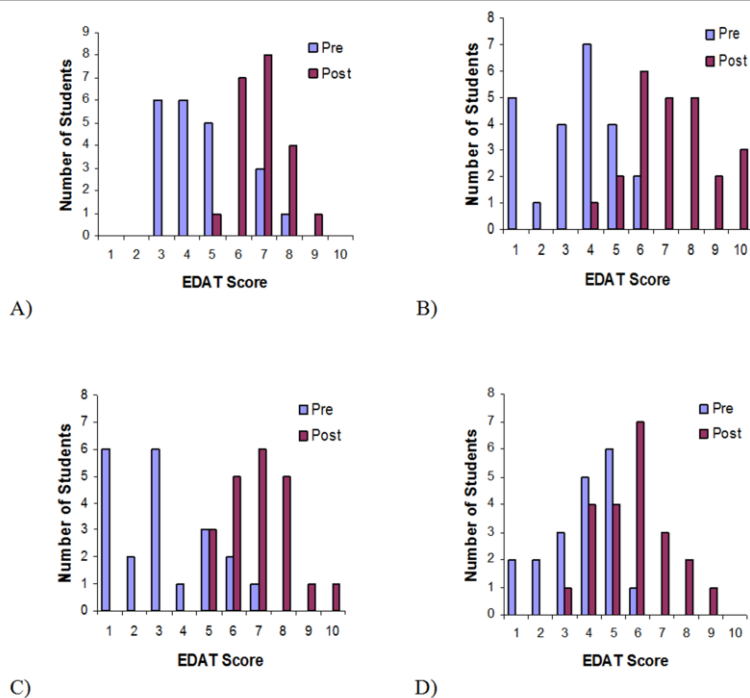


Fig. 4. (A-D) Frequency distribution of student pre- and posttest EDAT scores for participating experimental teaching sections of introductory non-majors biology. The x-axis of the graphs shows the EDAT score and the y-axis shows the number of students with that score. (A) Experimental Group 1. (B) Experimental Group 2. (C) Experimental Group 3. (D) Experimental Group 4.

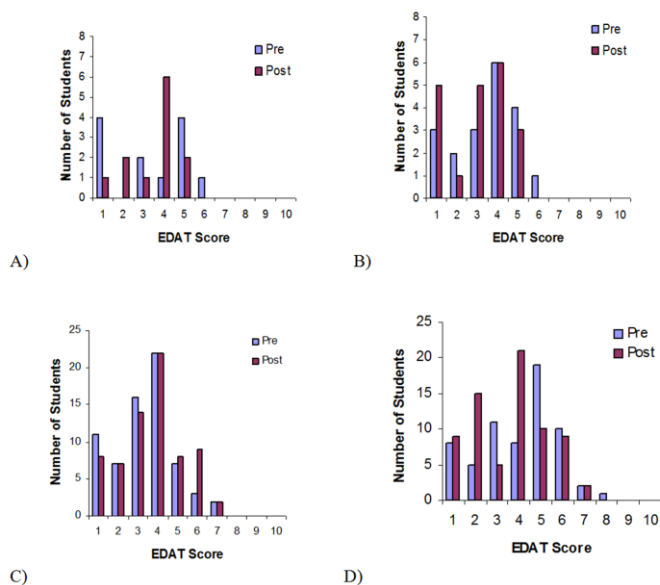


Fig. 5. (A-D) Frequency distribution of student pre- and posttest EDAT scores for participating traditional teaching sections of introductory non-majors biology. The x-axis of the graphs shows the EDAT score and the y-axis shows the number of students with that score.

- (A) Traditional Group 1.
- (B) Traditional Group 2.
- (C) Traditional Group 3.
- (D) Traditional Group 4.

out that gains in the EDAT are not limited to one instructor. Since this is a small sample size, further work is in progress using the EDAT in many other courses with other instructors and will help to clarify this issue.

Demographic Factors That Do Not Impact EDAT Scores

We were interested in finding out if other factors influence EDAT scores. With the use of a two-sample t-test, no male-female differences were found in EDAT gains ($p=0.961$) suggesting that the teaching techniques were similarly beneficial or not for both male and female students and that the EDAT is not biased with regard to gender. To find out if there is a statistically significant difference in EDAT pre-scores or gains depending on age or pre-score (note: in our data set students ranged in age from 18-25 years), we used a One-way ANOVA. The data indicate that the mean scores of students ages 18-25 years do not differ: students did not come into the course with a higher score because of their age, and those students who did make gains did so regardless of their age and pre-score.

One might think that students who have more college experience in general would perform better on the EDAT. Students who have more college experience may have had more science courses or other courses or experiences that promoted the development of their scientific thinking. Using a One-way ANOVA we looked at the difference in pre-scores and gains made between freshman, sophomores, juniors or seniors on the EDAT. Results indicated that there was no difference: on average, students in our sample, regardless of their year in college, are not entering introductory non-majors biology with the ability to score above 3.6 on

the EDAT. Although we did not find differences between pre-scores or gains for this sample of undergraduate students enrolled in non-majors introductory biology for the EDAT based on gender, age, or year in college, some differences may exist. Current work involves a larger sample of students who also include science majors.

CONCLUSIONS

The EDAT is sensitive to improvements made in experimental design ability: the Experimental Groups made significant gains and the Traditional Groups did not make gains. It is possible that some of the Experimental vs. Traditional Group differences in EDAT scores are due to other unexamined factors such as incoming ACT or SAT scores, GPA, or previous science courses the students have taken, so conclusions about the differences in outcomes among these groups are limited. However, Traditional Group 1, an Honors section of the course requiring students to have a minimum 3.5 GPA, did not have an average EDAT score that was different from the non-Honors sections of the course. Current research involves investigating the role of these variables when the sample size is larger and includes science majors, and whether EDAT gains are maintained with time after the end of the course. The main purpose of this study was to design, implement, and determine some of the characteristics and effectiveness of the EDAT, our diagnostic test for experimental design ability, in an introductory biology course, and our data demonstrate the utility of the EDAT to this end. The EDAT was designed to be content independent so that it can be used with any student population. Similarly, by design, the EDAT has a very low requirement for quantitative skills. For example, it is

sufficient for students to understand that a large sample size is desirable, however, knowing the actual number of subjects that is sufficiently large for statistically significant data is beyond the scope of the EDAT. Our reasoning for this approach is that we expect that not all students will have highly developed experimental design skills. Rather our goal is that, in everyday life decisions, all students will be aware of the criteria for good experimental design, have the ability to ask questions of data to help them determine if conclusions are warranted, and will understand the limitations to conclusions.

ACKNOWLEDGEMENTS

The authors thank our colleagues for allowing us to test the EDAT in their classrooms and the reviewers for their helpful comments.

HUMAN SUBJECTS

This work is in compliance with the policies and has the approval of the Bowling Green State University Human Subjects Review Board.

REFERENCES

ALLEN, D. AND K. TANNER. 2006. Rubrics: Tools for Making Learning Goals and Evaluation Criteria Explicit for both Teachers and Learner. *CBE-Life Sciences Education* 5: 197-203.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. 1989. *Science for All Americans. A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology*. AAC&U, Washington, DC.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. 2011. *Vision and Change in Undergraduate Biology Education: A Call to Action*. AAC&U, Washington, DC. Accessed from <http://visionandchange.org/> on 10 April 2011.

HALPERN, D. 2001. Assessing the Effectiveness of Critical Thinking Instruction. *J. General Education* 50(4): 270-286.

HANDLESMAN, J., HOUSER, B., AND H. KRIEGEL. 2002. *Biology Brought to Life: A Guidebook to Teaching Students to Think Like Scientists*. McGraw-Hill, NY.

KLIONSKY, D.J. 2004. Talking biology: learning outside the book—and the lecture. *Cell Biol. Educ.* 3: 204 -211.

KNIGHT, J. K. AND W.B. WOOD. 2005. Teaching More by Lecturing Less. *Cell Biol. Educ.* 4: 298-310.

LEDERMAN, N.G., WADE, P.D., AND R.L. BELL. 1998. Assessing the nature of science: What is the nature of our assessments? *Science and Education* 7(6): 595-615.

MINITAB 15 STATISTICAL SOFTWARE. 2008. Minitab Incorporated. State College, PA.

MOSKAL, B. M. 2000. Scoring rubrics: what, when and how? *Practical Assessment, Research & Evaluation* 7(3). Accessed from <http://PAREonline.net/getvn.asp?v=7&n=3> on 14 April 2007.

NATIONAL RESEARCH COUNCIL. 1995. *National Science Education Standards*. National Academy Press, Washington, DC.

NATIONAL RESEARCH COUNCIL. 1996. *National Science Education Standards*. National Academy Press, Washington, DC.

NATIONAL SCIENCE FOUNDATION. 1996. *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*. Directorate for Education and Human Resources, Washington, DC.

NORTH CAROLINA STATE UNIVERSITY. 2004. *LabWrite: Improving Lab Reports*. Accessed from <http://labwrite.ncsu.edu/> on 10 April 2011.

OMMUNDSEN, P. 2005. Critical Thinking in Biology Using Case Studies. Accessed from <http://capewest.ca/ct.html#Judging%20Testability%20of%20a%20Claim> on 12 July 2010.

OSBORNE, J. 2010. Arguing to Learn in Science: The Role of Collaborative, Critical Discourse. *Science* 328: 463-466.

STATISTICA (2008). StatSoft, Incorporated. Tulsa, OK. Accessed from <http://www.statsoft.com/> on 13 July 2010.

UNIVERSITY OF MICHIGAN-DEARBORN, SCHOOL OF EDUCATION. 2002. Rubric for "Experimental Design" component of the Science Education Portfolio (SEP). Accessed from http://www.umd.umich.edu/sep/rubric_expdes.htm on 12 July 2007.

APPENDIX

EVALUATION: Lab Report _____						Writer: _____
Section Points		no credit	attempted	partial credit	full credit	Section Scores
3	Title Describes lab content concisely, adequately, appropriately	[]	1	2	3	[]
15	PreLab Effectively defines the research problem and states the research question or goal					[]
12	Hypothesis States hypothesis and provides logical reasoning for it	[]	4	8	12	[]
12	Methods/Treatments/Controls Gives enough details to allow for replication of procedure Clearly identifies treatment(s) and necessary controls	[]	2	4	6	[]
		[]	2	4	6	
18	Results Opens with effective statement of overall findings Quantifies results if possible Accurately and carefully measures data/makes observations Format of tables and figures is clear and correct	[]	2	4	6	[]
		[]	1	2	3	
		[]	2	4	6	
		[]	1	2	3	
24	Discussion Logically explains why results support or refute hypothesis Backs up statement with reference to specific findings Thoughtfully demonstrates clear understanding of limitations to conclusions Suggests and describes follow-up experiment or question	[]	2	4	6	[]
		[]	2	4	6	
		[]	2	4	6	
		[]	2	4	6	
6	Conclusion Convincingly describes what student learned from this lab experience	[]	2	4	6	[]
1	References All appropriate sources in the report are listed and citations and references adhere to proper format	[]	x	x	1	[]
5	Presentation Report is written in scientific style: clear and to the point Grammar and spelling are correct	[]	1	2	3	[]
		[]	x	x	2	
4	Overall aims of the report: <i>the student...</i> Has successfully learned what the lab is designed to teach	[]	x	2	4	[]
100						[]
		Points Earned				[]
		Total Possible Points				100

Appendix. Lab report rubric modified from LabWrite (North Carolina State University, 2004) and used with students as a guide and for grading lab reports in the experimental sections of the introductory biology course.

INNOVATIONS

Use of the Frog Heart Preparation to Teach Students about the Spontaneous Mechanical Activity of the Vena Cava

Brent J.F. Hill, Ian Goodman, and William M. Moran

Department of Biology, University Central Arkansas, Conway, Arkansas 72035-0001

Email: bhill@uca.edu

Abstract: Most undergraduate physiology texts describe veins simply as reservoirs for blood and conduits for return of blood to the heart. This article describes a laboratory exercise that can be performed by students to demonstrate that veins are much more than reservoirs and conduits for blood flow: they possess a dynamic rhythmic contraction. In this exercise, we recorded the simultaneous beating of the frog postcaval vein (PCV; in mammals this is the inferior vena cava) and atrium by connecting them to separate force displacement transducers. *In vivo*, the PCV and atrium both contract ~ 35 beats/min; however, the contractions are not synchronous with each other. We developed a simple scoring method (comparative temporal analysis) to illustrate that the atrium contractions do not drive the contractions of the PCV. Instead the atrium and PCV contract independently of each other. To support our hypothesis that the atrium and PCV contractions were independent we removed the PCV from the frog and suspended it in an organ bath. The PCV rhythmically contracted as *in vivo*. The autonomic neurotransmitter, norepinephrine, did not affect the force of contraction and heart rate. In contrast, acetylcholine abolished the contractile activity. This investigation has encouraged discussions about the source and physiological significance of the rhythmic PCV contractions. This article provides some hypotheses about its significance, as well as possible evolutionary origins of the veins' mechanical activity. Overall, the implementation of this exercise into the classic frog heart preparation will deepen the students' understanding about the venous side of the cardiovascular system and give them insight into the integrative nature of physiology.

Key words: contraction, veins, physiology

INTRODUCTION

In many undergraduate physiology laboratories the classic frog heart preparation is used to teach Starling's Law of the heart, autonomic control of heart function, and the heart refractory period. In our senior-level animal physiology course students investigate Starling's Law by measuring the increase in magnitude of each heart beat with each incremental increase in tension applied to the apex of the heart. This is analogous to the increase in contractile strength of the heart with an increase in venous return. Autonomic regulation of the heart is explored by the application of norepinephrine and acetylcholine to activate the β -adrenergic and muscarinic receptors on the heart to increase and decrease heart rate, respectively. Likewise, students change the impulse frequency on an electrical stimulator to determine how much time needs to elapse after stimulation before another heart beat can be initiated (*i.e.* heart refractory period).

While performing these laboratory investigations, students recognized that the postcaval vein (PCV) next to the sinus venosus of the heart was 'beating.' In mammals the PCV is analogous to the inferior vena cava. In addition, the rhythmic PCV

contraction appeared to be independent of the heartbeat. Traditionally, physiology courses depict veins as reservoirs for blood and as conduits for venous return of blood to the heart. However, there is a dynamic regulation of venous diameter by hormonal and autonomic influences. Veins contract in response to norepinephrine, endothelin-1, platelet-activating factor, thromboxane A₂, and leukotrienes (Gao and Raj, 2005; Xu *et al.*, 2007). Relaxation is mediated by the inducers of nitric oxide formation, acetylcholine, and bradykinin (Gao and Raj, 2005).

Only a few studies have reported that the PCV contracts (*i.e.* beats) spontaneously (Victor and Nayak, 2003; Jones *et al.*, 2003; Huizinga and Faussonne-Pellegrini, 2005; Ghose *et al.*, 2008). Victor and Nayak (2003) formulated a "cardiovascular hypothesis" to describe the beating of the major veins in vertebrates (including mammals) as a 'waltz and duet.' This hypothesis proposes that there is a systemic venous 'waltz' caused by the sequential contraction of the veins, venous sinus, and right atrium. The return of unoxygenated blood to the heart is followed by the pulmonary 'waltz;' this is the sequential contraction of the pulmonary veins, pulmonary venous sinus, and

left atrium. The 'duet' is created because the systemic veins contract before the pulmonary veins. The physiological significance associated with this rhythmic beating is unclear.

After observing the rhythmic PCV contraction in lab, a student (one of the coauthors) in our animal physiology class developed hypotheses about the physiological significance of the PCV's mechanical activity and the autonomous nature of its beat. This paper describes experiments that this student completed. These experiments can easily be done by undergraduate students to show that the PCV contracts independently of the atrium. Furthermore, we provide a discussion about possible function(s) of the spontaneously contracting PCV that can be used by instructors to promote student discussion and planning of future experiments. These experiments will deepen student knowledge of the cardiovascular system and improve their scientific skills by forcing them to formulate hypotheses that they will test.

METHODS

Animal Preparation

Bullfrogs ~ 5 inches in length were obtained from Carolina Biological Supply (Burlington, NC). Frogs were stored at room temperature (22° C) in a fiberglass container designed specifically for frogs. The container consisted of a "swimming pool" with a drain outlet and a shelf on which the frogs sat and were sprayed with charcoal-filtered tap water from an inlet nozzle. Before use in laboratory experiments, frogs were cooled in crushed ice for ~ 30 minutes and then double-pithed with a stainless steel needle. Next, the heart was exposed by cutting open the chest cavity with stainless steel scissors and kept moist by periodically dripping frog Ringers directly on the heart. The frog Ringers contained (in mM) 100 NaCl, 2.5 KCl, 1.0 CaCl₂, 1.0 MgCl₂, and 10 Tris buffer, pH 7.5. All salts and Tris buffer were obtained from Sigma (Saint Louis, Missouri). The use of the bullfrogs was approved by the University's IACUC.

In vivo experiments

The atrium and PCV for each frog were

connected to separate UFI model 1030 force displacement transducers (MacLab) using thread tied to a size 6 fishhook. The transducers were connected to MacLab Bridge Amplifiers that were, in turn, connected to an ADInstruments Powerlab/4st. Data were acquired with ADInstruments Chart 5.4 software and the digitized data displayed on the screen of an Apple eMac computer.

To further explore the source of the PCV beat, the PCV (immediately adjacent to the sinus venosus) was pinched with stainless steel forceps. The ends of the forceps were covered with heat shrink tubing to minimize damage to the PCV; this maneuver stopped blood flow from the PCV to the sinus venosus and to the atrium.

Organ bath experiments

The PCV was removed from each frog with stainless steel scissors and mounted in a 25 mL organ bath (GlobalTown Microtechnology, Bradenton, Florida) that contained frog Ringers. The isolated PCV was connected to a tissue holder (TSC-100S, GlobalTown Microtechnology) that was connected to a force-displacement transducer (GlobalTown). The transducer was connected to an ADInstruments Powerlab/4st, and data were acquired as described above.

Neurotransmitters

Acetylcholine (ACH) and norepinephrine (NOREPI) (Sigma) were used to inhibit or stimulate the activity of the heart and the PCV, respectively. Both neurotransmitters were made as 1 mM stock solutions in frog Ringers, and dripped onto the heart with a plastic pipette or added to the organ bath to modulate the activity of the PCV. Because NOREPI oxidizes easily, it was freshly prepared the day of the experiment.

Statistical Analysis

We developed a simple scoring method (comparative temporal analysis, CTA) that undergraduates could do in lab to determine if the PCV contraction was independent of the atrium beat in their *in vivo* experiments. We made the

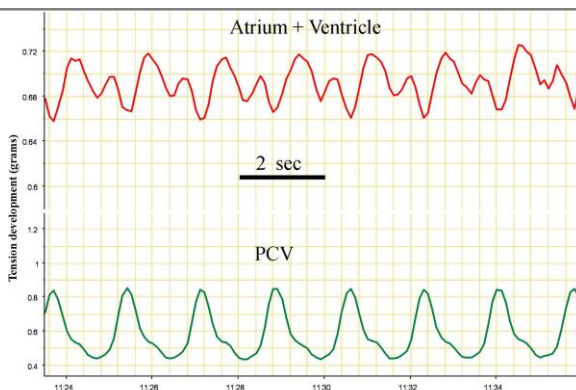


Fig. 1. Simultaneous recordings of the asynchronous contractions of the atrium and PCV in a bullfrog. Both the atrium and PCV contract at a frequency of ~ 35 beats/min. The smaller beat in the atrium trace is ventricular mechanical activity.

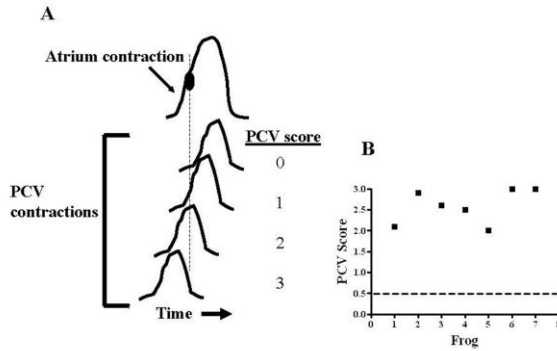


Fig. 2. Comparative temporal analysis of PCV and atrium contractions. A. Scoring method used to compare the time course of an atrium contraction to the PCV contraction. B. Individual PCV scores (n=7) illustrate that the PCV contraction occurs before the atrium contraction ($P < 0.05$). A PCV score of ~ 0.5 would have suggested that the atrium contraction drives the PCV beat.

assumption that if the atrium beat creates a PCV contraction, then it must precede the PCV contraction. The CTA was achieved by comparing the time-course of atrium and PCV contractions to generate CTA scores (Fig. 2A). A CTA score of zero indicates that the middle of the atrium upstroke corresponds to a relaxed PCV, thus suggesting that the PCV beats after the atrium. A score of 2 indicates that the PCV is fully contracted and occurs before the atrium contracts. Data are represented as the mean \pm standard deviation. Results were considered significant when $P < 0.05$ using a paired t-test or the Wilcoxon sign ranks test (comparative temporal analysis).

RESULTS

In vivo contractile activity of the atrium and PCV

The atrium and PCV both beat at an average rate of 35 beats/min at room temperature (22°C ; Fig. 1). Also seen in Figure 1 is the ventricular beat (smaller beat) that is superimposed on the atrium trace. Contraction of the PCV occurs after the ventricular contraction, and thus, precedes the atria contraction. In frogs there is a component of the electrocardiogram (ECG) that is attributed to the electrical activity of the PCV (Victor and Nayak, 2002, 2003). Although we did not record the ECG, students can record both the ECG and contraction of the PCV and correlate the two to demonstrate that the

electrical event (ECG) precedes the mechanical event (contraction of PCV).

Comparative Temporal Analysis

Conceivably the contraction of the atrium could create a PCV ‘pulse’ that appears as an independent beat (Victor and Nayak, 2003; Jones *et al.*, 2003). Therefore, we used a comparative temporal analysis (CTA) of the atrium and PCV contractions to test the hypothesis that the PCV beat is driven by the contractile activity of the atrium. According to this analysis, if the atrium beat induces a PCV contraction it will precede the PCV beat with a score of ~ 0.5 . As shown in figure 2B, the CTA scores (n=7 frogs) ranged from 2.0 to 3.0. These high scores indicate that the PCV contraction occurs before the atrial contraction. Therefore, we reject our hypothesis that the atrial beat drives contraction of the PCV. The frequency of the atrium and PCV contractions for the seven frogs were 36.0 ± 7.7 and 35.6 ± 7.4 beats/min, respectively.

The pinch experiment

The PCV was pinched with modified stainless steel forceps to stop blood flow from the PCV to the sinus venosus and atrium. In three out of five bullfrogs, pinching the PCV on the atrial side of the fishhook completely eliminated the beating of the atrium after several larger beats but had little effect on PCV contractile activity (Fig. 3); this effect was

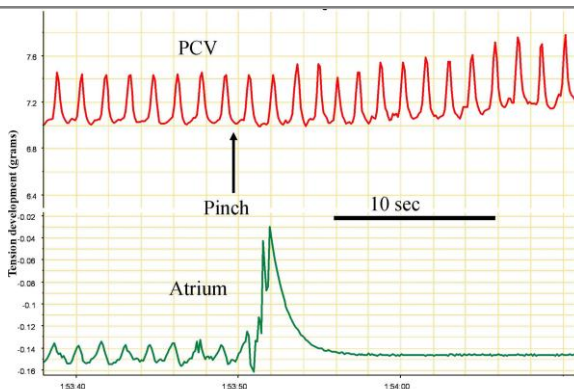


Fig. 3. A representative trace of a pinch experiment shows that the mechanical activity of the atrium is independent from the PCV contraction.

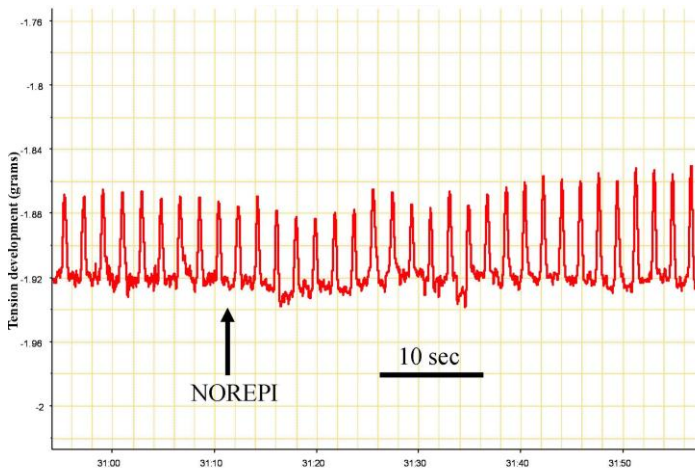


Fig. 4. The adrenergic agonist, NOREPI, has little effect on the spontaneous contractile force and rate of the PCV contraction.

reversible.

In the other two frogs, pinching the PCV reduced but did not completely abolish atrial mechanical activity. These experiments support the CTA results. We attribute the loss or reduction of contractile activity of the atrium to the marked decrease in venous return of blood to the heart via the PCV because this major vein returns more blood to the heart than does the anterior caval vein.

Organ bath experiments

The *in vivo* experiments detailed above imply that the mechanical activity of the atrium is not responsible for the PCV's rhythmic contractions. To isolate contractions of the PCV, the PCV was suspended in an organ bath. In three out of six PCVs that were mounted in organ baths, beating was spontaneous (Figs. 4 and 5). We suspect the lack of beating in the other three PCVs was due to "pacemaker" damage caused by the dissection. Application of 4 μM NOREPI caused a slight increase ($P > 0.05$) in PCV contractile activity (Fig. 4). NOREPI increased the force of contraction from 0.01 ± 0.01 g to 0.02 ± 0.01 g and heart rate remained unchanged from 35 ± 17.6 to 37 ± 14.2 beats/min. In contrast, 4 μM ACh gradually abolished the mechanical activity of the PCV (Fig. 5). ACh significantly decreased the contractile force from 0.02 ± 0.01 g to 0.00 ± 0.01 g and attenuated the heart rate from 36.00 ± 10.40 to 4.00 ± 6.93 beats/min.

DISCUSSION

In our animal physiology course students are required to write in scientific journal format about some of the experiments reported here as part of a formal laboratory report on frog cardiovascular physiology. Because undergraduate physiology texts do not mention the beating of the vena cava, students were particularly excited about the possibility that they were researching a physiological process that was not described in their textbook. These

experiments provide evidence that the PCV rhythmically contracts with the same frequency as the atrium contraction. However, the PCV contraction is independent of the atrium contraction and occurs after the ventricular contraction, and thus, precedes the atrium contraction. The muscarinic agonist, acetylcholine, effectively inhibited the contractile activity of the PCV. In contrast, the β -adrenergic agonist, norepinephrine, had little effect on the PCV contraction. The student excitement and desire to learn more about the spontaneity of the PCV contraction is a tremendous confirmation about the success of these experiments to inspire thinking about the cardiovascular system.

The rhythmic contractions of the PCV and atrium *in vivo* experiments allow students to visualize and hypothesize why the PCV and atrium contractions are out-of-phase with each other. The CTA provides evidence that the PCV contraction precedes the atrium contraction. This suggests that the atrium contraction does not drive the contractile activity of the PCV. Also, in the pinch experiment we were able to reduce/eliminate the atrial beat with little effect on the rhythmic activity of the PCV (Fig. 3). However, the contractile force of the PCV increased after the pinch was applied. This may be due to a myogenic reflex mechanism (Berne *et al.*, 2004) in which the increased force of contraction was due to blood building up in the pinched PCV, stretching the walls of the vessel. This stretch would then elicit a compensatory contraction by the venous smooth muscle. Taken together, these *in vivo* experiments support our conclusion that mechanical activity of the atrium does not drive the contraction of the PCV. The possibility exists that the electrical activity of the atrium is able to spread (via gap junctions and nerve pathways) to the PCV and drive its rhythmic contraction. However, once we isolated the PCV in an organ bath the rhythmic contractions

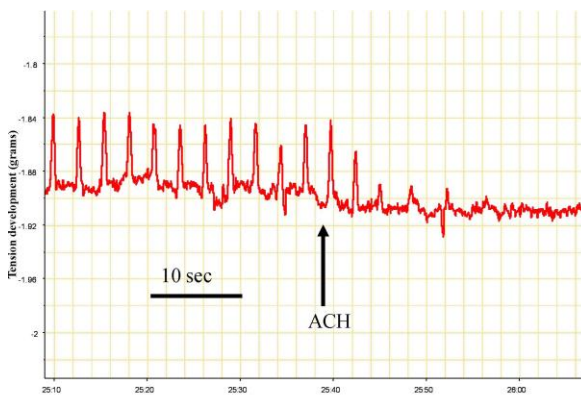


Fig. 5. The cholinergic agonist, ACh, abolished the rhythmic PCV contractile activity.

(~ 35 beats/min) were still identical to the frequency we recorded *in vivo*. Students have to be careful in removing the PCV from the frog because of damage to the ‘pacemaker.’ Ghose *et al.* (2008) similarly reported that the interstitial cells of Cajal in the frog, which are responsible for the rhythmic contractions of the gastrointestinal tract and closely associated blood vessels, can be easily damaged and lose their ‘pacemaker’ ability. Overall, our data support our hypothesis that the PCV possesses its own pacemaker ability.

When students perform experiments on the frog PCV, they will generate two important questions: (1) What is the source of the PCV beat? and (2) what is its physiological significance? The cardiovascular hypothesis formulated by Victor and Nayak (2003) proposes that there is a sequential contraction of the systemic and pulmonary veins (‘waltz and duet’). Importantly, this suggests that there is a poorly understood rhythmic ‘pacemaker’ in the venous circulation. Similar to our study, Ghose *et al.* (2008) described that the frog PCV demonstrates spontaneous rhythmicity of 36-40 beats/min. They attributed this ‘pacemaker’ ability to the interstitial cells of Cajal. However, they used the distal end of the PCV adjacent to the hepatic veins, which demonstrated some differences from our results using the proximal end of the PCV. In contrast to our data, Ghose *et al.* (2008) found that norepinephrine significantly decreased the frequency of contraction until the beat was completely abolished. In addition, the rhythmicity of the distal end of some PCVs demonstrated interrupted periods of rest in which the rhythmic contraction resumed a few minutes later.

Further, some unidentified cells of the PCV may have migrated from the sinus venosus of the heart and/or become ‘entrained’ from the pacemaker (*e.g.* sinus venosus) of the frog heart. Overall, the *in vivo* autorhythmicity of these veins may be modulated by its inherent autonomic regulation (Victor and Najak, 2003, Jones *et al.*, 2003). For example, vagal stimulation suppresses rat vena cava contractility

independent of heart rate (Jones *et al.* 2003). Likewise, in our isolated bath experiments, ACh abolished the PCV contractile activity (Fig. 4B). Thus, the medulla oblongata may regulate the chronotropic and inotropic effects of the PCV (*i.e.* vena cava).

Victor and Nayak (2002, 2003) developed two hypotheses to explain the physiological significance of the beating veins. First, contraction of the veins prevents backflow of blood from the atrium into the sinus venosus and therefore also the vena cava. However, the sinoatrial valve (also present in frogs) may prevent backflow after the atrium contracts. If the sinoatrial valve closes during PCV relaxation and atrium contraction, the contraction of the PCV is functionally insignificant in preventing backflow. Second, contraction of the vena cava aids venous return of blood to the heart and ventricular filling (Victor and Nayak, 2002). Both hypotheses are not mutually exclusive and need to be tested experimentally.

Our experiments support Victor and Nayak’s (2003) cardiovascular hypothesis, which describes how the veins rhythmically contract in a sequential manner whereby the systemic veins contract before the pulmonary veins (*i.e.* ‘waltz and duet’). This ‘waltz and duet’ is poorly understood, and in humans may have clinical significance (Victor and Nayak, 2002). Nevertheless, the possibility exists that the rhythmic contraction of the veins has no physiological significance. However, Victor and Nayak (2002, 2003) have described the cardiovascular hypothesis in a wide range of animals that includes snakes, turtles, crocodiles, fish (sharks), frogs, birds, and mammals. Therefore, the environment (aquatic *vs.* terrestrial) has little effect on the presence of this phenomenon. Because the ‘waltz and duet’ is present in a wide variety of animals we argue that it is physiologically relevant.

The evolutionary origin of the veins gives insight into the pumping action of these vessels. For example, in the Cephalochordata (*Amphioxus*) some

vessels contract and act as pumps to create blood flow (Solc, 2007). In these chordates, the primary pumping action is performed by the aorta ventralis, but the vena subintestinalis, vena portae, and vena hepaticae also contract autonomously (Solc, 2007). Further, these veins contract sequentially (reminiscent of the ‘waltz and duet’ of vertebrates) to pump blood in this primitive circulatory system. Hence, the beating veins in mammals and other vertebrates may have evolved from the beating vessels in the primitive chordates, supporting the notion that the ‘waltz and duet’ is physiologically relevant, as argued above. If true, the evolutionary origins of the beating veins suggests, as proposed by Victor and Nayak (2002), that the primary function of the contracting PCV and vena cava is to facilitate venous return of blood to the heart.

By studying the rhythmic beating of the PCV and the cardiovascular hypothesis, students will also gain insight into integrative physiology and the emergent properties of living organisms (Schultz, 1996). In this situation, the emergent properties are illustrated by the specialized ‘pacemaker’ cells found within the PCV that coordinate their function with the rest of the venous circulatory system to move blood throughout the vasculature to sustain life. Because the cardiovascular system distributes endocrine and neuroendocrine messenger molecules to target tissues, the cardiovascular system is integral to the regulation of the coordinated activities that maintain homeostasis.

In summary, students have much to learn by experimentally investigating the beating of the PCV in bullfrogs. They will learn about a cardiovascular phenomenon, ‘waltz and duet’, not covered in most, if not all, physiology texts. (We examined 14 widely used undergraduate physiology texts and found nothing on the spontaneously beating veins.) They will also learn that there is still much to discover about cardiovascular physiology, because the physiological significance and the mechanisms responsible for the regular mechanical activity of the veins are poorly defined (Jones *et al.*, 2003). Furthermore, students will strengthen their scientific skills in hypothesis formulation, experimental design, and drawing conclusions from experimental results. Finally, by investigating the mechanical activity of the major veins, students will gain a deeper knowledge of the cardiovascular system.

ACKNOWLEDGMENTS

The authors appreciate the financial support of the Department of Biology at the University of Central Arkansas.

REFERENCES

- BERNE, R.M., LEVY, M.N., KOEPPEN, B.M., AND B.A. STANTON. 2004. The peripheral circulation and its control. In *Physiology*, 5th ed. Mosby Publishing, 380p.
- GAO, Y., AND J.U. RAJ. 2005. Role of veins in regulation of pulmonary circulation. *Am. J. Physiol. Lung Cell Mol. Physiol.* 288: L213-226.
- GERMANN, W.J., AND C.L. STANFIELD. 2005. The Cardiovascular System: Cardiac Function. In *Principles of Human Physiology*, 2nd ed. Pearson-Benjamin Cummings, 830p.
- GHOSE, D., JOSE, L., MANJUNATHA, S., RAO, M.S., AND J.P. RAO. 2008. Inherent rhythmicity and interstitial cells of Cajal in a frog vein. *J. Biosci.* 33(5): 755-759.
- HUIZINGA, J.D., AND M.-S. FAUSSONE-PELLEGRINI. 2005. About the presence of interstitial cells of Cajal outside the musculature of the gastrointestinal tract. *J. Cell. Mol. Med.* 9(2): 468-473.
- JONES, J.F., O’LEARY, D.M., AND M. PICKERING. 2003. Vagal control of the cranial venae cavae of the heart. *Exp. Physiol.* 88 (3): 329-334.
- SOLC, D. 2007. The heart and heart conducting system in the kingdom of animals: A comparative approach to its evolution. *Exp. Clin. Cardiol.* 12(3): 113 – 118.
- SCHULTZ, S.G. 1996. Homeostasis, Humpty Dumpty, and Integrative Biology. *News Physiol. Sci.* 11: 238 – 246.
- VICTOR, S., AND V.M. NAYAK. 2002. The Evolution and Genesis of Supraventricular Waltz and Duet. *Indian J. Thorac. Cardiovasc. Surg.* 18: 84 – 90.
- VICTOR, S., AND V.M. NAYAK. 2003. Cardiovascular Hypothesis. Every Heart Beat is Under Neural Command: An Hypothesis Relating to the Cardiac Rhythm. *Heart, Lung, and Circ.* 12 (1): 11 – 17.
- XU, J., FINK, G.D., AND J.J. GALLIGAN. Increased sympathetic venoconstriction and reactivity to norepinephrine in mesenteric veins in anesthetized DOCA-salt hypertensive rats. *Am. J. Physiol. Heart Circ. Physiol.* 293(1): H160-168.

Creating Cost-Effective DNA Size Standards for Use in Teaching and Research Laboratories

Jeff Shultz

School of Biological Sciences, Louisiana Tech University, Ruston, LA 71272

Email: jlshultz@latech.edu

Abstract: I have devised a method with which a molecular size standard can be readily manufactured using Lambda DNA and PCR. This method allows the production of specific sized DNA fragments and is easily performed in a standard molecular biology laboratory. The material required to create these markers can also be used to provide a highly robust and reliable introduction of students to the PCR technique. Protocols for demonstrating the effect of the effect of amplification cycles and DNA and Primer concentration are provided.

Keywords: Size Standards, PCR, Laboratory Exercises, Cost Reduction

INTRODUCTION

Molecular size standards consist of fragments of DNA that are a specific size and are used in electrophoresis to determine the approximate size of an unknown sample. Figure 1a shows two commercially available size standards Promega G7541 and G8291. The cost per lane for these markers is \$1.23 and \$2.04 respectively. A reliable technique for producing size standards was sought in order to reduce this recurring cost.

MATERIALS AND METHODS

PCR Primers were designed (Supplemental File

1) by pasting Lambda (λ) DNA sequence (NCBI gi:215104; 48,502 bp) into the Primer3 program (Rozen & Skaletsky, 2000), then selecting a product size value equivalent to that of the target size (*i.e.* “100-100” for a 100 bp product). A 59-61° C T_m with a minimum 20% GC content were selected. The default settings of an 18-27 bp oligo length and GC% of 20-80% were used. λ DNA was ordered from Promega (Madison, WI cat # D1501) and diluted 1:100 from stock. Supplemental File 1 contains a step by step protocol for creating a specific amplification product.

Each Polymerase chain reaction (PCR) contained

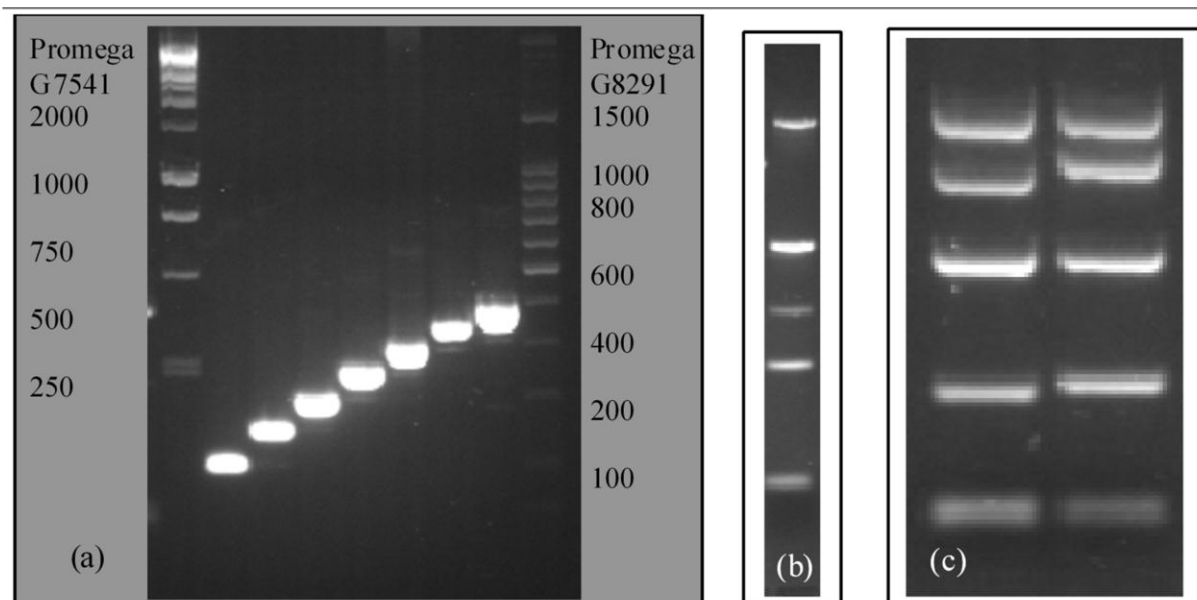


Fig. 1. Panel (a) Comparison of two commercially available size standards (Promega G7541 and G8291) and Lambda PCR amplification products ranging from 100-400 bp, in 50 bp increments. Lambda PCR product is highly concentrated and is typically diluted 10-20X in order to obtain clear amplification products, such as those shown in panels b and c. Panels b and c are additional examples of molecular size standards designed using this technique. Panel b shows a 100-250-350-500-1000 size standard. Panel c shows two size standards, left is 100-250-500-750-1000, right is 100-260-500-800-1000.

33 μL 2X PCR mix (cat # M7122, Promega, Madison, WI), 10 μL H_2O , 3 μL diluted (1:100) λ DNA and 4 μL of combined 10 mM forward and reverse primers. Amplification conditions were an initial 94° C denaturation for 3 min followed by 40 cycles of a denaturing step (94° C for 30 s), an annealing step (61° C for 60 s), primer extension (72° C for 60 s) and final extension for 5 minutes at 72° C. Each product was loaded separately into a 1.5% agarose gel (cat # BP160, Fisher Scientific, Waltham, MA) prepared with ethidium bromide (0.1 μL :20 mL gel matrix) and electrophoresed @ 4V/cm for 3-4 hours. Amplification patterns were documented with a UVP Gel documentation system (Upland, CA).

RESULTS AND DISCUSSION

A total of 22 unique primer pairs were designed to amplify fragments of λ DNA from 100-1150 bp in 50 bp increments (Table 1). This method allows the production of specific size DNA fragments, is easily performed and offers an extensive long term cost reduction versus commercially available products. Figure 1a-c shows a comparison of two commercially available molecular size standards and a test of specific size amplification products.

Initial Cost

Producing these fragments entails an upfront cost for the λ DNA (currently \$56 for 250 μg) and for the primers. The cost for each primer pair, assuming \$0.25/base, 25 nM concentration and 20 bp/primer is \$10. Thus, the cost for the primers and DNA to produce a marker similar to Promegas' #8291 with 11 sizes is \$166.

Cost per 100 Lanes of Standard

Go Taq Green Polymerase contains all components except primer and template needed for PCR and costs \$0.48 per 50 μL reaction. Primers are ordered at the 25 nM scale, then re-suspended into ~300 μL of 100 mM stock concentration. Once forward and reverse oligos are combined and diluted to 10 mM (see Supplemental File 2 for protocol) they are ready for PCR. At 4 μL per size, the primer cost is ~ \$0.02 per reaction. The cost per size fragment is therefore \$0.50 and the total cost of preparing an 11 fragment standard is \$5.50. I add 200 μL of molecular biology grade water to the 550 μL of product and 50 μL of Bromophenol Blue/Glycerol loading dye, making a final volume of 800 μL . At 6-8 μL volume loaded, the cost is ~ \$0.06 per lane. In essence, if the user expects to load more than one tube worth of size standard, manufacturing a 'proprietary' ladder becomes *very* cost effective.

Educational Lab Benefits

Other than the obvious long-term savings possible, these size standards are exceptionally robust. I have used them for several quarters to introduce students to the PCR technique, with a nearly 100% PCR success rate. Supplemental File 2 contains lab exercises for the creation of a size standard and that demonstrate the influence of primer and DNA concentration and PCR extension cycle number using these primers and λ DNA.

Table 1. Primer sequences used to generate specific amplification product sizes with PCR of Lambda DNA.

bp	Sequence	bp	Sequence
100 L	ATATCCGGCAGGAAACACTG	650 L	AAAGCCAGAACTCCCCGTAT
100 R	TAACGTTCTCCACCGACCTC	650 R	CTGTCACCCTTTGAGGTGGT
150 L	AGGATGACTGGTGGCGTAAC	700 L	GGCAGATCTCGATGATGGTT
150 R	AGTAAATTGCCGGCGTGATTC	700 R	CACGTTACCGGACCAGAAGT
200 L	GCAGACTGGAGGAGTTTTTCG	750 L	TGATACTGTGCCGGATGAAA
200 R	GTTTGCCGGGTCAATAAATG	750 R	TTAGGCAGAGACAGCGAAT
250 L	GGGAACGGGCGTTTTATTAT	800 L	TAAGCGGTGAGGCTCAGATT
250 R	CACACTGTCCGTCAGCTCAT	800 R	AGACACCTTCAGCTGGACT
300 L	GTCATACGCCAGCAGTGAAA	850 L	AGCCTGTAGCTCCCTGATGA
300 R	TGTTTGTCTGTTCTGGCTGAG	850 R	ATGCCTGGTACTTTGCCAAC
350 L	TTTTGATGAGGCGGATTTTC	900 L	GCAGAACGAAAAAGGTGAGC
350 R	ACCTTTCACCGGCATTGTAG	900 R	GCACACAGCGGAACCTTATGA
400 L	CTCTGGCGGTGATAATGGTT	950 L	CGCAGATGAGCTTGCCATA
400 R	TCGATTTCGTAGAGCCTCGTT	950 R	ATCTCGCTTCCACTCCAGA
450 L	ACCACCTCAAAGGGTGACAG	1000 L	TAAATTCGCACAGCAGCAAC
450 R	GGCCATGTTGTTGCTGTATG	1000 R	ACGTTTTTCAGGTTGGCATTTC
500 L	GATGCACGTAATCCCGTCT	1050 L	TGCATGTCCAGAGCTCATTC
500 R	GTATGAGCCGGGTCACTGTT	1050 R	AAGGCATTCCTACGAGCAGA
550 L	CCAGCTGCATCAGGATCATA	1100 L	GACGCACTGAATACCTGAA
550 R	CTGCTCCATCAGCTGTAAA	1100 R	TGCGTCACCTTCACCATAA
600 L	AGTCGAGCTGACGGAGGATA	1150 L	TCCAGACATGCTCGTTGAAG
600 R	ATCTGGCGATCAAAGGATG	1150 R	ACGGCAATAATCCGCATAAG

CONCLUSION

I have used λ DNA sequence to design PCR primers that amplify a specific fragment length of DNA. This procedure can be used on any DNA for which the sequence is known to produce specific sized DNA fragments. These amplification products are easily produced and offer an extensive long-term cost reduction versus commercially available products. In addition, these robust PCR components are useful for demonstration of basic PCR concepts.

ACKNOWLEDGEMENTS

I wish to acknowledge the excellent work of the Summer 2008 BISC491/591 class, who were instrumental in testing these primers.

REFERENCES

ROZEN, S., AND H. SKALETSKY. 2000. Primer3 on the WWW for general users and for biologist programmers. Humana Press, Totowa, NJ.

PERSPECTIVES

The Biology Major Capstone Experience: Measurements of Accountability

Thomas A. Davis

Program in Biology, Loras College, 1450 Alta Vista, Dubuque, IA 52004-0178

Email: tom.davis@loras.edu

Abstract: Loras College senior biology and biology research majors are required to take a comprehensive exam, give an oral presentation, write this talk into their thesis and participate in an exit interview with a non-biology faculty member before they graduate. Details of these capstone experiences will be discussed further. Other capstone experiences that might be included were discussed such as a hands-on lab skill assessment test, a 1-2 year research experience, and making an e-portfolio to include a resume and class artifacts. Suggestions for other items to consider in a senior capstone experience are included.

Key Words: capstone experience, biology major requirements,

INTRODUCTION

College and university biology faculty and graduating senior biology majors need ways to show that the educational experiences they have participated in together in the previous 3.5 years have resulted in measureable increases in scientific knowledge, writing, speaking, techniques or skills and critical thinking. College faculty need to generate artifacts that confirm their accountability. Learning outcomes that were presented early in the careers of college students need to be measured during the senior year for their level of accomplishment. Many of the recommendations of Bio 2010 (NRC, 2003) can be addressed by finishing an undergraduate experience in biology with a comprehensive senior capstone experience. The purpose of this article is to give some examples of activities of some capstone experiences so that more colleges and universities can incorporate some of them into their program outcomes, be more accountable for their teaching and use the results to improve their curriculum.

COMPONENTS OF AN “IDEAL” CAPSTONE EXPERIENCE

Overall, the “ideal” biology major senior capstone experience would contain the following components to measure essential aspects of their four years of training:

- A comprehensive exam that measures their recall knowledge.
- A 30 minute oral presentation on a recent biological hot topic and be able to show that they are an expert on this topic by answering questions well and confidently from their peers, faculty or the public.

- A 1-2 year research experience where their results are publishable and they have mastered several basic scientific research skills.
- A written thesis in the format of a scientific journal article that is ready to be sent in for publication.
- A skills/techniques assessment test where they work hands-on in front of a peer or faculty member to show their competence level in 1-5 above.

AN EXAMPLE AT LORAS COLLEGE

Seniors in biology at Loras College choose between a biology major and a biology research major. The biology major requires 34 credits of courses with accompanying support courses in Math, Chemistry and Physics. These students in their junior year in consultation with a biology faculty advisor pick a topic of personal interest. They construct a learning plan for this topic that includes a bibliography, a proposed timeline of study and culminates in a 30 minute oral presentation on this topic to their peers and faculty in senior seminar in their last spring semester. Essentially they train themselves to be an expert on this topic and present a written thesis in review paper format. In the past 5 years about 75% of graduating majors have chosen this option.

Biology research majors also take the same 34 credits and supporting courses but also get one more credit for doing their own research project that is supervised by a biology faculty member. They consult with a biology faculty member early in their junior year to construct a research proposal plan and timeline for the next 3 semesters. This work culminates in a 30 minute oral presentation of their

research results to their peers and biology faculty in their last spring semester. Essentially they train themselves to be an expert on their specific topic of research and present a written thesis as close to publishable journal format as possible.

Both majors are required to take an on-line, 57-question, comprehensive exam in November of their senior year. This exam was written by Loras biology faculty and consists of 6 subdivisions of the biology curriculum: Physiology, Molecular, Evolution, Ecology, Plant/Animal Biology and Genetics. The format of this exam is passage-based, like the MCAT, where a series of multiple choice questions follow each passage which has pertinent information, data, figures or background to answer the questions. Results of this exam are used for year-to-year comparisons of student performance and also to check on the information recall or retention of information in each biology subdivision. Students often ask, "Is this something I have to study for?" or "what happens if I fail?" Our response is, "No studying is necessary and all we ask is to give it your honest best shot." It seems to have been a consistent tool to gauge the knowledge recall levels of our students.

Both majors are required to participate in a 30 minute exit interview session with a non-biology faculty or staff person. This session uses about 10 minutes for written responses to 8-10 questions and then about 15-20 minutes for an oral discussion of their answers to share them with the group. Many times they speak out when they hear comments or suggestions from other students that are similar to theirs. This session has resulted in valuable feedback about our curriculum, its course sequence, experiences that they would have liked more of or that were missing, advising effectiveness, etc.

The biology faculty at Loras have also discussed a required lab skills/techniques assessment session for all seniors. This is still in the discussion stage. This session would include 5-6 learning outcomes that we think are important for all biology majors to be able to demonstrate competently before they graduate. We envision them coming into a lab and working at 3-4 stations for 30 minutes per station to show a faculty member the following skills: 1) troubleshoot PCR or an electrophoresis set up; 2) design an appropriate sampling procedure for a given experiment; 3) Read and explain a selected piece of primary literature in which they have some previous background; 4) pipette correctly producing serial dilutions; 5) analyze a set of data using appropriate statistics; and 6) be constructively critical of results in 1-5 for other fellow students. Having all these stations set up and ready for students to come in and

work with them is problematic but different versions of this are in discussion here.

OTHER EXAMPLES OF CAPSTONE COMPONENTS

Other components of a senior capstone experience could also be included or inserted to replace the recommended sections shown above. Building a resume and writing a cover letter with the feedback of biology faculty or campus career center experts would be valuable for any graduating senior. Making an e-portfolio with examples of writing, experimental data and results, field classes, posters, summaries of class discussions, pictures of service projects or notes from shadowing experiences could be inserted in the e-portfolio. Videotaping 3-4 senior oral presentations from one year can be shown to next year's class to show good or not-so-good examples of presenting a talk. Organizing a group service project to help the campus or local community might build camaraderie of senior majors. Going away on an overnight retreat for 1 or 2 weekends with faculty and students could be used to discuss environmental issues and/or increase the conservation connection or land ethic of each senior. Conducting a senior panel of majors for all underclassmen, declared majors or not, would allow them to talk about their biology experiences and answer questions from the younger students. Asking for a written reflection about how several subdivisions of biology interconnect might be a valuable experience for seniors. Asking them how information and lab work in Molecular Biology, Ecology and Evolution interconnect might be challenging but rewarding for not only students but faculty too. Giving students a chance to communicate and discuss controversial or hot topic issues in biology with campus or local community members is an excellent method for checking on the knowledge and application ability of graduating seniors. Topics like stem cell research, evolution in schools, the Gulf oil spill, or genetically modified organisms are examples of good discussion topics.

Other skills or techniques that could be measured or incorporated into a capstone experience to test level of competency include basic microscopy, diversity and taxonomy examples, or writing about their conservation or land ethic development over their four years. Another idea is to bring back a biology major who recently graduated in the last 2-3 years, have them be the guest of honor at the first senior seminar, have them talk about where they are now and their recommendations for current students about life after undergraduate college.

A few specific examples cited here show a variety of capstone experiences as well as discussion of why each of the components has been chosen.

Truman State University shows a variety of capstone experiences in different disciplines including biology (Truman, 2003). The Department of Biological Sciences at the University of Cincinnati has a good description of their capstone program including options for research, teaching, field trips and courses (U of Cincinnati, 2008).

Many ideas have been mentioned here for possible inclusion in a biology major capstone experience. It remains the prerogative of the biology faculty at each institution to pick the activities that will help them assess their students' learning and teaching most effectively. These suggestions also help biology faculty make measurements of learning outcomes so they can be more accountable for their time and money spent in the educational process.

ARTICLE NOTE

This article was written after the author led a roundtable discussion with faculty and students at the 2010 annual meeting of the Association of College

and University Biology Educators (ACUBE) at Lourdes College in Sylvania, OH October 8, 2010.

REFERENCES

NATIONAL RESEARCH COUNCIL. 2003. BIO 2010. *Transforming undergraduate education for future research biologists*. National Academies Press, Washington D.C. Accessed from <http://www.nap.edu/openbook.php?isbn=0309085357> on 18 Oct. 2010.

TRUMAN STATE UNIVERSITY, 2003. *Assessment Almanac*. Accessed from <http://assessment.truman.edu/almanac/2003/CH12.pdf> on 22 Dec. 2010.

U OF CINCINNATI, 2008. *Undergraduate Bulletin, Department of Biological Sciences, McMicken College of Arts and Sciences, University of Cincinnati*; Accessed from <http://www.artsci.uc.edu/collegedepts/biology/undergrad/capstone.aspx> on 22 Dec. 2010.

EDITORIAL

Studying and Grades: When Less is More and More is Less

James W. Clack, Ph.D

Department of Biology, Division of Science, Indiana University - Purdue University

It is no secret that grade inflation is prevalent in United States universities. Rojstaczer and Healy have shown that the Average GPA awarded by American universities has risen just over 0.6 GPA units since the 1940's (Rojstaczer, 2010), an average of almost 0.1 GPA units per decade. The average GPA for private universities in 2010 was 3.3 and for public universities was 3.0 – hardly corresponding to the classic grading scale where a “C” was an average grade. More data can be found on Dr. Rojstaczer's website that deals with grade inflation in American universities (Rojstaczer, 2011), including data on individual universities. In fact, I was able to find data on my own university system, Indiana University, from the site and a simple graph of the data revealed a startling trend. It appears that, given the current trend, my institution's students will attain perfection (average GPA of 4.0) in 2072!

This upward march of grades is not consonant with what we know about the current level of preparedness of graduating high school seniors. Students have been earning lower and lower scores on standardized college entrance exams over the years. For example, mean SAT scores decreased from about 1040 in the 1970s to about 1000 in the 1990s. The SAT was famously “recentered” in 1995, adding approximately 100 points to an average student's score, in order to get verbal and math scores back to an approximate mean of 500. Interestingly, students who earned higher SAT scores received lesser increases than those who earned lower scores. Both educators and policy makers have known for some time that science and mathematics education in the United States lags well behind that of numerous other countries. According to the last two International Mathematics and Science Studies, US high school seniors have hovered around 18th place in the world in terms of math and science proficiency for the last 15 years (National Center for Educational Statistics, 2011).

In addition, numerous studies show that college students are less engaged and study much less than they did in the past (Arum & Roksa, 2011). In fact, Babcock and Marks (2011) found that the time that students devote to academic activities has dropped over 50% since 1961. In 1961 students devoted

approximately 40 hours/week to classes and studying. In 2003 students devoted less than 20 hours/week to their classes and studies, confirming that students continue to relegate their education to a lower priority.

It is, therefore, extremely unlikely that the higher grades currently bestowed by United States universities are due to heightened student learning and proficiency. What is the root cause of what is now called “grade inflation?” There are probably a number of factors involved. One possible cause is the new consumerism (“student as customer”) promoted by students, administrators, and politicians. Many faculty members blame the ubiquitous “student evaluations,” which many feel really only measure student satisfaction and are inextricably tied to grades (Johnson, 2002). Another cause has to do with numbers (a.k.a. \$\$). Falling numbers of high school graduates, states in severe economic straits, and the burgeoning numbers of for-profit schools have conspired to financially pressure traditional academic institutions to maintain or increase enrollments. This inevitably translates into de facto pressure on faculty from administrators to attract more students. Of course, one easy way to do this is simply to relax standards and give out higher grades. We all understand that students seek out instructors who are known to award higher grades.

What can/should we do? Is the administrative and student pressure too much for instructors to bear? Is this an upwardly directed slippery slope? Given all the factors involved, it is hard to narrow the number of key factors to a manageable few. Some of the solutions that have been offered involve technological changes – simply normalizing grades in any class to the class average and assigning normalized or “Z scored” rather than traditional, empirical grades. It certainly wouldn't hurt to have administrators check class grades regularly and to take them into account when reviewing student evaluations. In the end, the true answer rests with each one of us. We must decide if we are giving out the grades that students have earned rather than those they want or expect. Whether we want it to or not, the buck (or grade) truly stops here – on each instructor's desk.

REFERENCES

ARUM, R., AND ROKSA, J. 2011. *Academically Adrift: Limited Learning on College Campuses*, London, University of Chicago Press, London. 259p.

BABCOCK, P., AND MARKS, M. 2011. The Falling Time Cost of College: Evidence from Half a Century of Time Use Data. *The Review of Economics and Statistics*, 93: 468-478.

JOHNSON, V.E. 2002. Teacher Course Evaluations and Student Grades: An Academic Tango. *Chance*, 15: 9-16.

ROJSTACZER, S. 2011. Grade Inflation at American Colleges and Universities [Online]. Accessed from: <http://www.gradeinflation.com> on 25 Apr 2011.

ROJSTACZER, S., AND HEALY, C. 2010. Grading in American Colleges and Universities. *Teachers College Record*.

NATIONAL CENTER FOR EDUCATIONAL STATISTICS. 2011. Trends in International Mathematics and Science Study [Online]. U.S. Department of Education Institute for Education Sciences. Accessed from: <http://nces.ed.gov/timss/> on 25 Apr 2011.

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.
- **Perspectives:** Reflections on general topics that include philosophical discussion of biology teaching and other topical aspects of pedagogy as it relates to biology.
- **Reviews:** Web site, software, and book reviews
- **Information:** Technological advice, professional school advice, and funding sources
- **Letters to the Editor:** Letters should deal with pedagogical issues facing college and university biology educators

II. Preparation of Articles, Innovations and Perspectives

Submissions can vary in length, but articles should be between 1500 and 4000 words in length. This includes references, but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract, but not figure or table legends. Concision, clarity, and originality are desirable. Topics designated as acceptable as articles are described above. The formats for all submissions are as follows:

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

Single Author:

"... 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).

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

(1) Articles-

(a) Single author:

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.

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

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

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. 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 blind unless requested by an author. If the article has a number of high resolution graphics, separate emails to the editor may be required.

VI. Editorial Review and Acceptance

For manuscripts to be sent out for review, at least one author has either joined ACUBE or agreed to page charges. Charges will be the membership fee at the time of submission per page. Once the authors' membership or page charge status has been cleared, the manuscripts will be sent to two anonymous reviewers as coordinated through the Editorial Board. Authors' names will be withheld from the reviewers. The associate editors will examine the article for compliance with the guidelines stated above. If the manuscript is not in compliance or the authors have not agreed to the page cost provisions stated above, manuscripts will be returned to authors until compliance is met or the page cost conditions have been met.

Reviewers will examine the submission for:

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

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewers. Acknowledgement of the reviewers' comments and suggestions must be made for resubmission and acceptance. 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.

VIII. Editorial Policy and Copyright

It is the policy of *Bioscene* that authors retain copyright of their published material.