

# **Bioscene**

**Journal of College Biology Teaching**



**Volume 37(2)**

**December 2011**

# Bioscene

Journal of College  
Biology Teaching

Volume 37(2) December 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>

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 Paul Pickhardt of *Heliconia  
vaginalis* Benth found in southern  
Belize.

## CONTENTS

<b>EDITORIAL &amp; GOVERNANCE INFORMATION.....</b>	<b>2</b>
<b>ARTICLES .....</b>	<b>3</b>
Teaching the Fundamentals of Biological Research with Primary Literature: Learning from the Discovery of the Gastric Proton Pump .....	3
<i>Lixin Zhu</i>	
A Vodcasted, Cross-Disciplinary, Behavioral Neuroscience Laboratory Exercise Investigating the Effects of Methamphetamine on Aggression .....	9
<i>Ryan A. Shanks, E. Megan Southard, Laura Tarnowski, Matthew Bruster, Stacia W. Wingate, Nancy Dalman, Steven A. Lloyd</i>	
Organizing a Campus Activity: An Alternative Learning Approach .....	17
<i>Mary Tracy Bee, James Montante, Kate Lanigan, Michelle Andrzejak, Greg Grabowski</i>	
<b>INNOVATIONS.....</b>	<b>23</b>
Classroom Modified Split-Root Technique and Its Application in a Plant Habitat Selection Experiment at the College Level .....	23
<i>Shannon S. Elliott and Peggy A. Winter</i>	
<b>PERSPECTIVES .....</b>	<b>30</b>
Higher Education Faculty Versus High School Teacher: Does Pedagogical Preparation Make a Difference? .....	30
<i>Jamie L. Jensen</i>	
<b>EDITORIAL.....</b>	<b>37</b>
Beware the Service Creep, My Colleagues! The Jaws That Bite, the Claws That Catch! .....	37
<i>James W. Clack</i>	
<b>SUBMISSION GUIDELINES .....</b>	<b>39</b>

# Bioscene: Journal of College Biology Teaching

Volume 37 (2) • December 2011

*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 (Perspectives &  
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

**Tara Maginnis**, University of Portland, President  
**Neval Erturk**, Converse College, Executive Secretary of  
Membership  
**Greg Smith**, Lakeland College, Executive Secretary of  
Finance, Local Arrangements Chair - 2012  
**Aggy Vanderpool**, Lincoln Memorial University,  
Secretary  
**Debbie Meuler**, Cardinal Stritch University, Program  
Chair  
**Melissa Daggett**, Missouri Western State University,  
Member  
**Chiron Graves**, Eastern Michigan University, Member  
**Cori Fata-Hartley**, Michigan State University, Member  
**Paul Pickhardt**, Lakeland College, Member  
**Karen Sirum**, Bowling Green University, Member  
**Kristen Walton**, Missouri Western State University,  
Member  
**Laura Salem**, Rockhurst University, past-President  
**Conrad Toepfer**, Brescia University, Historian  
**James Clack**, Indiana Univ – Purdue Univ, *ex officio*

## ARTICLES

### Teaching the Fundamentals of Biological Research with Primary Literature: Learning from the Discovery of the Gastric Proton Pump

Lixin Zhu

Digestive Diseases and Nutrition Center, Department of Pediatrics  
State University of New York at Buffalo, Buffalo, NY 14214

Email: [lixinzhu@buffalo.edu](mailto:lixinzhu@buffalo.edu)

**Abstract:** For the purpose of teaching collegians the fundamentals of biological research, literature explaining the discovery of the gastric proton pump was presented in a 50-min lecture. The presentation included detailed information pertaining to the discovery process. This study was chosen because it demonstrates the importance of having a broad range of knowledge, performing technique with precision, and thinking creatively, in the context of an interesting story about an enzyme which is important in our daily lives. Kasbekar and Durbin were the first team that tried to purify a gastric proton pump for characterization. They isolated the wrong ATPase because of inaccurate technique. Forte et al. improved the technique and isolated the gastric proton pumps. More importantly, for the first time Forte et al. demonstrated that the proton pump is a potassium ion dependent ATPase, or H<sup>+</sup>,K<sup>+</sup>-ATPase. The primary literature used here served as a valuable tool to demystify both the process of formulating a testable hypothesis and the pathway for a scientific discovery.

**Key words:** undergraduate; research article; H<sup>+</sup>,K<sup>+</sup>-ATPase.

#### INTRODUCTION

Research articles have been incorporated into undergraduate biological education for a variety of purposes. Unlike textbooks, research articles usually feature unanswered and controversial questions that can stimulate students' curiosity and motivate them to learn. Therefore, research articles have been used to facilitate the teaching of biological courses, such as genetics (Pall, 2000, Wu, 2009), neuroscience (Lynd-Balta, 2006) and biochemistry (Zhu, 2008). Research articles are also introduced to undergraduates in the forms of journal clubs and seminars to demystify scientific research and retain these students in a biological research career (Kozeracki *et al.*, 2006). One difficulty in using research articles for this purpose is that the critical thinking leading to the discovery is usually buried deep in the introduction section, and not readily identifiable by the students and instructors who are not in this particular field of research. Working with one of the greatest contemporary scientists, John G. Forte (University of California, Berkeley), allowed me unique opportunities to understand these "hidden" details of some revolutionary discoveries.

The State University of New York at Buffalo offers college students the opportunity to participate in a Discovery Seminar Program. The program provides students an opportunity to engage in a thought-provoking and challenging topic with a research faculty member. In preparing a lecture designed to demonstrate the fundamentals in

biological research to my undergraduate students, I found that Forte et al.'s discovery of the proton pump (Forte *et al.*, 1967) was well-suited for this purpose. Forte *et al.*'s discovery can be used as a tool to demonstrate the importance of a broad range of knowledge, performing technique with precision, and thinking creatively in biological research.

With the proton pump inhibitor being the second most prescribed medicine in the United States (Mullin *et al.*, 2009), the topic presented in this paper quickly caught the students' attention. In addition, the anticipation of the unveiling of the mystery of this great discovery was another enticement for them, especially for those considering graduate education or medicine-related education.

Being a simple story, this article (Forte *et al.*, 1967) is easy for students and biology instructors from different sub-specialties to comprehend. The critical experiments involved in the discovery of the proton pump are simply differential centrifugation and measurement of the enzymatic activity of ATPase, both being conventional methods for most biology instructors. With the differential centrifugation experiment alone the critical thinking leading to this discovery and the importance of performing technique with precision in biological discovery can be demonstrated. The simplicity of this 1967 article allows time for the inclusion of another related article (Limlomwongse & Forte, 1970) demonstrating the association of the proton pump molecule and the function of gastric acid

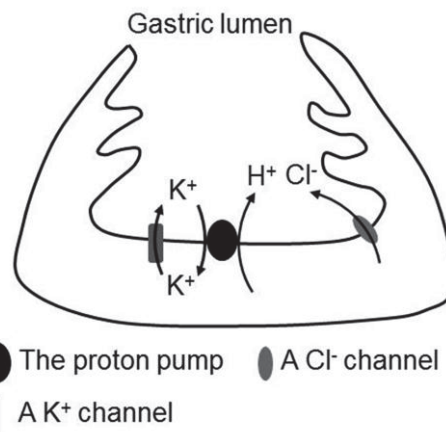
secretion. The second article is important for this lecture as it completes the discovery story introduced by the initial article, provides another example of critical thinking in biological discovery, and introduces additional interesting elements (tadpoles, gene knockout, etc.).

This module is designed for a 50-min lecture in any given class size. To use this study for the purpose described here, the instructor need only familiarize himself/herself with the material detailed in this report. To attract the attention of the students, I would begin by explaining the importance of gastric acid in our daily lives and the importance of the parietal cell as a productive model system in research. This part could be personalized according to the instructor's preferences and the students' academic level.

## RESULTS

### Introduction of the topic

The discovery and consequential study of the gastric proton pump has had many significant effects on science and our daily lives. This discovery is one of the most important cornerstones for the physiology of the stomach. Through the efforts of the scientists represented by John Forte, Catherine Chew, and James Goldenring etc., the study of the proton pump has evolved into a wonderful cellular model for the elucidation of many fundamental questions in general biology as well as stomach physiology, such as: the



**Fig. 1.** Schematic representation of the mechanism for the production of gastric acid by oxyntic cells (or parietal cells in mammals). The production of hydrochloric acid by the gastric oxyntic cells is a combined function of the proton pump (gastric  $H^+,K^+$ -ATPase), a  $K^+$  channel and a  $Cl^-$  channel. At the expense of one ATP, the proton pump pumps out one proton and takes in one  $K^+$ . This  $K^+$  is then recycled back to the gastric lumen through a  $K^+$  channel. A  $Cl^-$  channel is responsible for the concomitant outflow of  $Cl^-$ . The identities of the  $K^+$  and the  $Cl^-$  channel are the subjects of current research.

remodeling of the cytoskeleton (Forte *et al.*, 1998), PKA signaling (Chew *et al.*, 2002), the mechanisms

**Kasbekar and Durbin:**  
 (1) 600g/10min and 10,000g/10min to remove large membranes.  
 (2) 105,000g/1hr to collect microsomes

Mitochondria in microsome preparation, evidenced by cytochrome c oxidase activity

Characterization of the ATPase from a contaminated source

The ATPase is sensitive to  $HCO_3^-$ , but not  $K^+$

Incorrect conclusion: gastric acid is the result of a base pump actively removing base from the gastric lumen.

**Forte et al:**  
 (1) 30,000g/30min to remove large membranes.  
 (2) 150,000g/1hr to collect microsomes

Microsome preparation without detectable mitochondria contamination

Characterization of the ATPase from microsomes rich in proton pump

The ATPase is sensitive to  $K^+$

The discovery of the gastric proton pump: the  $K^+$  dependent ATPase.

**Fig. 2.** An example that more accurate technique leads to a great discovery. A side-by-side comparison of the techniques employed by two different research teams to identify the mechanism for the production of gastric acid. The less accurate technique led to a wrong conclusion that the acid was produced by a base pump; while the more accurate technique led to the discovery of the gastric proton pump.

for membrane trafficking (Goldenring *et al.*, 1996), vesicle docking and fusion (Calhoun & Goldenring, 1997), and the establishment of cellular polarity (Zhu *et al.*, 2010). The proton pump is responsible for the production of isotonic acid in gastric juice.

Therefore, our ongoing understanding of this pump may also lead to a better management of acid-related diseases such as GERD, a disease affecting roughly 7 million Americans (Everhart, 1994). In addition, this acid is the first powerful barrier separating the body from foreign invaders that are unavoidable in the food we consume. It is notwithstanding, of course, that the acid also activates pepsinogen, allowing our foods to be properly digested.

For all the aforementioned reasons, the discovery of the gastric proton pump (Forte *et al.*, 1967) by John Forte, Gertrude Forte, and Paul Saltman made a substantial contribution to medicine and science, and to the general public as well. In addition, this discovery is an excellent example of the process of scientific discovery. Here I dissect the procedure of this discovery in hopes that this example will inspire future generations of scientists to engage in the search for the secrets of life.

### **Background of the discovery**

#### *Previous hypotheses on the mechanism of gastric acid production.*

The discovery of the gastric proton pump resulted from a simple curiosity about the origin of gastric acid, and a large number of hypotheses were raised to explain the production mechanism. For example, Martin Hanke (Hanke, 1926) (University of Chicago) hypothesized that gastric hydrochloric acid is produced by the hydrolysis of organic chlorides. This was disproved soon after, however, by the fact that “the gastric secretion consists mainly of mine salts (sic)” (Davenport, 1992). The redox hypothesis of Conway (University College, Dublin) (Conway, 1949) claimed that yeast in the stomach is responsible for the production of gastric acid. This argument was based on *in vitro* experiments which showed that yeast can secrete acid in exchange for potassium. Ultimately, this hypothesis faded away due to a lack of any further supporting evidence. Notably, however, one hypothesis in particular was very close to the truth; in fact, it even partially led to the truth. Kasbekar and Durbin isolated microsomes from frog gastric oxyntic cells, which are equivalent to mammalian parietal cells in terms of acid secretion (Kasbekar & Durbin, 1965). From this preparation, a large amount of ATPase activity was detected and was found to be stimulatory by  $\text{HCO}_3^-$  but not  $\text{K}^+$ . We now know that  $\text{H}^+, \text{K}^+$ -ATPase has the very opposite character. However, Kasbekar and Durbin claimed that the ATPase drives the exchange of  $\text{HCO}_3^-$  and  $\text{Cl}^-$  (against the gradients of  $\text{HCO}_3^-$ ). Kasbekar and Durbin believed that this  $\text{HCO}_3^-$  pump facilitated the dissociation of  $\text{H}_2\text{CO}_3$  to form secreted HCl. In other words, Kasbekar and Durbin hypothesized that a base

pump actively removed  $\text{HCO}_3^-$  from gastric lumen and thereby produced gastric acid.

#### *Formulation of a new hypothesis for the mechanism of acid secretion: The importance of critical analysis of the previous literature, a broad range of knowledge and creative thinking.*

Unfortunately, Kasbekar and Durbin’s work was inconsistent with the well-established fact that  $\text{K}^+$  is an essential requirement for acid secretion. Forte *et al.* were well aware of this inconsistency and were critical of Kasbekar and Durbin’s work. Forte *et al.* eventually identified the problem with Kasbekar and Durbin’s experiment, namely contamination (Forte *et al.*, 1974, Soumarmon *et al.*, 1974). Kasbekar and Durbin’s microsome preparation was contaminated by mitochondria. Following Kasbekar and Durbin’s procedure, the microsome preparations consistently exhibited high activity of cytochrome c oxidase (Forte *et al.*, 1974, Soumarmon *et al.*, 1974), a mitochondrial enzyme. The characterization of microsomal ATPase done by Kasbekar and Durbin was actually a characterization of mitochondrial enzymes. Although Kasbekar and Durbin’s work led to an inaccurate conclusion, the idea to purify microsomal ATPase for further study proved to be beneficial and did contribute to Forte *et al.*’s discovery two years later. Consequently, having proved the old hypothesis inaccurate, the natural impulse to formulate a new hypothesis emerged.

In addition to Kasbekar and Durbin’s work, important observations made by other investigators had a strong impact on Forte’s new hypothesis. Firstly, earlier work by Sedar (Sedar, 1961) demonstrated that the microsomal membrane is implicated in acid secretion. The major evidence was that upon stimulation by histamine, the frog gastric oxyntic cells showed an apparent decrease in the tubular elements of the smooth-surfaced endoplasmic reticulum. Evidence also suggested that these tubular membrane elements incorporated onto the apical membrane of the oxyntic cells. Secondly, previous studies by Forte *et al.* also demonstrated that the rate of gastric acid secretion is directly correlated with the cellular concentration of ATP (Forte *et al.*, 1965). In addition, Skou’s discovery of  $\text{Na}^+, \text{K}^+$ -ATPase in 1957 (Skou, 1957) also had an influence on the discovery of  $\text{H}^+, \text{K}^+$ -ATPase. (Skou won the 1997 Nobel Prize in chemistry because of his work on  $\text{Na}^+, \text{K}^+$ -ATPase.) His findings revealed the first ion-stimulated ATPase activity.

All of these studies catalyzed the development of the new hypothesis that the gastric acid production is powered by a  $\text{K}^+$  driven ATPase, or  $\text{H}^+, \text{K}^+$ -ATPase on the microsomal membrane of oxyntic cells. In addition to critical analysis of Kasbekar and Durbin’s work, a broad range of knowledge contributed to this new hypothesis. The creative thinking behind this hypothesis merely consisted of compiling all the information from: Kasbekar and Durbin’s work;

Sedar's work on microsomal membrane (Sedar, 1961); and Forte's work on ATPase (Forte *et al.*, 1965). With this example, the pathway from the critical analysis of literature and gathering a broad range of knowledge to a "great idea" (a new hypothesis) is revealed.

**The test of the new hypothesis led to a great discovery**

Next, Forte et al. used Skou's methods and strategy on Na<sup>+</sup>,K<sup>+</sup>-ATPase (Skou, 1957) to test their hypothesis. To do this, Forte et al. first needed to isolate the microsomal membrane from the oxyntic cells. Isolation and purification are often critical steps in the discovery process. Knowing that Kasbekar and Durbin's approach led to mitochondrial contamination, Forte et al. revised the differential centrifugation technique for the isolation of microsomal membrane from gastric parietal cells (Figure 2). In Kasbekar and Durbin's experiments, the lysate of gastric oxyntic cells was run at 10,000g for 10min to remove large membranes before "microsomes" collected at 105,000g for 1h. As demonstrated by cytochrome c oxidase assays, 10,000g/10min did not remove all mitochondria. Therefore, Forte et al. revised the method for the isolation of microsomes from parietal cells. They ran the lysate at 30,000g for 30 min to remove large membranes before collecting microsomes at

150,000g for 1hr. Cytochrome c oxidase assays indicated that 30,000g/30 min did effectively remove mitochondria. Without mitochondria contamination, this microsomal membrane preparation allowed Forte et al. to discover the gastric proton pump. Here the power of utilizing more accurate technology in scientific discovery is made apparent.

With the right material, Forte et al. could then test whether the microsomal ATPase is dependent on K<sup>+</sup>. To this end, the isolated microsomal ATPase was incubated with different concentrations of K<sup>+</sup> and the ATPase activity was analyzed. Forte et al. observed a 5-fold increase in enzymatic activity when K<sup>+</sup> was increased from 0 to 1mM. The enzymatic activity continued to increase and eventually plateaued when K<sup>+</sup> was approximately 20mM. For the first time, it was demonstrated that the gastric microsomal ATPase is K<sup>+</sup> dependent. And this is the discovery of the first K<sup>+</sup> dependent ATPase.

**The conclusion and supportive follow-up studies**

Based upon their 1967 experiments, Forte et al. concluded: "A model system might be devised where K<sup>+</sup> serves not only as an enzyme activator, but also as the locally exchangeable cation in the secretion of HCl" (Forte *et al.*, 1967). Unlike previous hypotheses, this K<sup>+</sup>-ATPase hypothesis has survived more than 40 years and all follow-up molecular biological, structural biological, and biophysical

**Table 1.** The gene "knockout" tadpole study and the gene knockout mouse study: a comparison.

	The tadpole study <sup>a</sup>	The mouse study <sup>b</sup>
When was it performed?	1970	2000
The procedure of "gene deletion".	Examination of the proton pump expression with tadpoles of different developmental stages	<ol style="list-style-type: none"> <li>1, Analysis of the mouse proton pump gene structure;</li> <li>2, Generation of the plasmid vector targeting mouse proton pump;</li> <li>3, Transfection of embryonic stem cells and selection for recombinants</li> <li>4, Generation of chimeric mice by blastocyst-mediated transgenesis.</li> <li>5, Genotyping by Southern blot to identify homozygous and heterozygous mice from the offsprings of the chimeric mice.</li> </ol>
The result	Tadpoles before stage XXIV do not express proton pump in their stomachs and their stomachs do not produce acid; tadpoles beyond stage XXIV start to express proton pump in their stomach and their stomachs produce acid.	The homozygous proton pump knockout mice do not produce gastric acid; while the wildtype and heterozygous animals do.

<sup>a</sup> (Limlomwongse and Forte, 1970)

<sup>b</sup> (Spicer et al, 2000)

studies of the proton pump support this hypothesis.

One piece of data in particular, presented in the 1967 study, may seem odd. Since the  $\text{Na}^+, \text{K}^+$ -ATPase is sensitive to both  $\text{Na}^+$  and  $\text{K}^+$ , one would expect the microsomal  $\text{H}^+, \text{K}^+$ -ATPase to be sensitive to  $\text{H}^+$ , or pH; however, this is not shown in the data, and such hopeful speculation is, in fact, incorrect. By inhibiting carbonic anhydrase, it has been shown that the gastric  $\text{H}^+, \text{K}^+$ -ATPase is able to produce protons out of water (Davenport, 1946), indicating that this pump is fully functional even at extremely low proton concentrations. Therefore, a higher concentration of protons may not actually accelerate the enzymatic activity.

There are many fascinating follow-up studies on  $\text{H}^+, \text{K}^+$ -ATPase from the labs of Forte and other investigators. One in particular interests me for its ingenuity and creativity: an *in vivo* study that associates the gastric microsomal ATPase with acid secretion (Limlomwongse & Forte, 1970). It is an equivalent of a gene knockout study with less labor and a more intriguing procedure (See Table 1 for a comparison). This “knockout” system makes use of tadpoles at different metamorphosis stages. Forte et al. carefully characterized the stomachs of tadpoles at different metamorphosis stages and found that tadpoles start to produce gastric acid at stage XXIV (Forte *et al.*, 1969). Therefore, tadpoles before stage XXIV are equivalent to “knockout” animals as the function of gastric acid secretion is absent, while animals beyond stage XXIV are “normal controls.” Having established this elegant system, it must have been very exciting to analyze the ATPase activities at the different metamorphosis stages of the tadpoles. This ingeniously designed experiment yielded simple yet beautiful results: microsomal ATPase activities are at background levels all the way to stage XXIV, after which they experience a significant jump at stage XXV (Limlomwongse & Forte, 1970). The proton pump gene knockout mouse study performed in 2000 reported essentially similar results: the deletion of the proton pump gene caused achlorhydria (Spicer *et al.*, 2000).

## DISCUSSION

The purpose of this lecture is not to make students blindly memorize; rather, its purpose is to encourage students to contemplate the procedure of scientific discovery and to take in these essential ingredients for scientific research while enjoying an interesting subject.

Here is the take-home message for the students. A good scientist develops a broad range of knowledge through the experience of other knowledgeable scientists in his/her field. In this case, the works of Kasbekar, Durbin, and Sedar were the foundation for Forte’s hypothesis on a  $\text{K}^+$ -stimulated ATPase, while Skou’s work provided the methodology to test this hypothesis. Also, a good

scientist must be a master of techniques, particularly of those involved in his/her research. Inaccurate technique for the isolation of membrane vesicles was the major reason that Kasbekar and Durbin missed the enzyme for gastric acid production. Accurate technique for membrane isolation by Forte et al. was the key to the purification, characterization and discovery of proton pump. In addition, a successful scientist needs to think creatively. Usually great ideas were not generated from scratch. A compilation of selected literature and relevant knowledge could shed light on an innovative idea. Forte’s idea about  $\text{K}^+$ -driven ATPase came into being during active reading when he related his laboratory findings to literature.

## ACKNOWLEDGEMENTS

This work is supported by a Discovery Seminar Course Award from the State University of New York at Buffalo. I thank Adil Sarfraz (State University of New York at Buffalo) for his critical reading of the manuscript and for his valuable suggestions and feedback.

## REFERENCES

- CALHOUN, B.C., AND GOLDENRING, J.R. 1997. Two Rab proteins, vesicle-associated membrane protein 2 (VAMP-2) and secretory carrier membrane proteins (SCAMPs), are present on immunisolated parietal cell tubulovesicles. *Biochem J*, 325 ( Pt 2): 559-64.
- CHEW, C.S., CHEN, X., PARENTE, J.A., JR., TARRER, S., OKAMOTO, C., et al. 2002. Lasp-1 binds to non-muscle F-actin *in vitro* and is localized within multiple sites of dynamic actin assembly *in vivo*. *J Cell Sci*, 115: 4787-99.
- CONWAY, E.J. 1949. A redox theory of hydrochloric acid production by the gastric mucosa. *Irish Journal of Medical Science* 24: 801-804.
- DAVENPORT, H.W. 1946. In memoriam: the carbonic anhydrase theory of gastric acid secretion. *Gastroenterology*, 7: 374-375.
- DAVENPORT, H.W. 1992. A history of gastric secretion and digestion: Experimental studies to 1975, Oxford University press, p.
- EVERHART, J.E., EDITOR 1994. Digestive Diseases in the United States: Epidemiology and Impact. , US Department of Health and Human Services, Public Health Service, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases. Washington, DC: US Government Printing Office, p.
- FORTE, J.G., ADAMS, P.H., AND DAVIES, R.E. 1965. Acid secretion and phosphate metabolism in bullfrog gastric mucosa. *Biochim Biophys Acta*, 104: 25-38.

- FORTE, J.G., FORTE, G.M., AND SALTMAN, P. 1967. K<sup>+</sup>-stimulated phosphatase of microsomes from gastric mucosa. *J Cell Physiol*, 69: 293-304.
- FORTE, J.G., GANSER, A.L., AND TANISAWA, A.S. 1974. The K<sup>+</sup>-stimulated ATPase system of microsomal membranes from gastric oxyntic cells. *Ann N Y Acad Sci*, 242: 255-67.
- FORTE, J.G., LIMLOMWONGSE, L., AND KASBEKAR, D.K. 1969. Ion transport and the development of hydrogen ion secretion in the stomach of the metamorphosing bullfrog tadpole. *J Gen Physiol*, 54: 76-95.
- FORTE, J.G., LY, B., RONG, Q., OGIHARA, S., RAMILO, M., et al. 1998. State of actin in gastric parietal cells. *Am J Physiol*, 274: C97-104.
- GOLDENRING, J.R., SMITH, J., VAUGHAN, H.D., CAMERON, P., HAWKINS, W., et al. 1996. Rab11 is an apically located small GTP-binding protein in epithelial tissues. *Am J Physiol*, 270: G515-25.
- KASBEKAR, D.K., AND DURBIN, R.P. 1965. An adenosine triphosphatase from frog gastric mucosa. *Biochim Biophys Acta*, 105: 472-82.
- KOZERACKI, C.A., CAREY, M.F., COLICELLI, J., LEVIS-FITZGERALD, M., AND GROSSEL, M. 2006. An intensive primary-literature-based teaching program directly benefits undergraduate science majors and facilitates their transition to doctoral programs. *CBE Life Sci Educ*, 5: 340-7.
- LIMLOMWONGSE, L., AND FORTE, J.G. 1970. Developmental changes in ATPase and K<sup>+</sup>-stimulated phosphatase of tadpole gastric microsomes. *Am J Physiol*, 219: 1717-22.
- LYND-BALTA, E. 2006. Using literature and innovative assessments to ignite interest and cultivate critical thinking skills in an undergraduate neuroscience course. *CBE Life Sci Educ*, 5: 167-74.
- MULLIN, J.M., GABELLO, M., MURRAY, L.J., FARRELL, C.P., BELLOWS, J., et al. 2009. Proton pump inhibitors: actions and reactions. *Drug Discov Today*, 14: 647-60.
- PALL, M.L. 2000. The value of scientific peer-reviewed literature in a general education science course. *The American Biology Teacher*, 62: 256-258.
- SEDAR, A.W. 1961. Electron microscopy of the oxyntic cell in the gastric glands of the bullfrog, *Rana catesbiana*. II. The acid-secreting gastric mucosa. *J Biophys Biochem Cytol*, 10: 47-57.
- SKOU, J.C. 1957. The influence of some cations on an adenosine triphosphatase from peripheral nerves. *Biochim Biophys Acta*, 23: 394-401.
- SOUARMON, A., LEWIN, M., CHERET, A.M., AND BONFILS, S. 1974. Gastric HCO<sub>3</sub><sup>-</sup>-stimulated ATPase: evidence against its microsomal localization in rat fundus mucosa. *Biochim Biophys Acta*, 339: 403-14.
- SPICER, Z., MILLER, M.L., ANDRINGA, A., RIDDLE, T.M., DUFFY, J.J., et al. 2000. Stomachs of mice lacking the gastric H,K-ATPase alpha-subunit have achlorhydria, abnormal parietal cells, and ciliated metaplasia. *J Biol Chem*, 275: 21555-65.
- WU, J. 2009. Linking assessment questions to a research article to stimulate self-directed learning and develop high-order cognitive skills in an undergraduate module of molecular genetics. *CBE Life Sci Educ*, 8: 283-90.
- ZHU, L. 2008. Teaching glycoproteins with a classical paper: knowledge and methods in the course of an exciting discovery. *Biochemistry and Molecular Biology Education*, 36: 336-340.
- ZHU, L., CROTHERS, J., JR., ZHOU, R., AND FORTE, J.G. 2010. A possible mechanism for ezrin to establish epithelial cell polarity. *Am J Physiol Cell Physiol*, 299: C431-43.

# A Vodcasted, Cross-Disciplinary, Behavioral Neuroscience Laboratory Exercise Investigating the Effects of Methamphetamine on Aggression

Ryan A. Shanks<sup>2</sup>, E. Megan Southard,<sup>1</sup> Laura Tarnowski,<sup>1</sup> Matthew Bruster,<sup>1</sup> Stacia W. Wingate,<sup>2</sup> Nancy Dalman,<sup>2</sup> Steven A. Lloyd,<sup>1</sup>

<sup>1</sup>Psychology and <sup>2</sup>Biology Department, North Georgia College & State University, Dahlonega, GA 30597.

Email: [salloyd@northgeorgia.edu](mailto:salloyd@northgeorgia.edu)

**Abstract:** This article describes a laboratory experience utilizing videos to engage students in hypothesis-driven experimentation in behavioral neuroscience. It provides students with an opportunity to investigate the effects of chronic methamphetamine exposure on aggression in adult mice using a resident-intruder paradigm. Instructors and students only need Internet access to run this lab, which makes it accessible to most institutions, regardless of their facilities or resources necessary to conduct behavioral neuropsychopharmacology experiments. The laboratory experience described here provides instruction and hands-on experience with: 1) developing hypotheses and methodology to test these hypotheses; 2) operationalizing constructs and developing behavioral coding criteria; 3) collecting, analyzing, interpreting, and graphically displaying primary, behavioral data; and 4) working with complex, interdisciplinary ideas. Students who engaged in this laboratory experience demonstrated self-reported learning gains in course-specific outcomes, general and conceptual science learning, and the use of animal models in scientific experimentation.

**Key words:** laboratory exercise; behavioral neuroscience; animal models; methamphetamine; aggression; vodcast

## INTRODUCTION

There is a recent trend in science education of teaching by engaging students in the process of science and scientific discovery (AAAS, 1990; Handelsman, et al., 2004; AAC&U, 2007). Undergraduate engagement in research, whether through traditional independent research experiences or through its integration into the undergraduate curriculum, is associated with positive student outcomes related to learning, retention, graduation and post-graduate accomplishments, particularly for underrepresented populations (Nagda et al., 1998; Alexander et al., 2000; Foertsche et al., 2000; Seymour et al., 2000; Ishiyama, 2001; Ishiyama & Hopkins, 2001; Ishiyama, 2002; Bauer & Bennet, 2003; Lopatto, 2004; Summers & Hrabowski, 2006; Lopatto, 2007; Ramos Goyette et al., 2007; Brame et al., 2008; Gehring & Eastman, 2008; Miller, 2009; Wu, 2009). Despite their pedagogical benefits, smaller institutions with limited facilities and resources often face challenges in the implementation of research programs and/or the implementation of these experiences into the curriculum (Grisham et al., 2003). The effective use of technology, such as podcasting or vodcasting (i.e., video podcasting), may be able to help bridge this gap.

The laboratory exercise described below involves the use of a behavioral assay to measure

aggression using an animal model of drug abuse in the context of several important and controversial issues described herein. Since all laboratory materials are delivered online, there are no special facilities needed to conduct this laboratory, which also makes this a highly efficient laboratory exercise.

## Vodcasting in Education

Vodcasting is a video form of podcasting. Podcasting is a form of downloadable audio files compatible with MP3 players, which is associated with numerous positive learning outcomes (Evans, 2008; Hew, 2009; McKinney et al., 2009; Lloyd & Robertson, *in press*) and has been used for many years by colleges and universities (Hammersley, 2004; Donnelly & Berge, 2006). The newer, enhanced forms of vodcasting provide expanded media options for delivering course content (i.e., the addition of video), which have created a new form of portable learning (Donnelly & Berge, 2006). Unfortunately, there is a large gap between teaching practices and learning theory, which is obviated when the research involves technological innovations for college students (Fernandez et al., 2009; Hew, 2009).

## Development of the Laboratory Exercise

In order to address the need for novel, practical, accessible, and interdisciplinary undergraduate neuroscience laboratories, we developed a behavioral neuroscience laboratory sequence utilizing downloadable video files. Although widely accepted

to be an effective pedagogical tool, interdisciplinary instruction is not usually a component of undergraduate introductory biology courses. In addition, hands-on neuroscience learning opportunities also tend to be underrepresented in the typical undergraduate biology curriculum (Grisham et al., 2003). Since early exposure and hands-on engagement are key to the development of student interest, we created this interdisciplinary exercise specifically for freshman biology students. Self-report pretest/posttest data described below support the use of this novel laboratory. This vodcasted lab sequence demonstrates the effects of chronic methamphetamine exposure on aggression in the male mouse using a resident-intruder paradigm. The video files we created for this exercise are included as supplemental materials so there is no need for animal housing facilities and scheduled drug licenses to run these labs. We have provided additional supplemental materials including an extensive background (i.e., a review of the literature and novel, primary research data from our lab (see figures in the prelab handout)) and directed student exercises to accompany the video files. Therefore, it is possible for instructors to recreate the same lab experience using only a computer. All supplemental materials are available at: [www.northgeorgia.edu/Bioscene](http://www.northgeorgia.edu/Bioscene).

### **Background to the Laboratory Exercise**

#### *Methamphetamine and the hypothalamic-pituitary axis*

Methamphetamine (METH) is a potent indirect agonist for dopamine (DA), which is associated with oxidative stress, neuroinflammation, neural plasticity and neurodegeneration in the commonly studied DAergic mesocorticolimbic and nigrostriatal pathways (Krasnova & Cadet, 1999). However, the effect of METH on the DAergic tuberoinfundibular (TI) pathway is not clear. The TI pathway originates in the arcuate nucleus of the hypothalamus and terminates in the median eminence. The DA released from TI neurons is transported via long portal vessels to the lactotrophs of the anterior lobe of the pituitary gland where it inhibits the release of the hormone prolactin (Ben-Jonathan & Hnasko, 2001), which has numerous organizational and developmental effects on a wide variety of tissues and organs (Hair et al., 2002). In addition to its traditionally recognized role in lactation, prolactin is also a gonadotrophin regulator (Bartke, 1971) that stimulates testicular steroidogenesis (Takase et al., 1990) and spermatogenesis (Hair et al., 2002). The disruption of hypothalamic DA, pituitary DA receptors, or prolactin homeostasis is associated with reproductive disorders and dysfunction (Ben-Jonathan & Hnasko, 2001; Durham et al., 1996; Lucas et al., 1998; Steger et al., 1998; Thomas, Phelps, & Robinson; 1999). A

large body of literature demonstrates the potential for pharmacological treatments to affect this HPA-axis pathway. For example, TIDA activity is altered by selective DA agonists (Demaria et al., 2000; Durham et al., 1998; Martignoni et al., 1996), antipsychotics (Dickson & Glazer, 1999; Peabody et al., 1992), antidepressants (Van de Kar, Rittenhouse, Li, & Levy, 1996), analgesics (Bero & Kuhn, 1987; Kreek et al., 1999), atypical neuroleptics (Kapur et al., 2002), and transgenic manipulation of DA function (Ben-Jonathan & Hnasko, 2001; Bosse et al., 1997; Demaria et al., 2000). In relation to stimulant drugs of abuse, cocaine decreases prolactin mRNA in the pituitary, while amphetamines have a direct effect on testicular testosterone production (Tsai et al., 1997; DeMaria et al., 2000).

#### *Methamphetamine and aggression*

A number of studies link free and total testosterone, prolactin alterations, and disrupted neuroendocrine responses with normal and abnormal aggressive behaviors and traits (Dabbs & Morris, 1990; Dabbs et al., 1995; Banks & Dabbs, 1996; Stalenheim et al., 1998; Wingrove et al., 1999). Although testosterone influences aggression levels in humans and animals (Pope et al., 2000; Kawai et al., 2003; Grgurevic et al., 2008), the exact nature of this relationship is controversial. For example, Mazur & Booth (1998) suggest that testosterone can be both a cause and an effect of aggressive behavior, while a meta-analysis conducted by Book *et al.* (2001) shows a weak positive correlation between testosterone and aggression ( $r=0.14$ ) with a number of potential moderators and third variable explanations. METH abuse in humans is positively correlated with violence, impulsivity, and brain activity indicative of pathological aggression as well as disruptions in social cognitions and interactions, which are further risk factors for aggression (Homer et al., 2008). Furthermore, chronic intermittent METH exposure in mice increases the probability of and decreases the latency to attack an intruder and results in alterations in other forms of social interactions (Sokolov et al., 2004). Our lab has observed significant increases in testicular weight and increased serum testosterone levels in C57Bl/6J mice following chronic methamphetamine exposure (see supplemental material at [www.northgeorgia.edu/Bioscene](http://www.northgeorgia.edu/Bioscene)). The DAergic neurotoxicity caused by METH exposure could cause an increase in prolactin release, downstream increased testosterone, and subsequent increases in aggressive behavior.

### **METHODS**

All materials needed to run the novel laboratory described below can be obtained from the following

secure, permanent, university-supported link: [www.northgeorgia.edu/Bioscene](http://www.northgeorgia.edu/Bioscene). We created the following materials for this lab: 1) sixteen vodcasts created from videos demonstrating mouse-mouse interactions in a resident-intruder model of aggression; 2) a prelab handout introducing background information; and 3) a set of assignments related to this laboratory.

### Laboratory Sequences

The novel laboratory presented here was designed to instruct students towards several general learning outcomes, which included experimental design and methodology, statistical analyses and interpretation, and graphical data presentation. The students participated in a sequence of cross-disciplinary (psychology and biology) laboratory experiences involving hypothesis-driven experimentation at a level appropriate for freshman biology students. The laboratory experience was conducted as follows. In week 1, the students engaged in animal care and use training and were introduced to both the use of animal models in neuroscience research and the behavioral research experience to follow. In weeks 2 and 3, the students learned about and developed behavioral coding criteria and additional research hypotheses focused on the effects of chronic METH exposure on aggression. Small, collaborative groups of students were tasked with downloading, viewing, and coding a subset of predetermined vodcasts of resident-intruder interactions. The students were blinded to the experimental condition and coded the files according

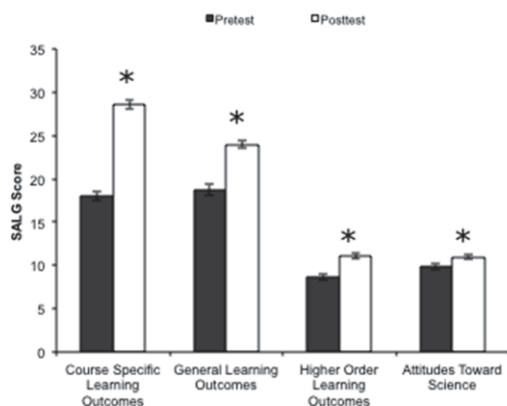
to the criteria previously established. In week 4, the students learned about and performed statistical analysis and graphical data presentation of the pooled data collected in week 3.

### Vodcasting and the Resident-Intruder Paradigm

All animal procedures were performed in compliance with the *Guide for the Care and Use of Laboratory Animals* (Clarke et al., 1996). Adult (3-4 months) male C57Bl/6J mice were injected daily with an i.p. dose of 5mg/kg methamphetamine HCl (n = 7; Sigma-Aldrich, St. Louis, MO) in a 2mg/ml solution or an equal volume of sterile saline (n = 9) for 10 days. These animals were singly housed in standard conditions (shoebox cage; 12hr light/dark cycle; *ad libitum* food and water) in order to establish a territorial home cage (resident animals). Five hours after the last dose, one age and weight matched adult male C57Bl/6J mouse (intruder animals; n = 16) was systematically introduced into each of the resident's cages (Olivier and Young, 2002). The resident-intruder interactions were digitally recorded for 10 minutes (Table 1). Behavioral coding of aggressive behaviors were performed off-line by two independent raters ( $\alpha = .97$ ) blinded to the experimental condition. The following indices of aggression were measured: the latency to first attack; the duration of attacks; and the total number of attacks (Demas et al., 1999; Sokolov et al., 2004). Aggressive behaviors were operationally defined to include: tail rattling, pawing or boxing, chasing, upright posture to gain dominance, persistent non-genital/investigatory sniffing and the coding of

**Table 1.** Video file descriptions and key.

<b>Video File ID</b>	<b>Treatment</b>	<b>Time to First Attack (sec)</b>	<b>Total Duration of Attacks (sec)</b>	<b>Total Number of Attacks</b>
C1-1	METH	600	0	0
C1-2	METH	450	21	9
C1-3	Saline	600	0	0
C1-4	Saline	600	0	0
C2-1	METH	600	0	0
C2-2	METH	403	21	10
C2-3d2	Saline	375	6	4
C2-4	Saline	600	0	0
C3-1b	METH	533	2	1
C3-2d1	Saline	460	3	2
C3-2d2	Saline	364	3	2
C3-3d1	METH	600	0	0
C3-3d2	METH	231	13	5
C3-4d1	Saline	600	0	0
C3-4d2	Saline	470	4	3
C3-5	Saline	600	0	0



**Fig. 1.** Pretest and posttest SALG construct scores. The novel laboratory experience produced larger self-reported gains in all areas. \*  $p < .05$

separate attacks required a two second or longer break in fighting (de Boer et al., 1999). The resident-intruder video files were optimized and compressed using iSquint (v1.5.2; Techspanion; <http://www.isquint.org>), uploaded and served on a University System podcast server, and made available to students through a one-click subscription via a HTML link posted in their course management system webpage.

## RESULTS

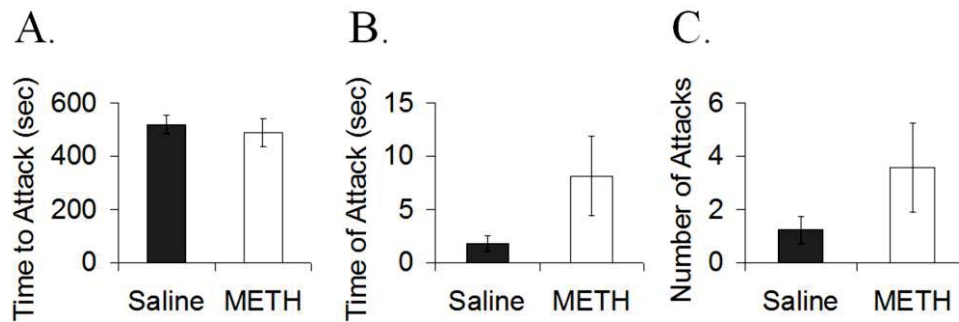
The impact of the novel laboratory experience was assessed using a modified version of the Student Assessment of their Learning Gains questionnaire (SALG; [www.salgsite.org](http://www.salgsite.org)) using a one group, pretest/posttest design. The 19-item questionnaire assessed self-reported learning across four constructs using a 5-point Likert-type response format (see Table 2). All statistical analyses were performed using PAWS Statistics (v18; IBM SPSS; Somers, NY). Students who engaged in the novel laboratory exercise reported higher values on the posttest compared to their baseline responses for questions related to: course-specific learning outcomes,  $t(105) = 14.18, p < .001$ ; general learning outcomes,  $t(105) = 6.70, p < .001$ ; higher-order learning outcomes,  $t(104) = 4.86, p < .001$ ; and attitudes toward science,  $t(105) = 2.47, p = .015$  (Figure 1). Summary responses to individual items are listed in Table 2. Since the SALG is a self-report questionnaire, the analyses that follow represent what the student thought they learned from this experience.

## DISCUSSION

Our results suggest that hypothesis-driven experimentation of a scientific and socially relevant topic led to a higher order understanding of the

**Table 2.** Summary of SALG scores by test.

SALG Question by Construct Assessed	Mean (SEM)	
	Pretest (n=53)	Posttest (n=54)
<b>Course-Specific Learning Outcomes</b>		
1. I have an understanding of how interdisciplinary research provides insight into scientific questions.	2.91 (0.15)	3.85 (0.10)
2. I have an understanding of how a hypothesis is tested in an experimental design.	4.08 (0.10)	4.59 (0.09)
3. I have an understanding of the relevance of statistical significance in relation to experimental data.	3.11 (0.15)	4.13 (0.10)
4. I have an understanding of how t-tests are used to analyze data.	1.36 (0.11)	4.04 (0.12)
5. I have the ability to establish criteria to analyze behavioral differences in animals.	1.92 (0.13)	4.15 (0.10)
6. I have the ability to accurately disseminate data graphically.	2.17 (0.13)	3.87 (0.12)
7. I have the ability to write concise and informative figure legends.	2.47 (0.14)	3.93 (0.12)
<b>General Learning Outcomes</b>		
8. I am able to identify patterns in data collected from scientific experiments.	3.30 (0.13)	4.02 (0.10)
9. I am able to gather quantitative data to answer questions about behavior.	2.91 (0.15)	4.13 (0.11)
10. I am able to work effectively with others in an academic setting.	4.38 (0.09)	4.50 (0.10)
11. I have confidence that I understand how to identify and quantify behavioral patterns, statistically analyze collected data, and disseminate the data in a figure suitable for publication.	2.34 (0.16)	3.70 (0.12)
12. I have confidence that I can understand the relationship between behavior and biological processes.	3.06 (0.16)	4.04 (0.12)
13. I have the ability to work with complex interdisciplinary ideas.	2.75 (0.15)	3.59 (0.11)
<b>Attitudes Towards Science</b>		
14. I have enthusiasm for interdisciplinary subjects.	3.57 (0.13)	3.69 (0.12)
15. I have interest in taking additional interdisciplinary classes	3.13 (0.14)	3.39 (0.14)
16. I have a positive view of using animal models to answer scientific questions.	3.15 (0.17)	3.93 (0.13)
<b>Higher-Order Learning Outcomes</b>		
17. I am capable of using systematic reasoning in my approach to problems.	3.06 (0.14)	3.69 (0.13)
18. I am capable of using a systematic approach to analyzing data.	2.96 (0.13)	3.72 (0.13)
19. I am capable of using a multi-disciplinary approach to answer scientific questions.	2.60 (0.14)	3.72 (0.14)



**Fig. 2.** Samples of student results from the laboratory exercise. Students graphically demonstrated the effects of methamphetamine on aggression using three different operational definitions: the number of attacks (A), the time to first attack (B), and the total duration of attacks (C) from the resident-intruder vocasts.

scientific process without sacrificing fundamental teaching outcomes specific to a course. For example, students learned specific information about the importance of control groups, how to graphically display data, the meaning of statistical significance, and how to operationalize a construct. However, they also learned how to identify and analyze patterns in data sets as well as how to work with and use complex multi-disciplinary ideas and how to use comparative research and systematic reasoning to test hypotheses. Students also showed significant positive changes in their attitudes toward science and experimentation involving animal models. Further, the videos successfully exposed students to experimentation and data collection opportunities, which would otherwise not be available in a laboratory setting. An example of student results following the completion of this laboratory exercise is shown in Figure 2.

We built upon the premise of Grisham et al. (2003) in an effort to meet a demonstrated need of faculty teaching neuroscience with limited resources to provide hands-on learning opportunities for their students. This laboratory exercise also provided an effective means of engaging students in cross-disciplinary behavioral neuroscience as a first year experience. Early exposure to undergraduate research and integrative learning are recognized high impact practices that are effective for meeting explicitly stated goals for excellence in education as well as specialized curricular goals for STEM education (AAC&U, 2002; AAC&U, 2007; Elrod, 2010).

#### ACKNOWLEDGEMENTS

This work was supported by the NGCSU CURCA, LITP, and QEP.

#### REFERENCES

- AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. 1990. *The Liberal Art of Science* (Report No. 90-13S). Washington, DC: American Association for the Advancement of Science.
- ASSOCIATION OF AMERICAN COLLEGES AND UNIVERSITIES. 2002. *Greater Expectations: A New Vision for Learning as a Nation Goes to College*. Washington, DC: Association of American Colleges and Universities.
- ASSOCIATION OF AMERICAN COLLEGES AND UNIVERSITIES. 2007. *College Learning for the New Global Century: A Report from the National Leadership Council for Liberal Education & America's Promise*. Washington, DC: Association of American Colleges and Universities.
- ALEXANDER, B., FOERTSCH, J., DAFFINRUD, S., AND R. TAPIA. 2000. The "Spend a Summer with a Scientist" (SAS) Program at Rice University: a Study of Program Outcomes and Essential Elements, 1991-1997. *Council on Undergraduate Research Quarterly* 20: 127-133.
- BANKS, T., AND J.M. DABBS. 1996. Salivary testosterone and cortisol in a delinquent and violent urban subculture. *J Soc Psychol* 136: 49-56.
- BARTKE, A. 1971. Effects of prolactin on spermatogenesis in hypophysectomized mice. *J Endocrinol* 49: 311-16.
- BAUER, K.W., AND J.S. BENNETT. 2003. Alumni perceptions used to assess undergraduate research experience. *J Higher Education* 74: 210-230.
- BEN-JONATHAN, N., AND R. HNASKO. 2001. Dopamine as a prolactin (PRL) inhibitor. *Endocrine Reviews* 22: 724-763.

- BERO, L.A., AND KUHN, C.M. 1987. Differential ontogeny of opioid, dopaminergic, and serotonergic regulation of prolactin secretion. *Journal of Pharmacology and Experimental Therapeutics* 240: 825-30.
- BOOK, A.S., STARZYK, K.B., AND V.L. QUINSEY. 2001. The relationship between testosterone and aggression: a meta-analysis. *Aggression and Violent Behavior* 6: 579-599.
- BOSSE, R., FUMAGALLI, F., JABER, M., GIROS, B., GAINEDINOV, R.R., WETSEL, W.C., MISSALE, C., AND CARON, M.G. 1997. Anterior pituitary hypoplasia and dwarfism in mice lacking the dopamine transporter. *Neuron* 19: 127-138.
- BRAME, C.J., PRUITT, W.M., AND L.C. ROBINSON. 2008. A Molecular Genetics Laboratory Course Applying Bioinformatics and Cell Biology in the Context of Original Research. *CBE-Life Sciences Education* 7: 410-421.
- CLARK, J.D., BALDWIN, R.L., BAYNE, K.A., BROWN, M.J., GEBHART, G.F., GONDER, J.C., GWATHMEY, J.K., KEELING, M.E., KOHN, D.F., ROBB, J.W., SMITH, O.A., STEGGARDA, J.-A.D., VANDENBERGH, J.G., WHITE, W.J., WILLIAMS-BLANGERO, S., VANDEBERG, J.L. (1996) Guide for the Care and Use of Laboratory Animals. Institute of Laboratory Animal Resources, National Research Council, Washington D.C.
- DABBS, J.M., CARR, T.S., FRADY, R.L., AND J.K. RIAD. 1995. Testosterone, crime, and misbehavior among 692 male prison inmates. *Person Individ Diff* 18: 627-33.
- DABBS, J.M., AND R. MORRIS. 1990. Testosterone, social class, and antisocial behavior in a sample of 4,462 men. *Psychol Sci* 1: 209-11.
- DE BOER, S.F., LESOURD, M., MOCAER, E., AND J.M. KOOLHAAS. 1999. Selective antiaggressive effects of Alnespirone in resident-intruder test are mediated via 5-Hydroxytryptamine<sub>1A</sub> receptors: a comparative pharmacological study with 8-hydroxy-2-dipropylaminotetralin, Ipsapirone, Buspirone, Eltoprazine, and WAY-100635. *Journal of Pharmacology and Experimental Therapeutics* 288: 1125-33.
- DEMARIA, J.E., NAGY, G.M., LERANT, A.A., FEKETE, M.L., LEVENSON, C.W., *et al.* 2000. Dopamine transporters participate in the physiological regulation of prolactin. *Endocrine* 141: 366-375.
- DEMAS, G.E., KRIEGSFELD, L.J., BLACKSHAW, S., HUANG, P., GAMMIE, S.C., *et al.* 1999. Elimination of Aggressive Behavior in Male Mice Lacking Endothelial Nitric Oxide Synthase. *The Journal of Neuroscience* 19(RC30): 1-5.
- DICKSON, R.A., AND GLAZER, W.M. 1999. Neuroleptic-induced hyperprolactinemia. *Schizophrenia Research* 35: S75-S86.
- DONNELLY, K.M., AND Z.L. BERGE. 2006. Podcasting: Co-opting MP3 players for education and training purposes. *Online Journal of Distance Learning Administration* 9. Accessed from <http://www.westga.edu/~distance/ojdla/fall93/donnely93.htm> on 20 May 2011.
- DURHAM, R.A., JOHNSON, J.D., EATON, M.J., MOORE, K.E., AND LOOKINGLAND, K.J. 1998. Opposing roles for dopamine D1 and D2 receptors in the regulation of hypothalamic tuberoinfundibular dopamine neurons. *European Journal of Pharmacology* 355: 141-147.
- ELROD, S. 2010. Project Kaleidoscope 2.0: Leadership for twenty-first-century STEM education. *Liberal Education* 96: 24-33.
- EVANS, C. 2008. The effectiveness of m-learning in the form of podcast revision lectures in higher education. *Computers & Education* 50: 491-498.
- FERNANDEZ, V., SIMO, P., AND J.M. SALLAN. 2009. Podcasting: A new technological tool to facilitate good practice in higher education. *Computers & Education* 53: 385-392.
- FOERTSCHE, J., ALEXANDER, B.B., AND D. PENBERTHY. 2000. Summer research opportunity programs (SROPs) for minority undergraduates: a longitudinal study of program outcomes 1986-1996. *Council of Undergraduate Research Quarterly* 20: 114-119.
- GEHRING, K.M., AND D.A. EASTMAN. 2008. Information fluency for undergraduate Biology majors: applications of inquiry-based learning in a Developmental Biology course. *Cell Biology Education* 7: 54-63.
- GRISHAM, W., JONES, H.B., AND S.H. PARK. 2003. Sex differences and organizational effects of androgen in spinal cord motor nuclei. *The Journal of Undergraduate Neuroscience Education* 2: A28-35.
- GRGUREVIC, N., BUDEFELD, T., RISSMAN, E.F., TOBET, S.A., AND G. MAJDIC. 2008. Aggressive behaviors in adult SF-1 knockout mice that are not exposed to gonadal steroids during development. *Behavioral Neuroscience* 122: 876-884.

- HAIR, W.M., GUBBAY, O., JABBOUR, H.N., AND G.A. LINCOLN. 2002. Prolactin receptor expression in human testis and accessory tissues: localization and function. *Mol Hum Reprod* 8: 606-11.
- HAMMERSLEY, B. 2004, February 12. Audible revolution. *The Guardian*. Accessed from: <http://www.guardian.co.uk/media/2004/feb/12/broadcasting.digitalmedia> on 20 May 2011.
- HANDELSMAN, J., EBERT-MAY, D., BEICHNER, R., BRUNS, P., CHANG, A., *et al.* 2004. Scientific Teaching. *Science* 304(5670): 521-522.
- HEW, K.F. 2009. Use of audio podcast in K-12 and higher education: a review of research topics and methodologies. *Educational Technology Research and Development* 57: 333-357.
- HOMER, B.D., SOLOMON, T.M., MOELLER, R.W., MASCIA, A., LAUREN, D., *et al.* 2008. Methamphetamine abuse and impairment of social functioning: a review of the underlying neuropsychological causes and behavioral implications. *Psychological Bulletin* 134: 301-10.
- ISHIYAMA, J. 2001. Undergraduate research and the success of first generation, low income college students. *Council on Undergraduate Research Quarterly* 22: 36-41.
- ISHIYAMA, J. 2002 Does early participation in undergraduate research benefit social science and humanities students? *College Student Journal* September: 380-6. Accessed from [http://www.bw.edu/resources/dean/fscs/fr/ishiyama\\_ug\\_res\\_artice.pdf](http://www.bw.edu/resources/dean/fscs/fr/ishiyama_ug_res_artice.pdf) on 20 May 2011.
- ISHIYAMA, J., AND V.M. HOPKINS. 2001. Assessing the Impact of the McNair Program on Students at a Public Liberal Arts University. *Opportunity Outlook* Apr: 20-24.
- KAPUR, S., LANGLOIS, X., VINKEN, P., MEGENS, A.A.H.P., DE COSTER, R., AND ANDREWS, J.S. 2002. The differential effects of atypical antipsychotics on prolactin elevation are explained by their differential blood-brain disposition: a pharmacological analysis in rats. *Journal of Pharmacology and Experimental Therapeutics* 302: 1129-1134.
- KAWAI, K., NOZAKI, T., NISHIKATA, H., AOU, S., TAKII, M., *et al.* 2003. Aggressive behavior and serum testosterone concentration during the maturation process of male mice: the effects of fetal exposure to Bisphenol A. *Environ Health Perspect* 111: 175-8.
- KRASNOVA, I.N., AND J.L. CADET. 2009. Methamphetamine toxicity and messengers of death. *Brain Res Rev* 60: 379-407.
- KREEK, M.J., SCHLUGER, J., BORG, L., GUNDUZ, M., AND HO, A. 1999. Dynorphin A1-13 causes elevation of serum prolactin through an opioid receptor mechanism in humans: gender differences and implications for modulation of dopaminergic tone in the treatment of addictions. *Journal of Pharmacology and Experimental Therapeutics* 288: 260-269.
- LLOYD, S.A., AND C.L. ROBERTSON. *in press*. Screencasting tutorials enhance student learning of statistics. *Teaching of Psychology*.
- LOPATTO, D. 2004. Survey of undergraduate research experiences (SURE): first findings. *Cell Biology Education* 3: 270-277.
- LOPATTO, D. 2007. Undergraduate Research Experiences Support Science Career Decisions and Active Learning. *Cell Biology Education* 6: 297-306.
- LUCAS, B.K., ORMANDY, C.J., BINART, N., BRIDGES, R.S., AND KELLY, P.A. 1998. Null mutation of the prolactin receptor gene produces a defect in maternal behavior. *Endocrinology* 139: 4102-4107.
- MAZUR, A., AND A. BOOTH. 1998. Testosterone and dominance in men. *Behav Brain Sci* 21(3): 363-397.
- MCKINNEY, D., DYCK, J.L., AND E.S. LUBER. 2009. iTunes University and the classroom: can podcasts replace professors? *Computers & Education* 52: 617-623.
- MILLER, R. 2009. Connecting Beliefs with Research on Effective Undergraduate Education. *Peer Review* Spring: 4-8.
- NAGDA, B.A., GREGGERMAN, S.R., JONIDES, J., VON HIPPEL, W., AND J.S. LERNER. 1998. Undergraduate student-faculty research partnerships affect student retention. *Review of Higher Education* 22, 55-72.

- OLIVIER, B., AND L.J. YOUNG. 2002. Animal Models of Aggression. In Davis, K.L., Charney, D., AND J.T. Coyle 2002. *Neuropsychopharmacology: The Fifth Generation of Progress*. American College of Neuropsychopharmacology, Nashville, TN 1699-1708pp.
- PEABODY, C.A., WARNER, M.D., GRIFFIN, M., BOUTROS, N.N., WORSLEY, I.G., AND FRIESEN, H.G. 1992. Prolactin bioassay in schizophrenia before and after neuroleptics. *Psychiatry Research* 41: 249-255.
- POPE, H.G., KOURI, E.M., AND J.I. HUDSON. 2000. Effects of supraphysiologic doses of testosterone on mood and aggression in normal men: a randomized controlled trial. *Archives of General Psychiatry* 57: 133-140.
- RAMOS GOYETTE, S., AND J. DELUCA. 2007. A Semester-long Student-directed Research Project Involving Enzyme Immunoassay: Appropriate for Immunology, Endocrinology, or Neuroscience Courses. *CBE-Life Sciences Education* 6: 332-342.
- SEYMOUR, E., WIESE, D., HUNTER, A., AND S.M. DAFFINRUD. 2000. Creating a Better Mousetrap: On-line Student Assessment of their Learning Gains. *Paper presentation at the National Meeting of the American Chemical Society*, San Francisco, CA. Accessed from <http://www.salgsite.org/docs/SALGPaperPresentationAtACS.pdf> on 20 May 2011.
- SOKOLOV, B.P., SCHINDLER, C.W., AND J.L. CADET. 2004. Chronic methamphetamine increases fighting in mice. *Pharmacology, Biochemistry and Behavior* 77: 319-26.
- STALENHEIM, E.G., ERIKSSON, E., VON KNORRING, L., AND L. WIDE. 1998. Testosterone as a biological marker in psychopathy and alcoholism. *Psychiatr Res* 77: 79-88.
- STEGER, R.W., CHANDRASHEKAR, V., ZHAO, W., BARTKE, A., AND HORSEMAN, N.D. 1998. Neuroendocrine and reproductive functions in male mice with targeted disruption of the prolactin gene. *Endocrinology* 139: 3691-3695.
- SUMMERS, M.F., AND F.A. HRABOWSKI. 2006. DIVERSITY: Enhanced: preparing minority scientists and engineers. *Science* 311: 1870-1871.
- TAKASE, M., TSUTSUI, K., AND S. KAWASHIMA. 1990. Effects of prolactin and bromocriptine on the regulation of testicular leutinising hormone receptors in mice. *J Exp Zool* 6: 219-229.
- THOMAS, G.B., PHELPS, C.J., AND ROBINSON, I.C.A.F. 1999. Differential regulation of hypothalamic tuberoinfundibular dopamine neurons in two dwarf rat models with contrasting changes in pituitary prolactin. *Journal of Neuroendocrinology* 11: 229-236.
- TSAI, S.C., CHEN, J.J., CHIAO, Y.C., LU, C.C., LIN, H., *et al.* 1997. The role of cyclic AMP production, calcium channel activation and enzyme activities in the inhibition of testosterone secretion by amphetamine. *Br J Pharmacol* 122: 949-955.
- VAN DE KAR, L.D., RITTENHOUSE, P.A., LI, Q., AND LEVY, A.D. 1996. Serotonergic regulation of renin and prolactin secretion. *Behavioral Brain Research* 73: 203-208.
- WINGROVE, J., BOND, A.J., CLEARE, A.J., AND R. SHERWOOD. 1999. Trait hostility and prolactin response to tryptophan enhancement/depletion. *Neuropsychobiology* 40: 202-6.
- WU, J. 2009. Linking assessment questions to a research article to stimulate self-directed learning and develop high-order cognitive skills in an undergraduate module of molecular genetics. *Cell Biology Education* 8: 283-290.

# Organizing a Campus Activity: An Alternative Learning Approach

Mary Tracy Bee<sup>1,2</sup>, James Montante<sup>1</sup>, Kate Lanigan<sup>3</sup>, Michelle Andrzejak<sup>1</sup>, Greg Grabowski<sup>1</sup>

<sup>1</sup>Biology Department, University of Detroit Mercy, Detroit, MI 48221

<sup>2</sup>Oakland University William Beaumont School of Medicine, Rochester, MI 48309

<sup>3</sup>Chemistry Department, University of Detroit Mercy, Detroit, MI 48221

Email: [mtracyma@udmercy.edu](mailto:mtracyma@udmercy.edu)

**Abstract:** Alternative teaching styles provide a unique and rewarding approach to reinforcing student knowledge and developing social skills. An approach that we implemented required students from the ecology class to organize and present information at the university-wide Earth Day celebration and exposition. In addition to the informational and research posters presented by the ecology class, the exposition included displays by local environmental groups, local and state agencies, student organizations on campus, research groups from the chemistry department, and an ethics class. We found that the level of student engagement far exceeded our expectations and that the students felt they had made a significant impact on the community. We highly recommend this approach to other faculty.

**Key Words:** Earth Day, Service Learning, Ecology, Innovative Teaching Approach, Experiential Learning

## INTRODUCTION

Student-centered pedagogy presents opportunities to increase student interest and involvement in learning. Alternative forms of teaching such as problem-based or project-based learning, inquiry-based learning, case studies, and community-based or service learning approaches have been utilized with great success for students and faculty alike (Draper, 2004; Wenzel, 2002). These approaches are each a type of experiential education, as is the community-based project presented here. Experiential education is defined as the process for learning through action (Kolb and Kolb, 2005).

Project-based learning has the capacity to benefit the student in ways that are very difficult to achieve in the classroom (Strage, 2004). Community-based or service learning projects foster personal growth by teaching students to take risks and accept challenges, develop their own personal values and beliefs, and accept responsibility for their learning (Eyler and Giles, 1999). The interactions in community-based projects also develop communication and leadership skills. Students learn how to interact with each other and members of the community in a professional manner, how to engage and cooperate with peers, and how to manage their time effectively while working towards long term goals. Students also learn to apply the knowledge from the classroom to the world around them and to develop critical thinking skills (Markus et al., 1993). Finally, and perhaps most importantly, students come to feel they are a part of the community around them and develop a sense of civic responsibility (Stage, 2004; Eyler and Giles, 1999).

This paper describes a community-based, alternative teaching strategy that was implemented in the senior level undergraduate ecology course at University of Detroit Mercy. University of Detroit Mercy is a private four year college with an enrollment of 5,600 students. The student population is diverse, and consists of 30 percent minority and 60 percent female students.

At University of Detroit Mercy, ecology is an upper-level biology course that has prerequisites of two semesters of freshman biology, two semesters of inorganic chemistry and one semester of elementary functions. Most of the students in the course are biology majors, although there are usually a few biochemistry or chemistry majors. The 34 students in the ecology course were required to participate in a semester-long project commemorating the annual Earth Day celebration. The goal of the project was to engage students in an active, community-based learning experience that was student driven and emphasized cooperative learning techniques among students. The project comprised twenty percent of their final grade in the course.

Concern over environmental issues has become mainstream thought over the last few decades, and a part of the life experience of typical university students. As a result, students are familiar with many environmental issues and they bring a variety of prior knowledge to the classroom. Mercury contamination in fish, water resource use, and global warming have become part of our daily news cycle and popular consciousness. Civic programs and governmental regulations dealing with environmental problems have become part of our everyday lives. Curbside recycling programs and hazardous waste reclamation

mandates on automobile oil, batteries, and tires are examples. In addition, younger university students have been increasingly exposed to the idea of environmental stewardship throughout their public and private educations. Because of their everyday exposure to environmental issues, most students have a sense that our environment is at risk and that managing it is a continuing and ongoing job. A project-based learning experience dealing with environmental issues and remedial actions naturally resonates with them.

Earth Day presents an ideal opportunity to engage university students since it is an example of how university students helped to affect meaningful change in both the United States and the rest of the world. The first Earth Day celebration, held on April 22, 1970, was organized by Senator Gaylord Nelson of Wisconsin with the help of university students. It involved two million people in communities throughout the United States (Lewis, 1990) and it represented a watershed moment in US history when the environmental movement became part of mainstream politics. The impact of that first Earth Day on the environmental movement, and on the laws passed in the few years afterwards, was substantial. The creation of the United States Environmental Protection Agency, the passage of the Clean Air Act, Clean Water Act, and other legislation protecting the drinking water, oceans, and soils were direct results of Earth Day. By 1980, Earth Day was celebrated by 500 million people in 175 countries across the planet. Furthermore, the USA EPA estimates that currently over a billion people take part in Earth Day events annually (Jackson, 2011).

In summary, the increasing interest in environmental issues among young people, the unique potential that community-based education has for affecting students, and Earth Day's historical connection to university education all make Earth Day seem like the perfect alternative teaching opportunity.

## METHODS

At the beginning of the semester students were given an introduction to the history of Earth Day that highlighted the seminal role university students played in the founding of Earth Day. They also learned about the substantial impact Earth Day had on both the environmental movement and the environmental legislation enacted in the early 1970's.

After reviewing the syllabus description, students were given an interest form that asked them to rank their preference for involvement in one of the following four activities: (a) organizing the Earth Day exposition for the entire campus, (b) conducting a research project and presenting it as a research poster at the Earth Day exposition, (c) developing

and implementing a physical project to make the campus a more "green" environment, and then presenting it at the exposition in poster format, and (d) organizing an informational booth for the exposition on an environmentally-oriented topic and providing attendees with an item related to the topic.

Students were assigned by the instructor to one of the four activities based on their preference rankings. Allowing the students a choice on their assignments was meant to give them a feeling of confidence and ownership over the assignment. It was thought that students with more laboratory experience might gravitate towards research projects for example, while tactile learners with less laboratory experience might chose to work on a greening project for the campus. Students were then grouped in teams of three or four, and one person from each team was elected as the team leader. The team leader served as the main liaison with the professor and ensured that the team was progressing in a timely manner to reach their final goals. There were two organizational teams, two greening teams, three research teams, and four informational teams.

The Earth Day exposition was held during the second to the last week of the semester. Students were informed of the event date on the first day of class. This time frame allowed students to commit to the date well in advance and gave them plenty of time to plan and complete their project.

Organization teams were responsible for the logistics involved in running the exposition and in community outreach. The organization teams worked together to create a list of logistic goals, which they divided between the teams. This component was designed to raise student and attendee awareness of the public and private organizations that address environmental problems, how these organizations approach the problems, and how they interact with each other and the community. The organizational teams contacted the local and state governments, environmental groups, and educational institutions and arranged for them to set up informational booths at the exposition. Members of this group also worked with the university marketing department to publicize the exposition and invited various local political figures in Detroit and the State of Michigan. In addition, organizational teams solicited donations from local businesses and the community, posted advertisements around campus, set up before and cleaned up after the exposition, and arranged for a campus fraternity to provide heavy labor. A deadline was set for initial ideas from the organizational teams, but student involvement evolved considerably as the semester progressed. The professor met with the organization teams bimonthly outside of class time.

Table 1. EARTH DAY ASSESSMENT. Student responses to the statements are listed as means with standard errors in parentheses. Students answered questions out of 10, with 1 as the lowest and 10 as the highest, n=34.

Question number	Survey statement	Student response
#	<b><i>Earth Day as an Educational Tool</i></b>	
1	I utilized leadership skills	8.0 (2.1)
2	This helped me learn and use effective time management	8.0 (2.0)
3	I learned more than a textbook had to offer	8.2 (2.0)
5	This helped me develop my abilities to correspond with professionals and/or develop my researching/investigational skills	8.0 (2.5)
6	Participating in this event INTELLECTUALLY intrigued and challenged me	8.1 (1.8)
7	I learned the importance of being environmentally AWARE	8.8 (1.2)
8	I learned the importance of being environmentally ACTIVE	8.9 (1.3)
9	I was pleased by the interaction members of OTHER departments	8.5 (1.8)
10	Interacting with members of OTHER departments aided in my learning	7.4 (2.2)
	<b><i>Earth Day: How it affected me personally</i></b>	
11	I made a difference	8.3 (1.6)
13	I will get involved more in the future	8.4 (2.0)
14	This event was fun	8.6 (2.9)
15	I liked working as a team with other members	7.8 (2.3)
16	I like how all of the teams worked together in our class as a whole to produce Earth Day	8.7 (1.7)
17	I felt part of our university community	8.4 (2.2)
18	This affected my outlook on the world (for the better)	8.6 (1.9)
20	This motivated me to change my current way of living	8.2 (1.9)
	<b><i>Earth Day as an Behavior-Affecting Tool</i></b>	
21	I was proud of how <u>I</u> made an impact	8.2 (2.1)
22	I was proud of how <u>my team</u> made an impact	8.4 (2.2)
23	I was proud of how <u>our class</u> made an impact	8.9 (1.7)
24	I felt satisfaction from the hard work I accomplished	8.4 (2.2)
25	I felt that the attendees were interested in Earth Day	8.2 (1.9)
26	There were more people there than I expected	8.9 (1.6)
27	I felt part of a community	8.4 (1.2)
	<b><i>Earth Day: The Future</i></b>	
29	To what extent did this help you learn the material of the course?	7.7 (2.4)
30	To what extent did you grow in your own sense of worth as a person engaged in making our society better?	7.5 (2.7)
31	I think that Dr Bee should keep this Earth Day assignment as part of the ecology course requirement	8.7 (1.8)

Open-ended question: What would you do differently next year?

Research teams conducted experiments related to various environmental issues and presented their findings as a research poster. This component was designed to raise student and attendee awareness of the role scientific research plays in our assessment of environmental problems and strategies for mitigation efforts. The students in the research teams were introduced to some of the methods used to assess and monitor environmental parameters and received guidance in conducting their analyses by a collaborating faculty member in the chemistry department. Examples of projects conducted by the research teams included the assessment of metal concentrations in local sediments and the levels of calcium and magnesium in Detroit city water. Deadline dates for research proposals, data collection, data analysis, and drafts of the final reports and posters were set on the third, sixth, eighth and tenth week of the semester respectively.

Greening teams worked on projects to improve the environmental profile of the campus. This component was designed to demonstrate practical examples of changes students and attendees could make that would have a positive effect on the environment. Students presented an informational poster on their project. Financial resources and the time frame of the project limited the scope of many projects. Examples of projects included planting and handing out tree seedlings and the design of a new campus flowerbed using perennial rather than annual species. Deadline dates for the selection of the project and the final poster were set early in the semester. Individual project completion goals were monitored by the instructor throughout the semester.

Informational teams constructed display booths each of which highlighted an environmental issue and distributed materials related to their topic to expo attendees. The goal of this component was to raise

student and attendee awareness of environmental concerns and their causes, mitigation efforts we employ, and technological developments related to environmental concerns. Presentation topics ranged from local applications like composting and recycling to planetary concerns like global warming. Examples of items distributed included pamphlets on global warming, posters delineating local watersheds, and cans of pop with information about recycling attached to them. Deadline dates were set for topics, materials to be distributed, rough drafts, and final posters on the third, sixth, eighth, and tenth week of the semester respectively. Progress on presentation development was monitored by the instructor throughout the semester.

The instructor reserved the campus facility for the exposition and notified other faculty of the event. All faculty and their students were invited to attend, and forms verifying student attendance were distributed at the organizational booth in case any faculty awarded credit for attendance. The exposition was held during university "free" time, which is a designated time when no classes are offered on campus, to ensure that all students had a chance to attend.

Students in the organizational, informational, research, and greening project teams were individually graded for the quality of their project or presentation, their knowledge of the topic as assessed by the instructor during their presentation, and their post-exposition reflection. Each of these counted as 30% of their project grade. In addition, all students filled out a confidential peer evaluation form for each member of their team, which provided insight into the efforts of each participant. The peer review counted as 10% of the grade for the project. The organizational teams were graded on the quality of the exposition itself (60%), their post-exposition reflection (30%), and peer review (10%). Students completed a survey (questions listed in Table 1) and post-survey reflection within one week after the event.

Collaboration with the chemistry department was critical to the success of the research teams. The chemistry department provided the instrumentation for the ecology research projects and instruction on its use, including a flame atomic absorption spectrophotometer that was obtained through a NSF-CCLI grant. Original research was carried out by students in the ecology course and presented at the exposition. In addition, students in the chemistry department's quantitative chemical analysis course also presented group posters reviewing chemical analyses used in environmental studies in the United States National Parks. Topics ranged from snowmobile exhaust pollution at Yellowstone National Park to airborne pesticide contamination on Isle Royale National Park.

## RESULTS

Approximately 300 students attended the Earth Day exposition. In addition to the presentations by our ecology students, students from collaborating classes also set up booths. Examples include six booths from the analytical chemistry class and a booth on environmental ethics from a psychology course. Individuals from the community also participated with booths on global warming and political action. The Sierra Club, Detroit Science Center, Wayne County Water Management, Michigan Department of Environmental Quality, and two local watershed organizations participated in the exposition. The library exhibited copies of environmental resources and texts, and played the movie *Inconvenient Truth* in their booth. In all, approximately 40 booths were set up. Little Caesar's donated free pizza and soft drinks for the duration of the exposition, which was a tremendous draw for our students, and a local band called Silent Violet performed music with an environmental theme for free.

Feedback from our students was overwhelmingly positive (Table 1). The work involved in the project was in addition to the normal workload in the course. At the beginning of the semester, many students expressed feelings of being overworked in the course or worried over how the exposition would affect their grade in the course. However, after the exposition many expressed feelings of pride and satisfaction. Most students found their participation in the exposition highly rewarding.

Student reflections of the project showed similar themes. First, many students felt the exercise was an effective educational tool that helped them to understand and learn the material. Some of these comments include: "it gave me a chance to share some of my newfound knowledge with people in our college and community. By talking about the information over and over it really solidified it in my head" and "I learned so much more than just what a textbook had to offer." One student noted that "this experience taught me about networking and corresponding with professionals," and another claimed that "it was a great success for me intellectually."

A second theme identified throughout the student reflections was the sense of pride that students felt from this experience. Comments included: "I was proud to be part of this assignment", "...this was the most fun I've had out of a class assignment throughout my entire college career", "I feel satisfaction from all the hard work", "... our class had accomplished something great", "I'm so proud of our class", and "You could see the pride on people's faces as they either presented or strolled through the displays."

Third, the exercise changed the students' perspective on the impact they can have on

environmental issues. Comments in this vein included: "...this lead me to realize that just one student can make a difference", "... inspired me to be passionate about the environment." Further, "I will forever be conscious of my impact on the environment as well as my role in the solution" and "I believe we made an impact."

As with all experiences, there is always room for improvement. Student comments included "...have recycle bins next year for the trash," and "...include a battery recycling depot."

## DISCUSSION

A major goal of any service learning experience, and of Earth Day itself, is to allow individuals to discover that they are part of a larger whole, that their futures are tied to everyone else, and that they are part of a community. In this regard our exposition far exceeded the expectations of both faculty and presenters. The students were pleasantly surprised with the number of attendees and felt part of a community. In addition, the students were pleased with their interactions with members from other departments, and with how all the teams worked together to produce the exposition. Perhaps the most telling point in this regard was how the students ranked their feeling of pride in the exposition. Although they clearly felt that one person can make a difference, and that they as individuals contributed to making a difference, their pride in the success of the exposition was overwhelmingly attributed to the entire class. As noted in the informal survey, pride in the performance of the entire class as a whole was followed next by pride in their team and lastly pride in their individual accomplishment.

A major advantage of alternative teaching and service learning strategies in particular is that they have real world relevance. Students are asked to create, to problem solve, and to act and think independently. This kind of experience has the potential to engage students and to make the course material meaningful to students in a way that didactic study cannot. It also has the potential to profoundly affect their world view, and their lives. Our Earth Day exposition achieved this result. The assessment results show that the students overwhelmingly felt that participation in this project taught them the importance of being environmentally aware and active. They also felt that the experience changed their outlook on the world for the better, and that they were more likely to become involved in environmental issues in the future. Lastly, they found the experience to be fun.

In addition, the students felt the Earth Day exposition was a successful learning experience and that participation in the project taught them more than they could learn from a textbook. Students strongly favored keeping the assignment as part of the class in the future. Why did they value this

experience so much? Our personal observations include that the students internalized the importance of being environmentally aware and active. More importantly, they learned to apply that knowledge, as demonstrated by the comments suggesting that future expositions include recycling containers. Furthermore the students realized that the information they learned in the classroom was relevant to the world in which they live. They felt that their efforts and abilities have a real and demonstrable impact on the world around them. We believe that the high level of energy at the exposition contributed to this internalization and that the students themselves felt changed by their experience. The students reported that they wanted to change the way they live and that they felt they could make a difference. They learned that they were part of a community. The experience left them with a more positive outlook on the world. One student commented that her favorite booth was the one where tree seedlings with planting instructions were handed to all attendees. "I beamed with pride as I walked through the room carrying my little pine tree. I went home and planted it that night, and one day when my kids ask me where it came from I'll let them know how I worked hard and really made a difference in the world on Earth Day." The faculty felt the same way about this project.

In conclusion, this assignment was a great success and it is highly recommended that other faculty incorporate this approach. In our experience, it fostered a sense of ownership and responsibility that allowed the students to internalize their knowledge, and that ultimately changed the way they viewed their coursework, their role in society, and themselves.

## ACKNOWLEDGEMENTS

Support for instrumentation comes from NSF CCLI grant #0535943. We'd like to acknowledge the extraordinary efforts of Karrie Clark, donors to the exposition, and all of the students of the UDM ecology class (winter term 2007).

## REFERENCES

- DRAPER, A. 2004. Integrated Project-Based Service-Learning into an Advanced Environmental Chemistry Course. *J. Chem. Educ.* 81(2): 221-224.
- EYLER, J. AND D. GILES. 1999. *Where's the learning in service learning?* San Francisco, CA: Jossey-Bass. 315 p.
- JACKSON, L. 2011. "About Earth Day Network". Accessed from [www.earthday.org](http://www.earthday.org) on 21 July 2011.
- KOLB, A. AND D. KOLB. 2005. Learning styles and learning spaces: Enhancing Experiential Learning in Higher Education. *Acad. Manag. Learn. Edu.* 4(2): 193-212.
- LEWIS, J. 1990. The spirit of the first Earth Day. *EPA Journal*: January/February 1990.
- MARKUS, G., HOWARD, J., AND D. KING. 1993. Integrating community service and classroom instruction enhances learning: Results from an experiment. *Educ. Eval. Pol. Anal.* 15: 410-419.
- STRAGE, A. 2004. Long term academic benefits of service-learning: when and where do they manifest themselves? *Coll. Stud. J.* 38: 257.
- WENZEL, T. 2002. Community-based Projects in Analytical Chemistry Courses. *Anal. Chem.* 74(9), 279A-280A.

## Classroom Modified Split-Root Technique and Its Application in a Plant Habitat Selection Experiment at the College Level

Shannon S. Elliott<sup>1</sup> and Peggy A. Winter<sup>2</sup>

<sup>1</sup>Florida Department of Law Enforcement, Pensacola, FL 32501

<sup>1</sup>Pensacola State College, Pensacola, FL 32504

<sup>2</sup>University of West Florida, Pensacola, FL 32514

Email: [selliott@pensacolastate.edu](mailto:selliott@pensacolastate.edu)

**Abstract:** The split-root technique produces a plant with two equal root masses. Traditionally, the two root masses of the single plant are cultivated in adjacent pots with or without roots from competitors for the purpose of elucidating habitat preferences. We have tailored this technology for the classroom, adjusting protocols to match resources and time periods characteristic of undergraduate teaching laboratories. Our classroom modified split-root technique is presented here through detailed instructions as part of an eight-week college laboratory experience. Adapted from the literature on root competition, this exercise also enables students to determine how Sugar Ann English pea plants allocate their root masses when experiencing competition, and more specifically, the applicable habitat selection model. This novel laboratory experience offers hands-on activities for students to learn more about the structure and development of roots, root competition, the crucial role of roots in plant survival, and plant cultivation.

**Key Words:** Split-Root technique, root competition, habitat selection models, root development, plant ecology, plant physiology, Hotelling's  $T^2$  test

### INTRODUCTION

Studying how plants respond to their environment enables growers to increase production of specific organs. For example, if an agricultural crop such as the Kenyan bean is found to overproduce roots when experiencing competition, much energy will be transferred away from fruit production. To increase the fruit yield, the goal is to breed cultivars that do not over-proliferate their roots when experiencing competition. The study of root processes, including root competition, to maximize the production of a more valuable component of the plant, usually the fruit, is a central objective of agriculture and of interest to those studying plant ecology and physiology (Maina, Brown, & Gersani, 2002).

Roots function in anchorage, hormone production, water and mineral absorption, water and mineral conduction, and in water, mineral, and food storage; therefore, they are crucial to the survival of the plant. However, since roots are usually below the ground, out of view, the average observer often discounts them. Thus, experiments designed to elucidate root processes provide the student with concrete evidence of their essential role. In addition, when conducting such experiments, students experience scientific techniques and data evaluations used in research, plus an introduction to reviewing

current scientific literature. The split-root technique offers a unique opportunity to accomplish all of these goals.

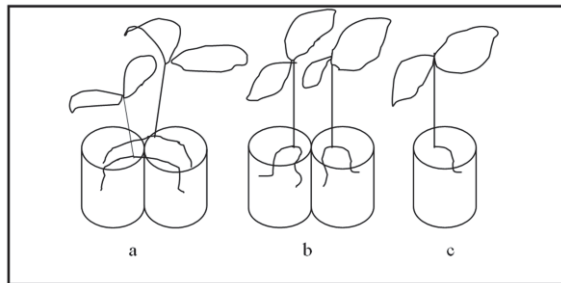
Although the split-root technique was developed over 100 years ago (Bohm, 1979), its recent resurrection provides a unique tool for investigating environmental effects on root development and root-shoot interactions. Germlings are manipulated during development to form two equal or twin root masses (Figure 1). For experimental purposes, a split-root plant is positioned on the fence with its root halves in separate pots to create a "fence-sitter," while another split-root plant has its twin roots in a single pot,



Fig. 1. A mature split-root pea plant.

called an “owner” (Maina et al., 2002, Figures 2a-b). The removal of half the root mass from a split-root plant forms a “single-root” plant, also useful in examining root-shoot responses (Figure 2c).

Originally, the split-root technique was employed to test nutrition effects on root growth



**Fig. 2.** Drawing of two fence-sitters (a), two owners (b), and a single-root plant (c).

(Bohm, 1979). For example, the control received water, while the experimental plants received water with dissolved nutrients usually formulated as Hoagland’s medium (Hoagland & Arnon, 1950). Depending on the species, generally the larger root mass was developed by plants experiencing a higher nutrient concentration. Beginning in the 1990’s, new experimental designs using split-root plants investigated topics such as impact of competitors, root discrimination, and root habitat selection models (Fallik, Reides, Gersani, & Novoplansky, 2003; Maina et al., 2002; Gersani, Brown, O’Brien, Maina, & Abramsky, 2001; Gersani, Abramsky, & Fallik, 1998; and Gersani & Sachs, 1992).

The split-root technique holds promise for meaningful, constructive learning experiences involving seed germination, plant development, nutrition, nutrient absorption, competition, plant culture, and habitat selection. However, the procedure for creating split-root plants in the literature is time-consuming and was not yet adapted for the classroom schedule. For example, the split-root technique involves carefully removing planted seeds and manipulating them several times in one week. The person or persons performing the literature-based split-root technique must have exceptional hand coordination and extra time during the initial week. A modified split-root technique using the Sugar Ann English pea (*Pisum sativum* var. Sugar Ann English) was developed for the classroom (Figure 3) and is presented here as part of an eight-week laboratory experience adapted from the literature (Maina et al., 2002) that focuses on determining the habitat selection model employed by the pea (Elliott, 2007). This exercise was designed, taught, and analyzed in Medicinal Botany and Plant Biotechnology Laboratory at the University of West Florida (UWF) as part of a Doctor of Education/ Biology Education Specialization degree.

## Habitat Selection

Plants cannot simply get up and move to a better location when resources are diminishing. Instead, a plant compensates by distributing energy to its organs in an appropriate way to sustain life (Gersani, et al., 1998). For example, if neighboring competition is fierce, a plant may partition its growth to certain areas such as increased root or shoot growth. The way in which plants assess and respond to their surroundings is called habitat selection. Three models explaining how plants distribute their roots are reported in the literature: (a) inter-plant avoidance response, (b) resource matching response, and (c) intra-plant avoidance response (Maina et al., 2002). Each of these models predicts how a plant should allocate root mass and energy under a variety of hazards and opportunities.

Inter-plant avoidance response presumes that plants prefer to proliferate roots in the absence of another plant (Maina et al., 2002). Plants employ different strategies to try to segregate their roots from the roots of other individuals. For instance, some plants produce a zone of depletion around their roots, which discourages other plants from foraging in this nutrient deficient environment. Other plants proliferate roots in order to physically hinder the invasion of other roots. In addition, some plants secrete allelopathic chemicals from their roots that inhibit root growth of other plants (D’Antonio & Mahall, 1991).

Resource matching response assumes that root proliferation matches the available nutrients within the soil (Maina et al., 2002). It is not the presence or absence of competitors near the plant that affects root growth, but the opportunity for nutrient uptake. If nutrients are highly accessible, then root production is substantial. If nutrients are limited, then growth is slow. Additionally, root mass produced prior to alterations in available nutrients is a factor. In general, the plant produces enough roots to take in as much nutrients as possible. Resource matching response is based upon the ideal free distribution principle that predicts that plants invest resources to equalize average returns.

Intra-plant avoidance response indicates that plants avoid proliferating roots among themselves (Maina et al., 2002). Under this approach, plants establish roots among neighbors to try to maximize whole-plant fitness. Plants seem to operate on the premise that it is better to ‘steal’ resources from a neighbor than from oneself. However, if plants overproduce roots in an attempt to take all the nutrients in the environment, they are engaging in a response called the “tragedy of the commons” (Gersani et al, 2001). Hence, the collective yield or, perhaps, the fruit of the plant is sacrificed because excessive energy goes into root production.

## MATERIAL AND METHODS

The habitat selection model employed by the pea can be determined through this eight-week classroom modified experiment. During the first three weeks, each student group creates split-root pea plants, then arranges them into fence-sitter and owner scenarios (Figures 2a-b). The roots of the plants in the fence-sitter scenario contact the roots of a neighbor, while the roots of each plant in the owner scenario isolate themselves. Each pot cavity contains the inert potting material, vermiculite, which does not have inherent nutrients. Each plant, whether in the fence-sitter or owner scenario, receives equal amounts of nutrients (0.5 strength Hoagland’s medium) applied twice a week.

For four weeks following the initial set-up, students take observational data on the above-ground portion of the plants. After the growth phase, each student group harvests the plants and places them into pre-dried and weighed crucibles. Since vermiculite is utilized, precautions, such as masks worn over the nose and mouth, must be taken to avoid breathing vermiculite dust. After the harvested plants have been in an oven (75 °C) for a week, students determine the individual weights of the root, shoot, and flowers/fruit of each scenario and utilize the data for statistical analysis employing the Hotelling’s  $T^2$  test. The null hypothesis of this experiment is that the fence-sitters and owners are not different in regards to the mass of the roots, shoots, and flowers/fruits. Conversely, the alternative hypothesis is that the fence-sitters and owners are different in at least one of the organ masses. Each student group compares the root production for the fence-sitter and owner scenarios to reveal the habitat selection model of peas (Table 1). The Sugar Ann English pea plant utilizes the resource matching habitat selection model as determined from the literature (Gersani et al., 1998) and from our developmental phase experiments and two classroom trials.

### Materials and Equipment Needed

**Week 1:** Seed for Sugar Ann English peas, Bleach, Paper towels (autoclaved), Containers (jars or beakers), Plastic wrap, Cold room (15 °C), Sterile distilled water

**Week 2:** Paper towels (autoclaved), Razor blades (autoclaved, if possible), Plastic wrap, Cold Room (15°C)

**Week 3:** Razor blades (autoclaved, if possible), Masks, Planting trays, Vermiculite, Skewers (bamboo), Velcro strips, 0.5 strength Hoagland’s medium, Light bank of broad spectrum fluorescent lamps

**Weeks 4-7:** String, Ruler, Velcro strips , 0.5 strength Hoagland’s medium, Light bank

**Week 7:** 48 oven-dried crucibles, Crucible tongs, Razor blades, Balance to 3rd decimal, Masks, Washing baths, Drying oven

**Week 8:** Crucible tongs, Balance with mg accuracy

### Laboratory Instructions

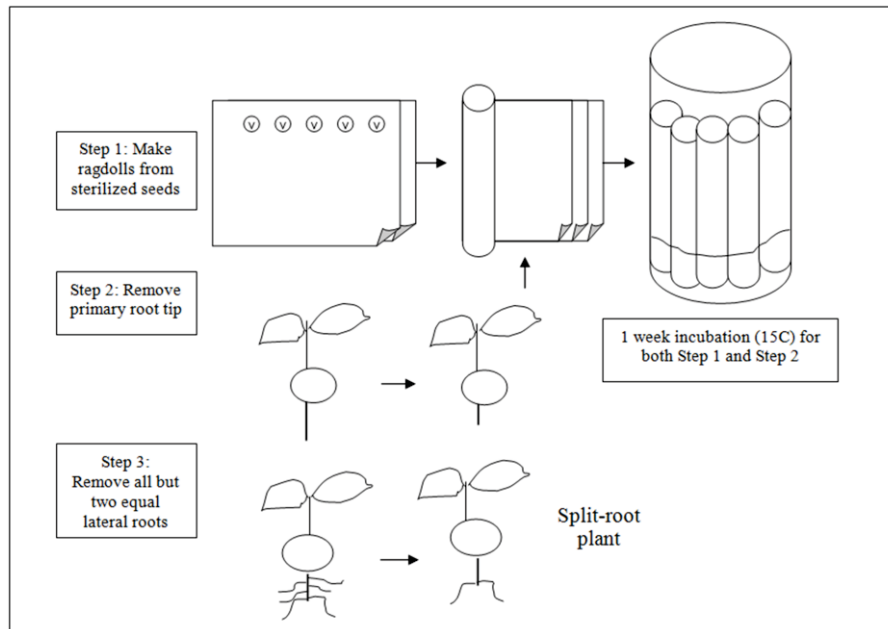
The following instructions are intended for students to perform in groups and with minimal before-class preparation by the instructor. To minimize student downtime during the first week, the instructor should surface sterilize the seeds by washing them in a bleach solution of 5-10% for 20 minutes and then rinsing 3 times for 5 minutes each with sterile distilled water. This can be performed prior to the start of class or during lecture introduction to habitat selection models.

#### *Week 1: Planting seeds in ragdolls*

1. Obtain 150 surface sterilized pea seeds.
2. For each ragdoll (Figure 3), layer 2 autoclaved paper towels and place them on a clean surface. Squirt sterile distilled water using a water bottle in a line 2/3 of the way from the bottom of the towels.
3. Starting 3 cm from the left side of the paper towels, equally space 5 seeds along the water line (Figure 3). Make sure that the radicles, which look a “V,” are pointing down. Add a third paper towel on top of the other two.
4. Roll the 3 paper towels horizontally beginning with the void space at the left.
5. Stand each tube-shaped ragdoll vertically with the peas near the top in a container, such as a 10 inch battery jar, that has 3-4 inches of sterile, distilled water.
6. Repeat steps 2-6 until all 150 seeds are in 30 ragdolls. Label the container(s) then cover with plastic wrap.

**Table 1.** Root production predicted for each plant habitat selection response.

Response	Root Production
Inter-plant avoidance	Fence-sitter < Owner
Resource matching	Fence-sitter = Owner
Intra-plant avoidance	Fence-sitter > Owner



**Fig. 3.** Ragdolls and modified split-root technique for the classroom. Ragdolls are prepared during week 1 (Step 1). Small, vertical ovals represent pea seeds (notice radicals pointing down) and rectangles are paper towels. The paper towels plus seeds are rolled to form a tube, subsequently placed vertically in a jar with distilled water. During week 2, about 0.5 cm of primary root tip are removed (Step 2) and germlings are incubated for another week in ragdolls. Split-root plants are formed in week 3 when all but 2 lateral roots are removed (Step 3).

7. Incubate the container(s) under a grow light in a cold room at 15 °C, which will provide the necessary cold hours for flower development.

*Week 2: Cutting the distal ends of the radicles*

1. Remove the ragdolls from the plastic wrapped container(s).
2. Lay a ragdoll flat on the lab bench, carefully unroll it, and remove the top paper towel. Observe that most peas have germinated.
3. If a pea seedling has a radicle over 2 cm, make a straight, horizontal cut with a razor blade to carefully remove the distal end of the root until only 1-1.5 cm remains. If a radicle is not present or too short, remove the pea from the ragdoll and discard.
4. Note: If the ragdoll or seed has any evidence of fungal or bacterial growth, discard the infected material properly.
5. Repeat steps 2-4 until all eligible seeds have their radicles cut.
6. Form new ragdolls following the same process as Week 1 but using the germinated pea plants with cut radicles instead of pea seeds. Stand the new ragdolls vertically in the container(s) with fresh, sterile distilled water.
7. Cover the container(s) with plastic wrap and return to the cold room outfitted with grow lights for another week.

*Week 3: Fashioning split-root plants*

1. Obtain the container with treated ragdolls.

2. Carefully unroll the ragdolls and remove the top paper towel.
3. Observe that lateral roots have formed along the entire length of the radicle.
4. Using a razor blade or your clean fingers, remove all lateral roots except two lateral roots that are approximately the same length. Do not cut the roots to make equal lengths.
5. Select split-root plants so roots are roughly the same size as the other split-root plants.
6. Repeat this process until 16 split-root plants are formed.
7. Obtain 8 small planting trays with potting cavities opposite each other such as annual flowering plants small potting trays. In a well-ventilated area, preferably outside and using a mask, fill 2 opposing cavities  $\frac{3}{4}$  full with vermiculite, an inert potting mix, in each tray. Wet the vermiculite with equal amounts of distilled water.
8. To each tray, add 2 bamboo skewers on the inside of the cavities (Figure 4).
9. For each fence-sitter scenario, stake a split-root pea to each skewer using thin Velcro strips, and then place one lateral root in each pot cavity (Figure 4). Gently add vermiculite to both cavities until full and re-wet the vermiculite to ensure roots are in a moist environment.
10. Repeat steps 8-9 to obtain four fence-sitter setups, and label as fence-sitter 1 a/b, fence-

sitter 2 a/b, fence-sitter 3 a/b, and fence-sitter 4 a/b.

11. Use the other 4 trays for owner scenarios and stake a split-root pea to each of the 2 skewers using thin Velcro strips. Place both lateral roots of each plant into only one cavity (Figure 4). Gently add vermiculite to both cavities, and re-wet the vermiculite to sufficiently moisten roots.
12. Repeat steps 9 and 11 to obtain 4 trays with owner setups, and label as owner 1 a/b, owner 2 a/b, owner 3 a/b, and owner 4 a/b.
13. Carefully transport the labeled fence-sitter and owner scenarios to a continuous grow-light apparatus consisting of 4, 30-Watt plant growth fluorescent bulbs elevated 0.5 m above the pot and exposed to room temperature, about 24 °C.
14. Twice per week, saturate the plants with approximately 40 ml of half strength Hoagland's medium per cavity. Once per week, saturate the plants with approximately 40 ml of distilled water to prevent accumulation of ions in the vermiculite.

*Weeks 4-7: Collecting observational data and harvesting*

1. For each plant, record the number of compound leaves, number of tendrils, and plant height during weeks 4-7. Stretch string between stem base and tip and then measure string length with a ruler for plant height.
2. Also, note if individual plants have developed flowers and/or fruit. If present, record the numbers of each reproductive structure, if present.
3. Document other observations such as wilting, chlorosis, or necrosis.
4. Calculate means for number of leaves, tendrils, height, flowers, and fruits of each scenario.

*Week 6:*

1. After taking measurements and making observations, number 48 crucibles while wearing gloves to avoid oils from hands affecting weight.
2. Using crucible tongs, place crucibles in a drying oven of 75 °C for one week.

*Week 7:*

1. After taking measurements and making observations, weigh and record the dry weight of 48 crucibles.
2. Harvest the root, shoot, and flower/fruit separately for each plant.
3. While wearing masks, add the roots plus vermiculite from each cavity to a wash bath to help remove the vermiculite. Gently shake the roots to remove the vermiculite and/or use forceps. Cut roots to fit within the assigned crucibles if necessary.
4. Since the roots are too intertwined in the fence-sitter scenario, harvest the roots from a single cavity instead of the roots for one plant and place in a single crucible. Place all roots from the neighboring pot in a second crucible.
5. Remove the reproductive structures (flower/fruit) from each plant for the flower/fruit determination. The shoot determination is the above-ground portion of the plant minus the flower/fruit.
6. Record the crucible number, plant number, and type of contents.
7. Return the crucibles, plus plant material, to the oven for another week so that differences in water content do not affect results for plant mass.

*Week 8: Determining dry weights*

1. Weigh and record the weight of each crucible plus plant dried material. Use crucible tongs and weigh immediately, so crucibles are exposed to the ambient air for



**Fig. 4.** Fence-sitter scenario where shoots from each plant are positioned on the pot rim and half the root mass occupies each pot (left picture). Owner scenario where each plant owns a single pot; thus, total root mass for each plant is isolated in a separate pot (right picture).

- the shortest possible time.
- To determine the sample weight, subtract the weight of the crucible taken the previous week from the weight of the crucible plus dried sample.
  - Record and organize the data and apply the Hotelling's  $T^2$  test. Report similarities and significant differences at  $\alpha=0.05$  level and draw conclusions based on the habitat selection model (Table 1).

## RESULTS AND DISCUSSION

During each week of growth, students calculate the means for above-ground parameters: number of leaves, number of tendrils, plant height, number of flowers, and number of fruits. The weekly means for each parameter are entered on a computer spreadsheet and graphed as a function of time (weeks) using Microsoft Excel® or a similar program. Students can compare averages of parameters between fence-sitters and owners. For example, students can determine if there is a difference in the flower/fruit production between scenarios. From our experience through teaching trials, the means for the above-ground parameters are similar between the fence-sitters and owners.

The root growth, while not visible during collection of above-ground data, is assessed as root mass along with shoot and flower/fruit masses at the end of the experiment. The root, shoot, and flower/fruit masses determined during the eighth week for each scenario are compared statistically through the Hotelling's  $T^2$  test (or MANOVA where  $n=2$ ), which is appropriate for comparing several means between two groups. Individual  $t$ -tests could be utilized for each individual mass such as root mass but statistical power is lost over multiple comparisons (3 individual tests, for root mass, shoot mass, and flower/fruit mass) instead of one comparison (incorporates all three using Hotelling's  $T^2$  test). Statistical analysis programs such as SPSS can be utilized and offer the instructor an opportunity to discuss terminology such as null and alternative hypotheses, alpha value,  $p$ -value, and sample size. The results from the literature and from classroom trials for peas showed no statistically significant difference between fence-sitters and owners (each group's  $p$ -value was above the alpha value set at 0.05); thus, the null hypothesis is **not** rejected, agreeing with the model for resource matching.

While students work in groups, individual student lab reports are necessary to ensure that each student understands the material and the results of the experiment. In addition, writing laboratory reports gives students practice with developing written skills in science. The instructor should present students with a clear outline of the sections or chapters within the report (e.g., Introduction, Materials and Methods, Results, Discussion, and References) and what is

required in each area. A rubric describing point allocations for grading reports is useful in further defining expectations.

## CONCLUSIONS

The split-root technique employed in the literature has been modified from an intensive week in the research laboratory to three-weekly meetings in the college teaching laboratory. In addition, the classroom modified technique meets important goals of novel laboratory exercises: reasonably inexpensive supply list, limited classroom equipment, short instructor before-class preparation, and numerous opportunities for additional experimental designs. Students can use the split-root technique to determine the habitat selection model of the pea (Weeks 3-8). These laboratory exercises require students to collect, record, and analyze above-ground parameters as well as perform statistical analysis using dry weights. Consequently, students actively participate in the scientific process including drawing conclusions based on data analysis and interpretation while improving laboratory skills.

The application of the modified split-root technique is not limited to determining the habitat selection model of the pea. Student groups can be challenged to develop their own experimental design to test any of the numerous aspects of root development, competition, or nutrition. In their arsenal, students have scenarios such as fence-sitters, owners, and single-root plants (only one lateral root) to use and other plants to investigate.

## ACKNOWLEDGEMENTS

We would like to thank the students at UWF who participated in this novel laboratory exercise as well as Dr. Theodore Fox for his input during development and implementation. We also wish to recognize UWF's Graduate Student Scholarly and Creative Activity Grant for financial support as well as Jeff Elliot for fabrication of light units.

## REFERENCES

- BOHM, W. 1979. *Methods of studying root systems*. New York: Springer-Verlag.
- D'ANTONIO, C. M., AND MAHALL, B. E. 1991. Root profiles and competition between the invasive, exotic perennial, *Carpobrotus edulis*, and two native shrub species in California coastal scrub. *American Journal of Botany*, 78, 885-894.
- ELLIOTT S. 2007. *The GIST Model for selection and modification of scientific research for the college teaching laboratory based on root competition investigations* (ERIC Document Reproduction Service No. ED503776).
- FALLIK, O., REIDES, P., GERSANI, M. AND NOVOPLANSKY, A. 2003. Self/non-self discrimination in roots. *Journal of Ecology*, 91, 525-531.
- GERSANI, M. AND SACHS, T. 1992. Development correlations between roots in heterogeneous environments. *Plant Cellular Environment*, 15, 463-469.
- GERSANI, M., ABRAMSKY, Z. AND FALLIK, O. 1998. Density-dependent habitat selection in plants. *Evolutionary Ecology*, 12, 223-234.
- GERSANI, M., BROWN, J. S., O'BRIEN, E., MAINA, G. G., AND ABRAMSKY, Z. 2001. Tragedy of the commons as a result of root competition. *Journal of Ecology*, 89, 661-669.
- HOAGLANK, D. R. AND ARNON, D. I. 1950. The water culture method for growing plants without soil. *California Agricultural Experiment Station Circular*, 374, 1-32.
- MAINA, G., BROWN, J., AND GERSANI, M. 2002. Intra-plant versus inter-plant root competition in beans: avoidance, resource matching, or tragedy of the commons. *Plant Ecology*, 160, 235-247.

## PERSPECTIVES

### Higher Education Faculty Versus High School Teacher: Does Pedagogical Preparation Make a Difference?

Jamie L. Jensen

Assistant Professor, Department of Biology, Brigham Young University, Provo, UT 84602

Email: [Jamie.Jensen@BYU.edu](mailto:Jamie.Jensen@BYU.edu)

**Abstract:** Higher education faculty are not held to the same standard of pedagogical preparation as primary and secondary teachers. This perspectives essay points out the difference in pedagogical preparations between higher education faculty and high school teachers. The essay highlights research indicating the importance of pedagogical training, offers suggestions on how to improve higher education teaching practices, and lists valuable teaching and assessment resources. Lastly, the essay encourages higher education faculty to seek pedagogical training and expend the necessary effort to become more effective instructors.

**Key Words:** Teacher preparation, teacher effectiveness, assessment, pedagogy, teaching strategies

#### INTRODUCTION

In the discipline of biology, students vary widely in the emphases they pursue. One of these emphases is in education with the end goal of being a high school biology teacher. Although total credit hours required to graduate in each degree program are generally consistent, at many universities, credit hours specified by a major in secondary education are substantially greater than for other majors in the department. This is because these students must not only learn the subject matter, but must spend an equal amount of time immersed in pedagogical training. Their peers, on the other hand, who choose to pursue a graduate degree with the intent to become a college teacher and researcher, rarely require pedagogical training. Is teaching in high schools versus institutes of higher education really so different? After personal observations and involvement in both high school and college teaching, my conclusion is that the challenges teachers face at either level are very much the same. The difference is in teacher preparation and accountability, and high school teachers, on average, have more of both. Does pedagogical training make a difference?

#### WHAT IS THE DIFFERENCE IN PEDAGOGICAL PREPARATION BETWEEN HIGH SCHOOL AND HIGHER EDUCATION?

The U.S. federal government has put in place stringent requirements to become certified as a primary or secondary teacher. According to the Interstate Teacher Assessment and Support Consortium (InTASC), a national organization that works with states to set state standards for K-12 teacher licensure, three standards must be met: an

understanding of the learner and the process of learning; an understanding of the content knowledge; and an understanding of appropriate and effective instructional practices (including how to plan lessons, strategies for implementation, and assessment of learning; InTASC, 2011). As a consequence, to become a high school teacher, minimum state standards require an average of 54 credit hours of subject-specific content (based on a comparison of secondary science education majors at 6 institutions across the country—see Table 1), approximately equivalent to any basic science major, with typically an additional 16 to 24 credit hours of pedagogical training, and 12 plus credit hours of student teaching, which translates to a minimum of ten weeks of full-time teaching in the classroom. This makes a secondary education major, on average, 33 credit hours more than a standard science degree (e.g., biology, physics, or chemistry), sometimes requiring a master's degree. The pedagogical training typically includes courses in child and adolescent development, multicultural and special needs education, cognitive psychology, behavioral theories, classroom management, the use of technology in the classroom, and curriculum design. Certainly some of these courses are necessary pre-requisites to teaching children. However, even those who will teach high school are required to learn about the development of the intellect. As higher education faculty, what qualifications are required? A masters and/or doctoral degree in the subject being taught (i.e., content knowledge) is all that is required at most undergraduate institutions. Although this statement may be over-generalized, and certainly most institutions of higher learning require a demonstration of teaching ability prior to hiring, it is

**Table 1.** Credit hour requirements for standard biology degrees and biology degrees with an emphasis in secondary education at six universities across the nation.

<b>Institution</b>	<b>Major</b>	<b>Approximate Major Credit Hours (content-specific hours for Biology Education Majors)</b>
<i>Arizona State University</i>	Biology	72
	Biology Education	96 (53)
<i>Baylor</i>	Biology	66
	Biology Education	90 (66)
<i>Brigham Young University</i>	Biology	65
	Biology Education	82 (53)
<i>Johns Hopkins University</i>	Biology	59
	Biology Education	98 (59; Requires an M.S.)
<i>Purdue University</i>	Biology	66
	Biology Education	84 (50)
<i>University of North Carolina</i>	Biology	56
	Biology Education	68 (43)
Average Biology Degree		53
Average Biology Education Degree		86 (54)

certainly not commonplace for pedagogical training or “on the job” teacher training to be a “mandatory” part of a graduate experience. You may ask, “So what? Does it make a difference?”

### **DOES THE RESEARCH SUPPORT THE IMPORTANCE OF PEDAGOGICAL TRAINING?**

Several peer-reviewed studies have produced evidence that pedagogical training leads to improved student outcomes. Postareff *et al.* (2008) showed that college professors who participated in at least one year of pedagogical training practiced more student-centered teaching and had a greater sense of self-efficacy than those who did not participate. Lawson *et al.* (2002) found that reformed teaching as a result of participation in the Arizona Collaborative for Excellence in Preparation of Teachers (ACEPT), a program focused on providing pedagogical training to college professors who teach major’s and nonmajor’s college courses, strongly correlated with improved student achievement on the course final exam. Pfund *et al.* (2009) found that participation in a pedagogical training program (the Summer Institute, sponsored by the National Academies) improved undergraduate teaching practices; participants reported, by survey, significant gains in their understanding of scientific teaching and their intention to implement such practices in their classroom. A follow-up survey revealed that 96% of alumni reported that they were continuing their efforts to improve their teaching. In addition, Martin and Lueckenhausen (2005) found that the more sophisticated one’s understanding of teaching and learning is, the more likely an individual is to adjust

their teaching strategies based on evidence of effectiveness. Perhaps this is because one is better able to assess effectiveness, if the process of learning is truly understood. Even at the primary and secondary level, the evidence shows that teachers who obtain a traditional teaching certificate lead to better student performance on standardized exams than those who do not (Fuller and Alexander, 2004; Greenwald *et al.*, 1996).

### **DO ADVANCED DEGREES AND YEARS OF EXPERIENCE MAKE FOR BETTER TEACHERS?**

The simple, evidence-based answer to this question is that, at least at the primary and secondary levels, advanced degrees in specific science/math content area make little impact on teaching quality. Research comparing secondary student performance on standardized exams and degrees obtained by their teachers shows that having a bachelor’s degree in the subject taught, at least in math and science, is a significant predictor of student performance on subject tests; however, graduate degrees had no additional effect (Darling-Hammond, 1999). Assessing the effect of advanced degrees on teaching in higher education is a much more difficult scientific endeavor. Since the attainment of an advanced degree is a pre-requisite to becoming a higher education faculty (at most institutions), an adequate control group is difficult to obtain. However, since the attainment of advanced degrees is often the only requirement to become a higher education faculty member, and since research shows that advanced degrees in a science content area have no effect on teaching quality at the primary and secondary level,

this minimal requirement may be of concern at the college/university level. Certainly more research is needed to assess the impact of advanced degrees by higher education faculty on student learning. Nonetheless, evidence is lacking that it has any positive impact.

Does experience alone make for a better teacher? Postareff *et al.* (2008) compared the amount of teacher experience (in years) of higher education faculty with approaches to learning (assessed using the Approaches to Teaching Inventory) and found no significant shifts from teacher-centered to student-centered teaching practices based on experience. What they also found was that one's sense of self-efficacy does significantly improve with experience. This should be a cause for concern: regardless of actual effectiveness (which most likely has gone unmeasured; see Table 2 for suggested ways to measure student learning), one's confidence and self-perceived success increase over time! And many faculty members have been doing this for a very long time, utterly convinced that a teacher-centered approach is effective, an approach that has been shown to be highly resistant to change (Gibbs and Coffey, 2004; Lindblom-Ylänne *et al.*, 2006).

#### IS THERE EVIDENCE TO SUGGEST THAT A LACK OF TRAINING IS REALLY A

#### PROBLEM?

That is a difficult question to address. According to the research listed previously, it would appear that, yes, without training, teachers have lower student achievement. However, assessing the effectiveness of a teacher has proven to be a complicated and problematic task. At the primary and secondary level, it has been attempted by evaluating the success of students on standardized tests of ability and achievement, determined by each state (e.g., The Utah Basic Skills Competency Test [UBSCT], the Arizona Instrument to Measure Standards [AIMS], or the Maryland High School Assessment [HAS]) or by national norm-referenced tests such as the Iowa Test of Basic Skills [ITED], the TerraNova, the SAT and ACT. Although fraught with controversy, and in no way perfect, at least an effort is being made to hold teachers accountable for teaching practices. Many norm-referenced exams exist for college-level assessment (e.g., the GRE subject tests, the Major Field Tests [by the Educational Testing Service]). However, their use to assess teaching quality is not commonplace and their ability to accurately assess student conceptual understanding is questionable.

Many higher education faculty, especially at Carnegie Research I Universities (e.g., Harvard,

**Table 2.** Instruments for assessing teaching practices and student outcomes. Constructs being measured by each instrument are listed along with the source where the instrument can be found.

Instrument	Construct Measured	Citation
<i>Instruments for teacher assessment</i>		
Approaches to Teaching Inventory	Teaching approach: conceptual change/student-focused approach versus information transmission/teacher-focused approach	Prosser and Trigwell, 1999
Reformed Teaching Observation Protocol (RTOP)	Teaching approach: degree to which teaching is reformed to meet the national science and mathematics standards	Piburn <i>et al.</i> , 2000.
The measure of self-efficacy beliefs	Sense of self-efficacy in teaching practices	Trigwell <i>et al.</i> , 2004
<i>Instruments for student learning assessment</i>		
Student Assessment of their Learning Gains (SALG)	Learning outcomes for a wide range of courses	Access at <a href="http://www.salgsite.org">http://www.salgsite.org</a>
Introductory Molecular and Cell Biology Assessment (IMCA)	Understanding of basic biological concepts	Shi <i>et al.</i> , 2010
Biology Concept Inventory (BCI)	Understanding of basic biological concepts	Klymkowsky and Garvin-Doxas, 2008
Biology Attitudes, Knowledge, and Skills Survey (BASK; currently 3 versions)	Basic biological conceptual understanding and scientific reasoning ability	Lawson (currently available at <a href="http://www.public.asu.edu">http://www.public.asu.edu</a> )
The Classroom Test of Scientific Reasoning (LCTSR)	Scientific reasoning ability based on Piagetian stage theory including concrete, formal, and post-formal levels	Lawson, 1978
Nature of Science Surveys (NOS & VNOS)	Understanding of the nature of scientific inquiry	Lederman <i>et al.</i> , 2002; Oehrtman and Lawson, 2007

\* Other valuable resources: Angelo and Cross, 1993; Huba and Freed, 1999

Princeton, Yale, Columbia, Stanford) are evaluated by research outcomes, prominently visible in the form of publications and grant dollars. Although most colleges and universities will confirm that faculty members are accountable for teaching quality as part of their qualifications for tenure, the evidence of such quality is most often assessed by student evaluations, a controversial, difficult to interpret, non-standardized instrument (Emery *et al.*, 2003; Mason *et al.*, 2002; Wright, 2006). A call for more direct assessment of student outcomes is warranted and would most likely be beneficial. Table 2 provides several sources that can be used by individual higher education faculty to directly assess the effectiveness of their teaching.

### **ARE HIGHER EDUCATION FACULTY IN CHARGE OF TEACHING FUTURE TEACHERS?**

Some higher education faculty are directly responsible for teaching content-specific pedagogy to secondary education pre-service teachers as part of the teacher preparation program. For those teachers, pedagogical training is an obvious necessity. But, do those faculty members, whose primary focus is on research in a biological discipline, have an impact on future teachers? Their responsibility is to teach biological content in a way that students will gain conceptual understanding. Most primary and secondary education programs have requirements for general science courses. Those students, who will be future teachers, will experience biology for the first time, but also observe how to *teach* it, from biology faculty. What kind of an example is being set? The ACEPT showed definitive evidence that pedagogical training led to reformed teaching practices that increased undergraduate student achievement (Lawson *et al.*, 2002). In addition, it led to improved achievement of the junior and senior high school students whose teachers were enrolled in an ACEPT reformed class as part of their pre-service training (Adamson *et al.*, 2003).

Consider the effect that college and university faculty have upon graduate students. A survey in 2006 indicated that in the United States, roughly a third of graduate students ended up in faculty positions (Cyranski *et al.*, 2011), many of them without inclusion of a pedagogy course during their training. Although the offering of a future faculty training program is being more widely offered at many universities [e.g., the Center for the Integration of Research, Teaching, and Learning (CIRTL), an NSF-sponsored training program, or Preparing Future Faculty (PFF) programs that exist in over 295 participating universities], it is rarely a requirement for obtaining an advanced degree. So, where do *they* learn how to teach? As a graduate advisor, your responsibility is two-fold: instruct graduate students on how to be a successful researcher, but also instruct

them on how to be an effective educator. As Adamson *et al.* (2003) affirmed, “Teachers teach as they have been taught” (p. 940).

In light of the evidence previously described and Kevin Carey’s recent article in *Democracy* (2010) describing the lack of accountability for teaching quality at America’s colleges, higher education faculty should re-evaluate their teaching methodologies, hold themselves accountable for student learning, and re-dedicate their efforts to improve the profession of teaching.

### **BE A PART OF THE SOLUTION**

If high school teachers spend half of their professional preparation learning how to teach, shouldn’t higher education faculty take some responsibility for their own professional teaching preparation? Many faculty are so overwhelmed by scholarly and citizenry duties that teaching becomes a diminished priority. Moreover, at many institutions of higher education, research productivity is weighted significantly more heavily than teaching performance in merit pay evaluations and tenure and rank advancement decisions. However evidence supports the importance of teaching quality for student learning and should motivate an increase in attention and effort to improving teaching practices. So, how does one know if their teaching methods are successful and if not, how do they improve? Outlined below are some suggestions and resources to take an active approach to improving education.

### **TAKE AN EVIDENCED-BASED APPROACH**

Since most scholars are driven by scientific research, taking an evidence-based approach to teaching strategies may in fact be relevant and motivating. Educational research is a thriving scientific field where innovations are being tested and implemented regularly. For many, it is a new and unexplored opportunity for research. Most colleges and universities have departments and faculty members dedicated to educational research. Take advantage of collaborations with these individuals. Educational research can be, and in most cases has become, just as objective, controlled, and scientific as other scientific research, e.g., systematics, ecology, developmental biology. This is especially so if those individuals trained and practiced in traditional biological sciences become active participants in the endeavor.

### **FIND OUT WHAT THE RESEARCH HAS ALREADY SHOWN**

There is a plethora of evidence already available showing the effectiveness or ineffectiveness of different teaching strategies. Table 3 outlines some of the most well studied strategies and lists resources that can guide you in their implementation.

Seek out studies that might be applicable to your specific classes (i.e., teaching evolution to non-science majors, teaching introductory biology for majors, teaching microbiology or population ecology, etc.). There are several on-line search engines for finding scholarly articles in educational research (e.g., The Educational Resources Information Center [ERIC], [www.eric.ed.gov](http://www.eric.ed.gov); Google Scholar, <http://scholar.google.com>; Education Full Text, by WilsonWeb, <http://vnweb.hwilsonweb.com>; The Gateway for Educational Materials [GEM], [www.thegateway.org](http://www.thegateway.org)). In addition, many professional organizations specialize in disseminating educational research materials (e.g., ACUBE, NSTA, SCST, NARST, AERA) and many traditional scientific organizations have an education emphasis (e.g., ASM, SSE, AAAS, ASCB). Consider joining one or more of these organizations and taking advantage of member benefits from published educational journals, professional development workshops, and professional meetings on education.

### SEEK PEDAGOGICAL TRAINING

Many professional development opportunities are available. Many professional societies in the life sciences now offer workshops on pedagogy and even present research on education (e.g., ASCB, ASMCUE, AAAS). In addition, many professional societies specialize in improving undergraduate education and hold annual conferences for this sole purpose (e.g., NABT, NSTA, AAC&U, ACUBE). In addition, a variety of training workshops are available such as the ABLE workshops ([www.ableweb.org](http://www.ableweb.org)), the HHMI/NAS Summer Institute ([www.academiessummerinstitute.org](http://www.academiessummerinstitute.org)), the

POD network conferences ([www.podnetwork.org](http://www.podnetwork.org)), and workshops sponsored by SCST ([www.scst.org/conferences](http://www.scst.org/conferences)).

Pedagogical training does not have to be extensive or even formal in its acquisition. Resources abound. The National Research Council has compiled a review of significant research findings and suggested ways to link the research findings to actual classroom practice in their report, *How People Learn: Brain, Mind, Experience, and School* (Bransford *et al.*, 2000). This is a valuable resource with which all educators should become acquainted. In addition, the NRC has called for an increased emphasis on inquiry instruction. How many have heard of “inquiry”? Probably most. But, how many can properly define it and appropriately implement it in the classroom? The NRC (2000) published *Inquiry and the National Science Education Standards* to serve as a guide for teachers. Other resources are listed in Table 3.

### TAKE ADVANTAGE OF AVAILABLE RESOURCES

There is no sense in trying to reinvent the wheel when so many curricular materials are tried and tested, developed and planned, and readily available. Following is just a short list of available resources for developing effective lesson plans: BEN BiosciEdNet Digital Library managed by AAAS, Scitable by Nature Publishing Group, BioEdOnline.org by Baylor College of Medicine, The Biology Project by the University of Arizona, BioInteractive by the Howard Hughes Medical Institute, and the World Lecture Hall managed by the University of Texas at Austin.

**Table 3.** Teaching strategies that have been tested in college science classrooms. Student outcomes affected by each strategy with accompanying citations for effectiveness data are listed. Resources to help in the implementation of each strategy are also listed.

Evidences of learning	Resource(s) for implementation
<i>Inquiry</i> —teaching science as science is practiced Increases conceptual understanding, reasoning skills, and attitudes toward science over traditional expository teaching (Haury, 1993; NRC, 2000)	<i>Inquiry and the National Science Education Standards</i> (NRC, 2000); <i>Science Teaching and Development of Thinking</i> (Lawson, 2002); <i>Teaching Science as Inquiry</i> (Bass <i>et al.</i> , 2008); <i>NSTA’s Handbook of College Science Teaching</i> (Mintzes and Leonard, 2006)
<i>Formative Assessment</i> —prompting students to evaluate their own learning Increases conceptual understanding (McDonald and Boud, 2003; Nelson <i>et al.</i> , 2009; Nicol and Macfarlane-Dick, 2006)	<i>A Practical Guide to Alternative Assessment</i> (Herman <i>et al.</i> , 1992)
<i>Collaborative Learning</i> —allowing students to work in groups Increases student achievement, positive attitudes toward STEM subjects, and persistence in STEM majors (Johnson <i>et al.</i> , 1998; McKeachie <i>et al.</i> , 1986)	<i>Cooperative Learning: Theory, Research, and Practice</i> (Slavin, 1990); <i>Active Learning: Cooperation in the College Classroom</i> (Johnson <i>et al.</i> , 1991)
<i>Active Learning</i> —involving students in doing and thinking Increases conceptual understanding and student engagement (Hake, 1998; Handelsman <i>et al.</i> , 2007; McClanahan and McClanahan, 2002)	<i>Scientific Teaching</i> (Handlesman <i>et al.</i> , 2007); <i>Active Learning: Creating Excitement in the Classroom</i> (Bonwell and Eison, 1991)

## DISCUSSION

This perspectives essay is not meant to be discouraging or to paint a grim picture of the paucity of teaching excellence at undergraduate and graduate institutions. Many are outstanding teachers who have inspired and successfully educated hundreds and even thousands of students. For some, this essay may simply serve as a compliment to your already ongoing efforts to improve your teaching and as a welcome list of potential resources. For others, it may serve as an awakening and a realization that your advanced degrees and years of experience do not definitively qualify you as excellent educators. It takes dedication, self-reflection, and amenability to be great educators, and to adequately serve the students we have been appointed to teach. Fortunately, the road to improvement can be relatively easy, intellectually stimulating, and immensely rewarding. Resources abound, research is flourishing, and success is attainable. All it requires is dedicated effort, accompanied by appropriate training and support; and when teachers successfully instill in their students the same passion for learning and discovery that led them to their profession, the effort will be worth it.

## ACKNOWLEDGEMENTS

I thank Mrs. Jamie Wilson, a high school biology teacher at Gilbert High School, for being a true example of what a high school teacher should be and inspiring much of this perspective. I also thank Dr. Anton Lawson, an amazing educator at Arizona State University, for teaching me how to teach.

## REFERENCES

- ADAMSON, S.L., BANKS, D., BURTCH, M., COX, F., JUDSON, E., *et al.* 2003. Reformed undergraduate instruction and its subsequent impact on secondary school teaching practice and student achievement. *J. Res. Sci. Teach.* 40: 939-957.
- ANGELO, T.A., AND CROSS, K.P. 1993. *Classroom assessment techniques: A handbook for college teachers* (2<sup>nd</sup> ed.) Jossey-Bass, San Francisco. 427p.
- BASS, J., CARIN, A.A., AND CONTANT, T.L. 2008. *Teaching Science as Inquiry*. Merrill Prentice Hall, Upper Saddle River, NJ. 600p.
- BONWELL, C.C., AND EISON, J.A. 1991. *Active learning: Creating excitement in the classroom: ASHE-ERIC Higher Education Report No. 1*. George Washington University, Washington, D.C.
- BRANSFORD, J.D., BROWN, A.L., AND COCKING, R.R. (EDS.) 2000. *How People Learn: Brain, Mind, Experience, and School*. National Academy Press, Washington, D.C. 374p.
- CAREY, K. 2010. That old college lie. *Democracy* 15: 8-20.
- CYRANOSKI, D., GILBERT, N., LEDFORD, H., NAYAR, A., AND YAHIA, M. 2011. The PhD factory: The world is producing more PhDs than ever before. Is it time to stop? *Nature* 472: 276-279.
- DARLING-HAMMOND, L. 1999. *Teacher quality and student achievement: A review of state policy evidence*. Center for the Study of Teaching and Policy, Seattle. 44p.
- EMERY, C.R., KRAMER, T.R., AND TIAN, R.G. 2003. Return to academic standards: A critique of student evaluations of teaching effectiveness. *Qual. Assur. Educ.* 11: 37 - 46.
- FULLER, E.J., AND ALEXANDER, C. 2004. Does teacher certification matter? High school teacher certification status and student achievement. Paper read at the national meeting of the American Education Research Association, at San Diego, CA.
- GIBBS, G., AND COFFEY, M. 2004. The impact of training of university teachers on their teaching skills, their approach to teaching and the approach to learning in their students. *Act. Learn. High. Educ.* 5: 87-100.
- GREENWALD, R., HEDGES, L.V., AND LAINE, R.D. 1996. The effect of school resources on student achievement. *Rev. Educ. Res.* 66: 361-396.
- HAKE, R.R. 1997. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *Am. J. Phys.* 66:64-74.
- HANDELSMAN, J., MILLER, S., AND PFUND, C. 2007. *Scientific Teaching*. W. H. Freeman and Company, New York. 184p.
- HAURY, D.L. 1993. Teaching science through inquiry. *ERIC CSMEE Digest* (March Ed 359 048).
- HERMAN, J.L., ASHBACHER, P.R., AND WINTERS, L. 1992. *A practical guide to alternative assessment*. Association for Supervision and Curriculum Development, Alexandria, VA. 143p.
- HUBA, M.E., AND FREED, J.E. 1999. *Learner-centered assessment on college campuses: Shifting the focus from teaching to learning*. Allyn and Bacon, New York. 286p.
- INTASC. 2011. Model core teaching standards: A resource for state dialogue. Accessed from [http://www.ccsso.org/Documents/2011/InTASC\\_Model\\_Core\\_Teaching\\_Standards\\_2011.pdf](http://www.ccsso.org/Documents/2011/InTASC_Model_Core_Teaching_Standards_2011.pdf) on 7 July 2011.
- JOHNSON, D.W., JOHNSON, R.T., AND SMITH, K.A. 1991. *Active learning: Cooperation in the college classroom*. Interaction Book Company, Edina, MN. 140p.

- JOHNSON, D.W., JOHNSON, R.T., AND SMITH, K.A. 1998. Cooperative learning returns to college: What evidence is there that it works? *Change*. 4: 27-35.
- KLYMKOWSKY, M.W., AND GARVIN-DOXAS, K. 2008. Recognizing student misconceptions through Ed's tools and the Biology Concept Inventory. *PLoS Biol.* 6: 14-17.
- LAWSON, A.E. 1978. The development and validation of a classroom test of formal reasoning. *J. Res. Sci. Teach.* 15: 11-24.
- LAWSON, A.E. 2002. *Science teaching and development of thinking*. Wadsworth/Thomson Learning, Belmont, CA. 593p.
- LAWSON, A.E., BENFORD, R., BLOOM, I., CARLSON, M.P., FALCONER, K., *et al.* 2002. Evaluating college science and mathematics instruction. *J. Coll. Sci. Teach.* 36: 388-393.
- LEDERMAN, N.G., ABD-EL-KHALICK, F.S., BELL, R.L., AND SCHWARTZ, R.S. 2002. Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of the nature of science. *J. Res. Sci. Teach.* 39: 497-521.
- LINDBLOM-YLÄNNE, S., TRIGWELL, K., NEVGI, A., AND ASHWIN, P. 2006. How approaches to teaching are affected by discipline and teaching context. *Stud. High. Educ.* 31: 285-298.
- MARTIN, E., AND LUECKENHAUSEN, G. 2005. How university teaching changes teachers: Affective as well as cognitive challenges. *High. Educ.* 49: 389-412.
- MASON, K.H., EDWARDS, R.R., AND ROACH, D.W. 2002. Student evaluation of instructors: A measure of teaching effectiveness or of something else? *J. Bus. Adm.* 1: 2.
- MCCLANAHAN, E.B., AND MCCLANAHAN, L.L. 2002. Active learning in a non-majors biology class. *Coll. Teach.* 5: 92-96.
- MCDONALD, B., AND BOUD, D. 2003. The impact of self-assessment on achievement: The effects of self-assessment training on performance in external examinations. *Assess. Educ. Princ. Policy Pract.* 10: 209-220.
- MCKEACHIE, W.J., PINTRICH, P.R., LIN, Y.-G., AND SMITH, D.A.F. 1986. *Teaching and learning in the college classroom: A review of the research literature*. National Center for Research to Improve Postsecondary Teaching and Learning, University of Michigan, Ann Arbor. 124p.
- MINTZES, J.J., AND LEONARD, W.H. 2006. *Handbook of college science teaching*. National Science Teachers Association, Danvers, MA. 416p.
- NATIONAL RESEARCH COUNCIL. 2000. *Inquiry and the National Science Education Standards: A guide for teaching and learning*. National Academy Press, Washington, D.C. 202p.
- NELSON, J., ROBISON, D.F., BELL, J.D., AND BRADSHAW, W.S. 2009. Cloning the professor, an alternative to ineffective teaching in a large course. *CBE Life Sci. Educ.* 8: 252-263.
- NICOL, D.J., AND MACFARLANE-DICK, D. 2006. Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Stud. High. Educ.* 31: 199-218.
- OEHRMAN, M., AND LAWSON, A.E. 2007. Connecting science and mathematics: The nature of proof and disproof in science and mathematics. *Int. J. Sci. Math. Educ.* 6: 377-403.
- PFUND, C., MILLER, S., BRENNER, K., BRUNS, P., CHANGE, A., *et al.* 2009. Professional development: Summer institute to improve university science teaching. *Science*. 324: 470-471.
- PIBURN, M., SAWADA, D., TURLEY, J., FALCONER, K., BENFORD, R., *et al.* 2000. *Reformed teaching observation protocol (RTOP): Reference manual (ACEPT Technical Report No. IN00-3)*. Arizona Collaborative for Excellence in the Preparation of Teachers, Tempe, AZ.
- POSTAREFF, L., LINDBLOM-YLÄNNE, S., AND NEVGI, A. 2008. A follow-up study of the effect of pedagogical training on teaching in higher education. *High. Educ.* 56: 29-43.
- PROSSER, M., AND TRIGWELL, K. 1999. *Understanding learning and teaching. The experience in higher education*. Society for Research into Higher Education & Open University Press, Suffolk. 209p.
- SHI, J., WOOD, W.B., MARTIN, J.M., GUILD, N.A., VICENS, Q., *et al.* 2010. A diagnostic assessment for introductory molecular and cell biology. *CBE Life Sci. Educ.* 9: 453-461.
- SLAVIN, R.E. 1990. *Cooperative learning—Theory, research and practice*. Prentice-Hall, Englewood Cliffs, NJ. 194p.
- TRIGWELL, K., ASHWIN, P., LINDBLOM-YLÄNNE, S., AND NEVGI, A. 2004. Variation in approaches to university teaching: The role of regulation and motivation. Paper presented at the EARLI SIG Higher Education Conference, at the Baltic Sea.
- WRIGHT, R.E. 2006. Student evaluations of faculty: Concerns raised in the literature, and possible solutions. *Coll. Stud. J.* 40: 417-422.

## EDITORIAL

### **Beware the Service Creep, My Colleagues! The Jaws That Bite, the Claws That Catch!**

*"Service Creep"! The amount of service required for DSI, promotion, and tenure and the number of service requests faculty are receiving is on the rise and there seems to be no end in sight. "Service Creep" is stealing hours from faculty that they might use to develop/maintain a strong program of scholarship. This is the issue no one seems to be discussing regarding faculty workload, and it is one that needs to be addressed!"*

(Balzano, 2010)

These are difficult times for institutions of higher education, especially from the faculty perspective. As the number of unskilled and semi-skilled jobs in the United States declines, we are being asked to graduate higher numbers of students at a more accelerated pace. We are being asked to do so in the face of declines in the number of high school graduates as well as declines in the proficiency of students who gain admittance to higher education institutions. This situation is compounded by the current financial condition of the nation and by the drastic rise in the number of for-profit institutions, which have put tremendous financial pressure on universities, administrators and, ultimately, faculty members to admit and graduate more students. These factors are likely to increase faculty workload as both the number of classes and number of students per class taught by instructors increase in an attempt to generate more revenue.

There is, however, another less visible yet more insidious factor which is very quickly pushing up faculty workloads – service. In most colleges and universities, four types of service are typically recognized: service to the profession/discipline, service to the university or college, service to the department, and service to the community. Each of these is a valid component of service expectations for faculty members in higher education. However, administrations have recently been taking advantage of service by faculty by expanding their “service” roles significantly. True faculty service should involve using a faculty member’s expertise to somehow accomplish and/or enhance the core mission of the institution. Rather, what I have witnessed (and what I have learned from colleagues at other institutions) over the last few years is the expansion of “service” roles of faculty to include what are more accurately termed “administrative” tasks not related to faculty expertise nor to the core academic mission of the institution. These tasks include, but are not limited to:

1. Increasing numbers of tasks and committee memberships that address compliance issues, such as “assurance of learning,” strategic planning, and sundry other *ad hoc* task forces.
2. Recruiting and mentoring part-time faculty to teach classes that cannot be covered by existing full-time faculty.<sup>1</sup>
3. Performing tasks for marketing and admissions departments in order to increase enrollments.
4. Performing numerous tasks related to “student life” (helping students move into their dorms, participating in student festivals) in order to increase student satisfaction.
5. Fundraising.

These are, of course, heaped on top of normal institutional and/or departmental service tasks such as academic committee work, search and screen committees, promotion and tenure committees, and faculty council attendance. There is nothing wrong with faculty helping out with campus issues such as the ones listed above if they have both the time and interest to participate. The problem lies in the fact that many of these extra service loads are mandatory and the others, while not strictly mandatory, are necessary in order to be perceived as a good campus citizen by the administration. Ironically, the number of these extra non-academic tasks is increasing at the same time that the ratio of non-academic to academic full-time employees is skyrocketing (Greene *et al.*, 2010); one would presume that these employees should be performing the non-academic tasks being assigned to faculty.

One of the reasons that service by faculty is on the rise is that service load is extremely hard to quantitate when trying to construct a workload model for faculty. Excellent service is also very hard to document. Teaching has tangible benchmarks that

---

<sup>1</sup> This is another serious work and quality issue itself which may be discussed at a later date.

can be used to establish impact – student and peer evaluations, student success and other outcome data. Research also generates tangible “products” such as presentations, publications, and funding which are commonly used as benchmarks for impact. Identifying benchmarks that demonstrate the impact of one’s service to the profession or the institution is very difficult. Perhaps this is why so few faculty members are promoted and/or tenured on the basis of service.

Regardless, we must not allow this trend of administrative, non-academic service creep to continue. It is becoming a tremendous time burden on faculty and, by interfering with their teaching, scholarship and true service, undermines the core mission of their college or university.

With my warm regards for the holidays,  
James W. Clack  
Editor-in-Chief, *Bioscene*

## ACKNOWLEDGEMENTS

I would like to thank Janice Bonner and Debra Meuler for helpful comments and discussion.

## REFERENCES

- BALZANO, B.A. 2010. *Academic Affairs Task Force on Faculty Workload Final Report* [Online]. Brockport: Brockport College, SUNY. Accessed from:  
<http://www.brockport.edu/acadaff/workload/WorkloadTaskForceFinalReport.pdf> on 25 Nov 2011.
- GREENE, J.P., KISIDA, B., AND MILLS, J. 2010. *Administrative Bloat at American Universities: The Real Reason for High Costs in Higher Education* [Online]. Goldwater Institute. Accessed from:  
<http://goldwaterinstitute.org/sites/default/files/Administrative%20Bloat.pdf> on 25 Nov 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 JPEG. 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.