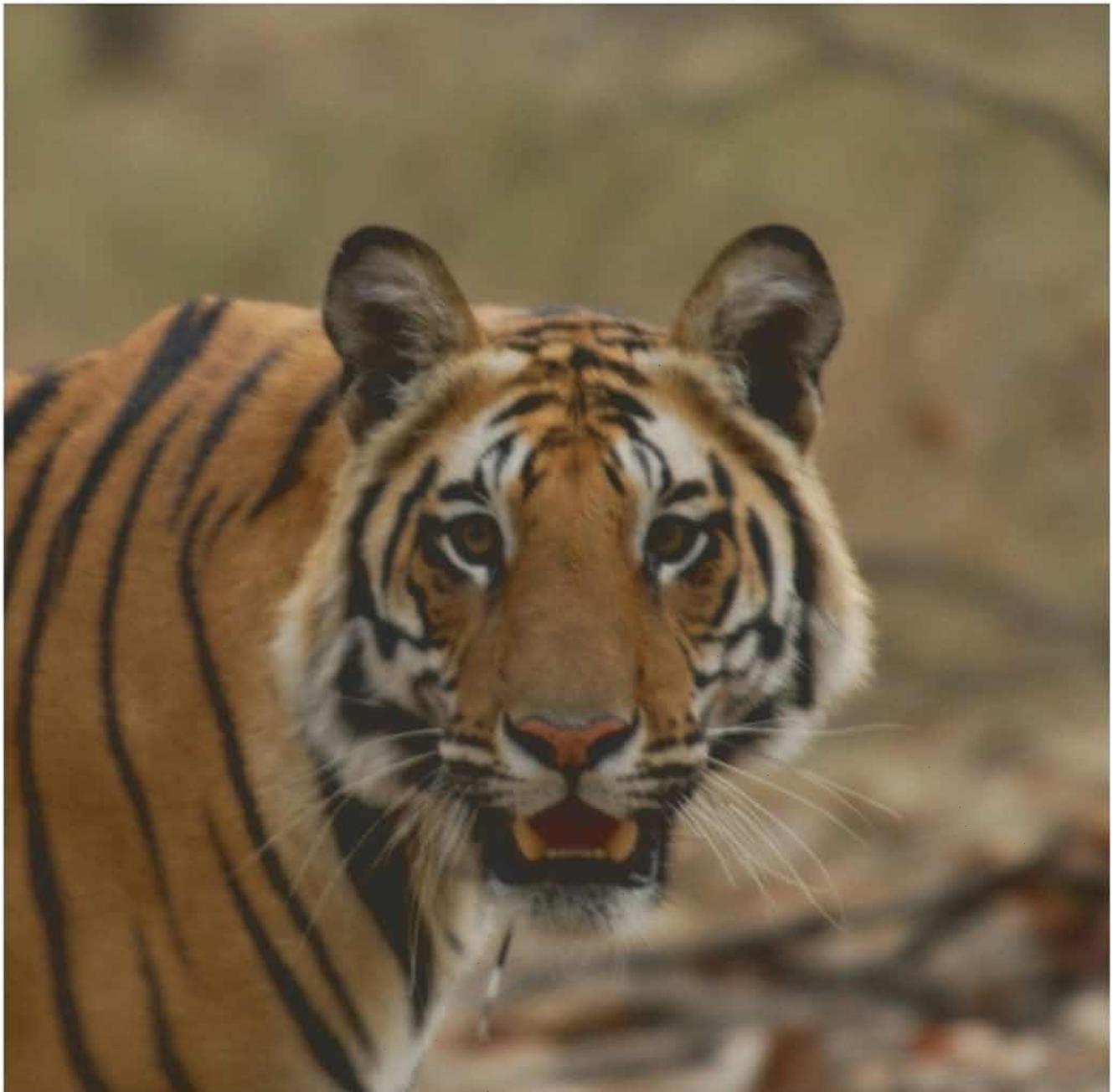


Bioscene

Journal of College Biology Teaching



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Stephen S. Daggett
Avila University

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Bioscene is normally published in March, May, August and December. Please submit manuscripts by July 1, 2007 for consideration in the next issue.



Cover image: Photograph of a tiger at a wildlife preserve in India courtesy of Charles Wyttenbach. Close inspection of the tiger's jaw reveals an embedded porcupine quill.

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Bioscene: Journal of College Biology Teaching

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Bioscene: Journal of College Biology Teaching
Guidelines for Submissions

I. Submissions to *Bioscene*

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

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

II. Preparation of Articles

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

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

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

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

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

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

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

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

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

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

or

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

E. References: References cited within the text should be included alphabetically by the author's last name at the end of the manuscript text with an appropriate subheading. All listed references must be cited in the text and come

from published materials in the literature or the Internet. The following examples indicate *Bioscene's* style format for articles, books, book chapters, and web sites:

Articles-

Single author:

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

Multi-authored:

GREEN, H., GOLDBERG, B., SHWARTZ, M., AND D. BROWN. 1968. The synthesis of collagen during the development of *Xenopus laevis*. *Dev. Biol.* 18: 391-400.

Books-

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

Book chapters-

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

Web sites-

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

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

F. Tables

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

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

G. Figures

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

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

III. Letters to the Editor

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

IV. Other Submissions

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

V. Manuscript Submissions

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

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

VI. Editorial Review and Acceptance

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

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

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

VII. Editorial Policy and Copyright

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

Call for Nominations for *Bioscene* Editorial Board

Call for Cover Art and Letters to the Editor for *Bioscene*

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

Temperature Relationships in Eastern Skunk Cabbage

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Abstract: A laboratory exercise is presented in which students determine where metabolic heat is primarily generated in blooming eastern skunk cabbage (*Symplocarpus foetidus*) plants. Students consider how color, shape, and orientation of spathes, and stage of flower maturation, may affect metabolic heat production and retention of both metabolic and solar heat, and determine whether the production of heat and odor are correlated. They discuss their results in terms of both physiological mechanisms and adaptive functions of heat production.

Keywords: Ecology, skunk cabbage, thermogenesis, pollination, biology majors, biology non-majors

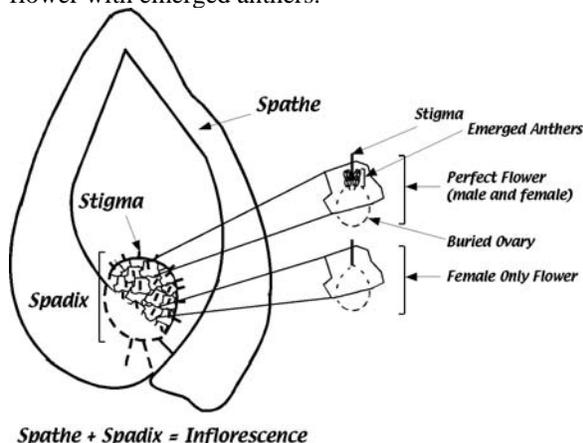
Introduction

The eastern skunk cabbage *Symplocarpus foetidus* is a common perennial plant that lives in wet deciduous forests of eastern North America. Its distribution ranges from southern Canada to the uplands of Tennessee and Georgia and from western Nova Scotia to southeastern Manitoba (Fernald, 1950 in Small, 1959). It is the first flower to bloom in the spring, emerging from the ground in February and March, when air temperatures vary from -15°C to $+15^{\circ}\text{C}$ (Knutson, 1974, Molles, 2005). Skunk cabbage flowers do not have the appearance of a typical flower. The outer covering of the inflorescence consists of a thick, pigmented bract (called a spathe) with an opening on one side. The interior of the inflorescence has a bulbous fleshy spike called a spadix, crowded with minute petal-less flowers (Mauseth, 2003; FIG 1). Flowers of the skunk cabbage are perfect, having both male and female reproductive parts. In many flowering plants there is a time separation of gender expression, known as dichogamy, that functions to prevent self-fertilization (Richards, 1994). Protogyny is when female function precedes male, and when male function precedes female it is known as protandry (Bertin, 1993). In eastern skunk cabbage, flowers are protogynous, with the female reproductive parts (pistils) becoming sexually mature before the male parts (stamens) (Knutson, 1974; Camazine and Niklas, 1984).

Living organisms, including both plants and animals, produce heat as a product of cellular respiration, but few plants respire enough or are large enough to be measurably warmer than their surroundings (Knutson 1979). Members of the plant family Araceae, including skunk cabbage, have evolved the ability to metabolically generate considerable quantities of heat. Skunk cabbages can raise the temperature of their flowers to 22°C , even when the surrounding temperatures are much lower than that (Knutson 1979). Temperature elevation in

skunk cabbage lasts for approximately two weeks (Molles, 2005), corresponding to the maturation of eggs and pollen in the spadix (Knutson, 1979). If the spathe is covered by snow during this period, it can melt right through the snow (Knutson, 1979). The skunk cabbage has an underground stem that stores large quantities of starch. During heat production, starch is translocated to the flower where it is metabolized at a high rate, generating the heat (Knutson, 1974).

FIG 1. Drawing of the spathe and inflorescence of *Symplocarpus foetidus* showing floral parts. Larger drawing shows the spadix during the female-only stage, with stigmas and portions of the styles showing. Smaller drawing shows a single perfect flower with emerged anthers.



Drawing by Barbara Nicholson

This heat, besides keeping the flower from freezing (Knutson, 1972; 1974), is thought to attract, shelter, delay, and reward pollinators (Moodie, 1976, Seymour *et al.*, 2003). It is also believed that the heat

assists in the diffusion of carbon dioxide and the skunky odors produced by the plant (Uemura *et al.*,1993). Various pollinators are attracted to both the heat and the odor, and maybe also to the CO₂ given off by the flower. Heat production in *Symplocarpus foetidus* is thought to assist pollination by accelerating the maturation of eggs and pollen in the spadix, by melting any overlying snow cover to expose the spathe, and by attracting a variety of pollinators through the emission of heat, odor and/or CO₂. Since heat production is critical to the reproductive success of skunk cabbage, we designed a lab activity that allows students to investigate some thermogenic relationships that might be found.

Materials and Methods

Skunk cabbage usually grows in moist soils or wetlands, even in small patches of such habitat, so it may be easy to find relatively close to your school. These areas can provide outdoor educational opportunities for students but are usually not considered because of their wet nature. Getting students to enter into these wetlands may pose problems depending on the wetness of the soil. The instructor should choose sites in advance: they must be dry enough to support the weight of an adult walking around the area. All rare and/or endangered plants should be noted and protected during the activity. Students and teachers will need waterproof boots that are mid-calf to knee-high. We have purchased a classroom set of boots covering a range of sizes for students to use during this lab. Boots are sanitized with an antiseptic spray between uses.

Heat production by *Symplocarpus* begins before the spathe opens (personal observation). Initially, all of the flowers on a spadix are female, with only the stigmas and a portion of the styles exposed above the spadix surface (FIG 1). Heat production is most intense during this stage and declines as the stamens erupt and pollen begins to be produced (Knutson,1979). Stamen eruption and pollen release occur from the top of the spadix to the bottom (Camazine and Niklas,1984). In order to capture the most intense heat production by the spadix, timing of this lab is critical. We monitor our central Connecticut skunk cabbage populations on a weekly basis beginning on February 1 to ensure that the lab is conducted during the hottest period. In Connecticut, the period of maximum heat production usually occurs during the third or fourth week in March. Knutson (1972) also reports that heat production peaks during mid to late March in northeast Iowa. When the anthers dehisce, they produce large quantities of pollen, making them easy to identify. With careful observation, the progression from female-only to perfect (male and female) flowers can be documented, and recording this

information is useful as it provides information about the stage of spadix maturity. Not all plants in a patch mature at the same time. Although the spadix is clearly visible in FIG. 1, this is not always so, particularly with younger spadices (whose spathes have smaller openings). A simple test to determine which stage the flowers are in is to insert a finger or small paint brush into the spathe opening and brush it across the top of the spadix: if anthers have dehisced, pollen will adhere to the brush or your finger.

Thermodynamics that might be involved

Heat production is energetically expensive for skunk cabbages. Knutson (1974) estimated that the rate of heat production relative to body size in these plants was equivalent to that of a small mammal. Given the large heating cost that these plants experience, it was anticipated that skunk cabbage might have evolved adaptive mechanisms to reduce heat loss, or to acquire additional heat from solar radiation. The spathe itself is very insulative. It is thick and fleshy with large air spaces within its tissues that remind one of Styrofoam. The spathe color and opening orientation may also affect the efficiency of heat gain and loss. We were interested in discovering whether south-facing spathe openings captured more solar radiation than north-facing ones, and whether dark-colored spathes absorbed more solar radiation than light-colored ones. Variation is also present in the width of the spathe opening, and this has implications for heat retention in the spathe. Reportedly the spathe color changes as the flowers mature. Early spathes are yellow-green or yellow in color with few dark mottles, while older spathes acquire darker colors or more dark mottles (Kevan,1989).

Only spathes that are fresh looking, without any obvious tears or other damage, should be measured. A certain percentage of the spadices in a population are "metabolic duds" (personal observation). These bear female flowers in a state of deterioration or abortion, and they will not progress to the perfect stage. They are identifiable by having a flaccid, not turgid, spadix, and by not producing any heat. Students should be informed of the presence of such spadices and instructed not to measure them.

This exercise can be tailored to middle school, high school or college-level students depending on the complexity and length of the investigation that the instructor desires. The laboratory outline presented here was prepared for a course in ecology and evolution for second-year college biology majors.

The Laboratory Exercise

Materials for each group of 3-5 students:

- Clipboard
- Data sheet

- Thermocouple
- Compass
- Ruler
- Small paintbrush or Q-tip cotton swabs
- Dice or random number table (transect method)
- Rope or tape to mark transect lines (transect method)

The type of instrument needed to measure temperature will depend upon the research questions being addressed. For accurate measurements of very small surfaces a thermocouple is the best choice. A thermometer will suffice if you are interested in conducting this lab in a simpler but less precise fashion.

We conducted this lab over a period of two weeks. During the first week students collected data, which were then handed in to the instructor. During the second week students received a pooled data set compiled and summarized by the instructor, and spent their time in the computer lab creating graphs and conducting data analyses.

Groups of students were instructed to work far enough apart that each group measured different plants. Students were instructed to select 10 inflorescences to measure, and six types of measurements were taken at each inflorescence. Students were asked to consider how they choose which inflorescences to measure, to avoid sampling bias. One possibility is for them to measure the first 10 inflorescences they encounter that are easy to reach, undamaged, and are producing heat. Usually the students completed their field measurements in approximately an hour. In larger patches, transect sampling is appropriate and would serve to spread out students and provide a method to randomize samples. Transect lines could be randomized along a baseline using dice or a random number table.

Observations and Measurements

1) Relative strength of the smell emanating from the spathe from a distance of 15 cm (6 inches) from the opening of the spathe. We used the following scale: 0 = no smell is detected, 1 = a slight smell, 2 = moderate smell, 3 = gross, a strong smell.

Individuals vary in the sense of smell, so one student in the group should be designated as the "smeller" and conduct all of these observations, being careful to smell each plant from a consistent 15 cm distance in front of the spathe opening.

2) Temperature

- a. Air surrounding the spathe, one hand spread distance out from the spathe
- b. Ground surface next to the spathe, 3 cm away from the base of the spathe
- c. Leaf surface temperature (if a leaf is present): will require a thermocouple
- d. Outside wall of floral spathe: will require a thermocouple
- e. Spadix surface in the region of the most open flowers

3) Compass direction (NW, N, NE, E, SE, S, SW, W) that the spathe opening was facing. Students could instead measure the direction of the spathe opening relative to the sun azimuth, where 0° indicates that the center of the spathe opening is in the direction of the sun azimuth.

4) Diameter of the opening of the spathe at its widest point.

5) Sex of the flowers on the spadix. If the spathe opening is large enough for this to be seen, determine whether anthers are present and if so, how far down the spadix they can be found. If this can't be seen, insert a finger, paintbrush, or Q-tip cotton swab to test for the presence of pollen. As it is possible to observe the progression from female-only flowers to perfect flowers, each spadix may have only female flowers, only perfect flowers, or both. If students are conducting a detailed study involving different stages of spadix maturation, they may want to consider dissecting the spathe after the remaining measurements are taken.

6) Color of the spathe using the following categories: a) yellow/green (Y), b) predominantly yellow/green with some purple/red mottles (Y/P), c) predominantly purple/red with some yellow/green mottles (P/Y), d) purple/red (P).

Results

Results are reported in a table of data recorded in the field (a completed TABLE 1), a table of class data compiled by the instructor (TABLE 2), and six graphs showing relationships between spadix temperature and other characteristics. Using the individual field data (TABLE 1), bar graphs were drawn showing the temperature of: a) air, b) ground surface, c) leaf surface, d) outside wall of spathe, and e) spadix surface. Individual plants were placed on the X-axis and temperature on the Y-axis (FIG 2). Pooled class data (TABLE 2) were used to graph the following relationships:

- 1) Spadix temperature and orientation of the spathe opening (FIG 3). Data were grouped into the 8 compass directions and a mean temperature was calculated for each compass direction. Mean spadix temperature was placed on the Y-axis, and the compass points on the X-axis.

TABLE 1. Data collection table used for this lab.

Data Sheet

Skunk Cabbage Lab

Names _____

Flower	Air temp. °C	Ground temp. °C	Leaf temp. °C	Temp. of outside wall of spathe	Temp. of spadix surface	Direction of spathe opening	Diameter of spathe opening (cm)	Flowers Female, Perfector Both	Relative odor emitted (0-3)	Spathe colors: 1°/2°
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

FIG 2. Example of data collected by a single group in 2003 showing temperature relationships between the air, ground and various parts of the skunk cabbage.

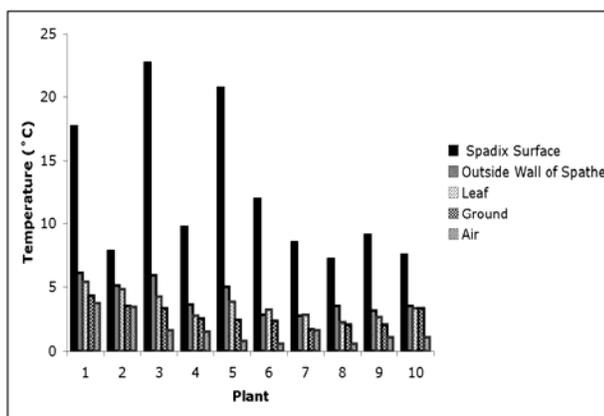


FIG 3. Graph showing the mean temperature of the spadix surface when different orientations of the spathe opening are considered. Data are from Table 2, year 2003.

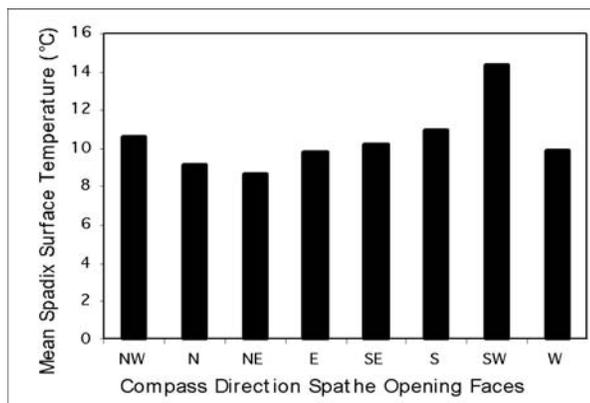


TABLE 2. Summary table of data collected in 2003 and 2004. Mean temp. = Mean temperature, St. Dev. = standard deviation, No. of observations = number of observations.

	2003			2004		
	Mean temp	St. Dev.	No. of obser.	Mean temp	St. Dev.	No. of obser.
Air	2.5	1.2	70	3.3	1.7	150
Ground	3.5	0.9	70	4.0	1.4	150
Leaf	3.9	1.0	70	5.0	2.5	150
Outside Wall of Spathe	4.5	1.2	70	5.5	3.2	150
Spadix Surface	10.4	6.4	70	13.1	6.7	150

2. Orientation of the Spathe Opening	Mean temp	St. Dev.	No. of obser.	Mean temp	St. Dev.	No of obser.
NE	8.69	5.12	8	9.20	3.76	9
N	9.14	5.57	8	14.07	6.77	22
NW	10.60	1.98	2	12.87	6.88	18
E	9.83	5.92	13	12.86	6.84	23
W	9.87	6.90	6	13.45	5.92	21
SE	10.24	7.10	14	16.41	6.32	15
S	10.93	7.28	12	11.83	8.27	30
SW	14.40	7.38	7	13.47	6.36	12
	sum		70			150

3. Sex of the Spadix	Mean temp	St. Dev.	No. of obser.	Mean temp	St. Dev.	No of obser.
Female	11.98	7.05	30	15.73	6.33	86
Perfect	9.17	5.56	4	9.57	5.44	64
	sum		70			150

4. Diameter of Spathe Opening	Mean temp	St. Dev.	No. of obser.	Mean temp	St. Dev.	No of obser.
0-0.4 cm	12.78	6.91	8	13.93	8.50	6
0.5-0.9 cm	9.65	6.56	8	15.15	7.66	30
1-1.4 cm	12.62	6.81	22	13.31	7.08	51
1.5-1.9 cm	9.59	5.45	16	12.50	5.42	43
2.0-2.4 cm	7.74	6.37	7	11.52	6.15	13
2.5-2.9 cm	8.30	4.83	6	12.58	0.91	4
3.0-3.4 cm	3.45	0.78	2	6.67	3.21	3
>3.5 cm	4.9	-	1			
	sum		70			150

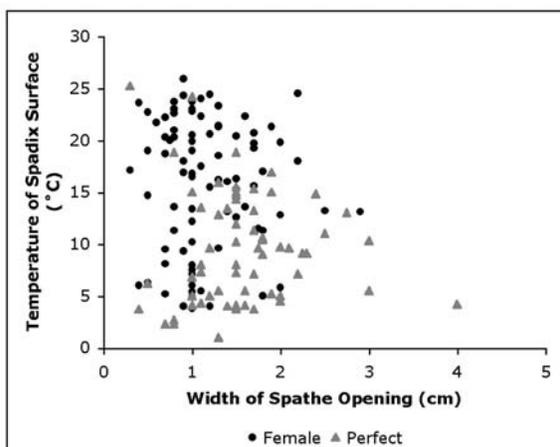
TABLE 2 cont.'d.

5. Color of Spathe	Mean temp	St. Dev.	No. of obser.	Mean temp	St. Dev.	No of obser.
Yellow	12.2	8.39	5	10.48	4.63	4
Yellow/Purple	10.6	7.03	11	13.93	7.11	35
Purple/Yellow	12.55	6.93	28	12.55	6.94	62
Purple	13.67	5.99	26	13.67	5.99	38
	sum		70			139

6. Odor production	Mean temp	St. Dev.	No. of obser.	Mean temp	St. Dev.	No of obser.
None	11.2	7.11	11	12.18	6.77	28
Mild	9.2	5.67	27	14.61	6.8	47
Moderate	10.87	6.85	23	10.58	6.33	32
Gross	11.82	6.57	9	14.04	6.47	29
	sum		70			136

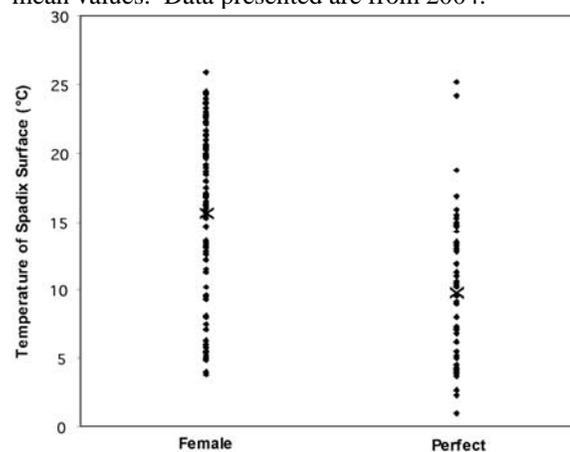
2) Width of the spathe opening and the temperature of the spadix (FIG 4). The data were grouped into width (cm) categories of: 0-0.4, 0.5-0.9, 1.0-1.4, 1.5-1.9, 2-2.4, 2.5-2.9, 3.0-3.5 and > 3.5 cm, and mean spadix temperature was calculated for each category. Width categories were placed on the X-axis and mean spadix temperature on the Y-axis. If different symbols are used for different categories of maturation (female, perfect, both), this will help students to think about how spadix maturation may correlate with width of the spadix opening.

FIG 4. Graph showing the relationship between spadix surface temperature and diameter of the spathe opening, with sex of the flowers indicated. Data presented are from 2004 only.



3) Maturation stage of the open flowers and temperature of the spadix (FIG 5). Mean spadix temperature was calculated for each of the maturation categories. Maturation categories were placed on the X-axis and spadix temperature on the Y-axis. In our sample lab, any spadix producing pollen was designated as perfect, thus we have only two categories: perfect and female.

FIG 5. Graph showing temperature of the spadix surface for female and perfect spadices. “X”s indicate mean values. Data presented are from 2004.



4) Color of the spathe and the mean temperature of the spadix. Data were grouped into four color categories: a) yellow/green, b) predominantly yellow/green with some purple/red mottles, c) predominantly purple/red with some yellow/green mottles, or d) purple/red.

The mean temperature of the spadix was calculated for each category. Color categories were placed on the X-axis in the order above (predicted as less to more effective in absorbing solar radiation) and mean spadix temperature was shown on the Y-axis.

- 5) Odor production and spadix temperature. The mean spadix temperature was calculated for each odor category. Odor was plotted on the X-axis and mean temperature of the spadix on the Y-axis.

Copies of relevant articles on skunk cabbage were placed on reserve in the library and students were required to refer to several of these in their laboratory reports. They were asked to discuss the following questions, and to attempt to answer “why” questions in terms of both physiological mechanisms and adaptive function.

- 1) Which parts of the plant were significantly different in temperature from the surrounding air temperature, and which part of the plant was the hottest, suggesting an origin of the heat? Are any of the 10 spadices that you measured not producing heat? Why might this occur?
- 2) Is there any relationship between the spadix temperature and the orientation of the spathe opening? How might the orientation of the opening affect the temperature inside the spathe?
- 3) Is there a relationship between the maturity of the open flowers and the temperature of the spadix? Why might the sex of the flowers influence the temperature of the spadix?
- 4) Is there a relationship between the diameter of the spathe opening and the temperature of the spathe or spadix? Why might this relationship occur?
- 5) Is there a relationship between the color of the spathe and the temperature of the spadix? Why might this relationship occur?
- 6) Is there a relationship between the amount of odor production and the temperature of the spadix? Why might this relationship occur?
- 7) Heat generation in skunk cabbages is metabolically expensive, using large quantities of their stored energy. After conducting this exercise and reading the articles on reserve, what do you feel is the primary adaptive function of skunk cabbages producing heat?

If the primary selective pressures on skunk cabbages were to maximize temperature while conserving heat and reducing metabolic costs, what orientation of the

opening, what size of the opening, and what color of the spathe might be optimal for heat conservation and reduction of metabolic costs?

Discussion

Figure 2 is an example of a graph such as those students would generate showing the relationship between air and ground temperature and the temperature of different parts of the skunk cabbage. This graph shows the variability in the data produced by spadices that are in different stages of maturation. The spadix surface is 4.7-16.6°C warmer than the outer wall of the spathe. Leaves are also slightly warmer than the ground or air, suggesting that some of the heat produced by the spadix is conducted through all parts of the plant. From this figure students can easily see that the spadix is most likely where heat is produced.

Figure 3 presents data for 2003 relating compass direction of the spathe opening to the temperature of the spadix. In 2003, southwest facing spathe openings had the warmest spadices and north and northeast facing spathe openings had cooler spadices than those facing south, southeast, or southwest. Since these data were taken in the morning, it might have been expected that southeast or south-facing spathe openings would have had the warmest spadices, but of course factors such as wind could have had an effect, as well as the particular combination of spadix sexes and spathe opening widths in the plants with openings in each compass direction.

The sex of the flowers is correlated with both the temperature of the spadix and the width of the spathe opening. Figure 4 presents data from 2004. In this graph younger female spadices have narrower openings and hotter temperatures than older perfect (male and female) spadices. In 2004, the mean spadix temperature was statistically significantly different between females and perfect spadices (Mann-Whitney $U = 4226$, $p < 0.001$). In this year females had a mean spadix temperature of 15.7 °C, while perfect spadices had a mean spadix temperature of 9.6°C (FIG 5, TABLE 2). In 2003, females also tended to be warmer than perfect spadices, with mean spadix temperatures of 12°C, compared to 9.1°C, respectively, though the difference was not statistically significant (Mann-Whitney $U = 709.5$, $p = 0.194$). Fig. 5 shows the range of temperature values for perfect and female spadices in 2004.

We have found that the spadix is consistently the warmest part of the plant, generally followed by the outer spathe wall, and then the leaf. Spadix temperature correlates best with sex of the flowers (females are on average warmer, though

temperature ranges for female and perfect spadices show considerable overlap). There also may be a weak correlation between spadix temperature and diameter of the spathe opening, independent of the correlation between spadix temperature and sex. Color of the spathe was not found to influence the temperature of either the outside wall of the spathe, or of the spadix itself. Odor production was found to be very variable, with no apparent relationship to the temperature of the spadix or the color of the spadix, thus results for these are not presented.

Additional Enrichment Exercises

- Conducting this lab with more detailed observation of the progression from female-only to perfect flowers, and recording the information in more than two or three categories of spadix maturity. This may not be possible to do without significant damage to the spathe and may require dissection of the spathe.
- Temperature regulation in skunk cabbages. Measure spadix temperatures or respiration rate of individuals over a period with varying air temperatures. Knutson (1974, 1979) and Ito *et al.* (2004) report that *S. foetidus* is capable of temperature dependent thermoregulation.
- Duration of heating and survival of the flower. Knutson (1979) reports that each flower produces heat for two weeks or slightly longer. If exposed to temperatures below freezing after this time period, the flower will freeze and die.
- A study of the distribution of the “metabolic duds” to see how frequently these occur in the population.
- Examine the influence of heating on the leaves. Is it possible that in addition to promoting the maturation of eggs and pollen tubes, heat production might also speed up the emergence of the leaves, giving this plant additional time for photosynthesis before the tree canopy establishes? Compare the rates of leaf growth and unfurling in plants with their spadices intact, vs. plants that are “metabolic duds” or plants with their spadices removed.
- Track spathe color and compass orientation of the spathe opening in the same plants from year to year to see if color and/or opening position are genetically (or microenvironmentally) determined, or

variable. If these characteristics are found to be constant within the same plant, transplantation experiments could determine whether the microenvironment has an effect.

- Track spathe color and opening widths in a single individual to document darkening of the spathe and increasing opening of the spathe over time.
- Bagging experiments to see if *Symplocarpus foetidus* like its relative *S. renifolius* needs to be cross-pollinated before seeds are produced (Uemura *et al.* 1993).
- Investigation of pollinators and pollination biology. This was part of our earliest versions of this lab, but few pollinators were observed, so that portion of the lab was eliminated. We still have many unanswered questions regarding the role of pollinators in fertilizing *S. foetidus*. Some questions are: 1) Which species are primarily responsible for pollinating skunk cabbage? 2) How many insects currently visit our populations? 3) Does our observation of few pollinators indicate that skunk cabbage has lost many of its pollinators due to urban development?

Examine the role of odor production for anti-herbivory purposes. *S. foetidus* has calcium oxalate crystals in the leaves that are hypothesized to deter herbivores (Knutson, 1974). As this plant is particularly abundant in the early spring, when few other leaves and flowers are available to herbivores, odor production might also discourage grazing. In addition to examining plants for signs of insect and mammalian herbivory, the leaves could be offered (along with other leaves without defensive chemicals, perhaps including lettuce and spinach) to insect and/or mammalian herbivores. Care must be taken that the herbivores will have adequate food without needing to eat skunk cabbage leaves, and there may be some danger of poisoning naïve herbivores.

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Students in four classes of Biology 202, Principles of Ecology and Evolution, and a class of Biology 133, Introductory Ecology Lab, are recognized for their efforts and assistance in data collection and preliminary data analysis. We thank Thomas Mione for helping us to collect relevant journal articles and for reviewing the manuscript.

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Call for Applications -- John Carlock Award

This Award was established to encourage biologists in the early stages of their professional careers to become involved with and excited by the profession of biology teaching. To this end, the Award provides partial support

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The recipient of the Award will receive a certificate or plaque that will be presented at the annual banquet; and

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

Squirrel Foraging Preferences: Gone Nuts?

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Abstract: This field exercise examines the feeding preferences of Gray Squirrels (*Sciurus carolinensis*). Students present squirrels with a variety of food types in a cafeteria-style arrangement in order to test hypotheses about foraging preferences. This exercise, which is appropriate for introductory biology, ecology, and animal behavior classes, is designed to allow students to be involved in the entire scientific process. Students design the experiment, collect the data, and analyze and interpret the results.

Keywords: Foraging, foraging preference, feeding preference, diet choice, squirrels

Introduction

Animals often prefer specific food types. Many reasons may be responsible. Particular food resources may provide more energy, or they may be more profitable (provide more energy per time spent foraging). Certain prey may be more conspicuous, easier to find, open, capture or handle, or provide essential nutrients. Some studies have found that animals prefer larger, more profitable prey (Werner and Hall, 1974; Krebs, 1978). Other studies have found that when prey have hard cases or shells, foragers may avoid prey that are tough or difficult to open, even if they are large (Meire and Eryvynck, 1986). Foragers may also avoid prey that are spiny or difficult to handle (Barnhise, 1991), or prey that is evasive (Vinyard, 1982). Additionally, prey choice may be influenced by prey that provide predators with essential nutrients (Belovsky, 1978).

The foraging preferences for a particular species can be examined by designing experiments in which individuals are presented with a range of different resources to measure prey selection. In this experiment, students examine the food resource preference of Gray Squirrels (*Sciurus carolinensis*) by presenting them with a “cafeteria-style” selection: squirrels are given a selection of several different food items presented in equal amounts (FIG 1). This laboratory works well for testing the feeding preferences of Gray Squirrels, but can be adapted to work with any field rodent that forages on nuts and seeds. Gray Squirrels can be found in forests, parks, cities, and suburbs. Like many animals, they are particularly active in the morning and evening. They feed on a wide range of nuts, seeds, fruit, and bark (Whitaker, 1996). They nest in cavities in trees, or in large nests they build in the tops of trees. Gray Squirrels are scatter-hoarders. In the fall, they are especially active and run about gathering nuts and seeds that they store in a many different small holes that they dig in the ground. During the winter and

spring, they rely on these cached nuts and seeds (Whitaker, 1996).

FIG 1. A cafeteria-style arrangement of various food types. Students can examine squirrel foraging preferences by placing out equal quantities of various food types and measuring food selection. Note: the term “shelled nuts” refers to nuts that have had the shell removed. Students often use this term to mean the opposite. Therefore, to avoid confusion, I prefer to say “nuts with shells” and “nuts without shells.”



Methods

In my class, rather than give the students the methods, I encourage the class to think about the issues involved in designing an experiment and allow students to design their own field experiment. Below, I have outlined the issues that the class should discuss.

Food

The class should first discuss how various factors, such as the size of food items (energy consumed), type of food (nuts, seeds, fruits, “natural” food items versus novel food items), and ease of opening (nuts in shells versus nuts without shells),

influence prey selection. Students should consider what food items they could use in their experiment (some could be field collected such as acorns, others could be purchased). For example, they could use raisins, peanuts, walnuts, sunflower seeds, pecans, etc. (nuts can be in shells or without shells).

After discussing factors that might influence squirrel foraging preferences, students should decide on a hypothesis to test. I ask students to generate a list of possible hypotheses they could test, then we discuss the alternatives and the class chooses one. For example, the class could test the hypothesis that squirrels will prefer nuts without shells to nuts in shells because nuts without shells take less time to handle. Or, students might want to test the hypothesis that squirrels will prefer large nuts to small nuts. Many different possible hypotheses are available.

Based on the hypothesis that the class decides to test, the class should then choose several (e.g. two to six) different types of seeds and/or nuts of varying sizes or differing in ease of opening. Students need to decide what food types will be appropriate to test their hypothesis, and whether the food items will be field-collected or purchased. When I conduct this lab, the class discusses the hypothesis to test and works out the details of the experimental design during one week, and provides me with a list of items that I need to purchase. Then, the investigation is implemented during a following week. I like to schedule the field lab for two weeks after the experimental design lab to provide time to purchase items. If students decide to use any field-collected prey, they have this time period to gather the necessary items.

Experimental Design and Procedures

Students should discuss all of the details of the experimental design before conducting the experiment. The class needs to decide how many of each type of food type will be set out, where the food will be placed, at what time of day the experiment will be conducted, how the experiment will be observed, for how long the investigation will continue, and how many replicates will be presented. I have conducted this experiment over several years and have explored a number of different permutations. Below, I outline some suggestions that I have found to be helpful based upon the results we have generated.

Students need to decide when and where the experiment will be conducted. We have found that foraging activity varies at different times of day and across different habitat types (e.g. open park areas, forested habitat). Students will get the best results if all students select similar habitats and conduct their experiment during the same time of day. Suitable sites include wooded areas near campus and forested habitats. I have had students conduct this experiment

in the afternoon during lab period (1200–1500 h) and that works, but I have found that squirrel foraging activity tends to be highest in the morning. Therefore, in recent years, I have changed to having students conduct the field portion of this laboratory independently. After being supplied with all of the necessities, students prepare the food items. I give students one week to independently conduct their experiment during a morning that fits their schedule. The class usually decides on a time when everyone should conduct their experiment (for example, any morning from 0800–1200 h). Having students conduct the field data collection independently also avoids the potential of bad weather during a scheduled laboratory day, and I find students like working independently.

The more replicates students can implement, the better the class results will be, and the greater the chance of finding a significant foraging preference — if one exists. I generally have between twelve to sixteen students in my Animal Behavior class. To increase the number of replicates, each student sets out two replicates of their experiment (at the same time and day), giving a total of 24–36 replicates. Each replicate requires little time, so two per student is manageable. A student sets his or her replicates out near each other, but not too close together (no closer than the approximate length of a football field).

FIG 2. A squirrel foraging.



I have found that if students observe their study sites the entire time (from a distance with binoculars), they get few or no visitors to their study sites. Therefore, what I have found works better is a mixture of students observing their study sites (from a distance with binoculars) for short periods of time, and then leaving and giving squirrels a chance to forage without fear of human interference (FIG 2). What we have done in the past is set food out at a

specific time (for example, 0800 h). Each student observes his or her two replicates from a distance with binoculars for 10 min, then leaves and returns at 0900 h to collect the one-hour data (records the number of each type of food type taken). The student then observes from a distance for 10 min, leaves, and returns at 1000 h to collect the two-hour data (recording cumulative numbers of each food type taken). The student then observes again for 10 min, leaves, and returns at 1100 h to collect the three-hour (and final) data.

Students need to decide how much of each food type to set out. They should set out equal amounts of each food type. Students want to set out enough of each food type so that when they leave their food stations for an hour, some of the food will still be there when they return. I suggest using at least twenty pieces of each type of food, more if possible.

Data Collection and Analysis

The instructor can lead students through a discussion of what data should be collected to test for food preferences. Students should record the

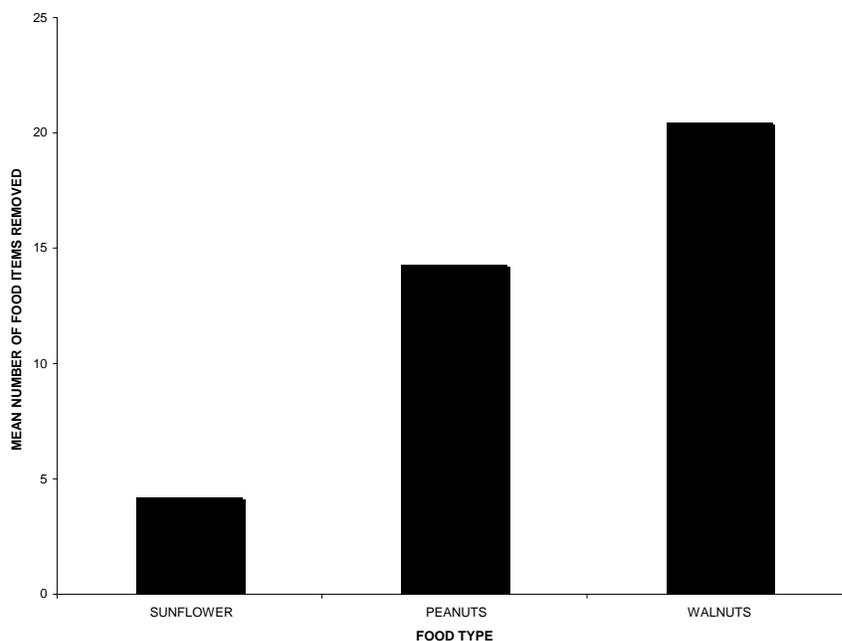
cumulative number of each food type removed each hour (as discussed above) and should periodically look for visitors at the food patches. Students should design a data table to ensure that all students collect data in the same manner.

Results and Discussion

This laboratory gives students an opportunity to statistically analyze data. I have conducted this lab in my class after students have been introduced to statistical analyses. The instructor can lead the students through a discussion of what results are expected.

Graphing the data will let students visualize whether squirrels have feeding preferences as predicted by the students' hypothesis. Students can graph the results to examine if equal numbers of each food type were removed by animals. To test for food preferences, students can plot the mean number removed (on the y-axis) versus food type (on the x-axis; see FIG 3). Graphs can be generated for each data set (e.g., for each of the three hours during which data were collected).

FIG 3. Graphical analysis of feeding preferences. The mean number of food items removed for each food type is plotted for the second hour of observation. Equal numbers of the three food types were left for three hours and we recorded the cumulative number of each type of food that had been removed. All food types (sunflower seeds, peanuts and walnuts) were in shells.



Students can statistically analyze the data to determine whether animals removed equal numbers of each food type. For each data set (each hour), students can calculate the mean number of each food type removed by animals and then use appropriate statistical tests (e.g., t-tests, Mann-Whitney U tests,

ANOVAs, or Kruskal-Wallis tests to compare means).

Students can present their results in written (laboratory reports in scientific format) or oral venues. For lower division courses, students could write a shorter report by answering a series of questions provided by the instructor. Questions students can address include: Did animals show food

preferences? Was the hypothesis supported? If the class did not get the results that were expected, what biological factors might explain the observed results? What is the purpose of observing at one-, two-, and three-hour intervals? Which data set provided the

FIG 4. Occasionally other animals such as chipmunks or birds will visit the food patches.



best results? What animals were observed visiting the study sites, occasionally animals besides squirrels may visit the food patches (FIG 4). How might this influence the results?

In conclusion, this field exercise provides students with an opportunity to design and conduct an experiment, and analyze and summarize their results. Finding field-based experiments that involve testing a hypothesis can be challenging, and this exercise provides means of reliably and quickly generating interesting results suitable for analyses.

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Learning to Teach Inquiry: A Course in Inquiry-Based Science for Future Primary School Teachers

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Abstract: We developed a course in inquiry-based science for students training to become primary school teachers. The emphasis of the course was teaching students to do inquiry-based science activities themselves, as this is the best way of learning how to teach using inquiry-based methods.

Keywords: Inquiry-based science, teacher education, college science, biology, open learning.

Introduction

Documents such as the National Science Education Standards (NRC, 1996) and the Benchmarks for Science Literacy (AAAS, 1993) emphasize the importance of teaching science through inquiry. Despite these recommendations inquiry-based science is not widely used as a method for the teaching of science in schools. One of the possible reasons for this are the teachers responsible for its use in the classroom (Keys & Bryan, 2001). Teachers may have little experience of conducting inquiry-based investigations themselves and therefore have little understanding about what inquiry involves and how it can be taught.

We decided to tackle this problem by developing a course in inquiry-based science for students training to become primary school teachers.

The emphasis of the course is in increasing student's own personal experience of inquiry-based science. The course contains a number of varied and interesting inquiry-based activities in which students are expected to participate and complete (TABLE 1). We feel that these activities more effectively teach students about inquiry than traditional lecturing.

While completing these inquiry-based activities students gained practice in using science process skills, and gained an understanding of how scientific investigations are conducted. The unique structure of the course means it could easily be adapted to teach scientific investigation skills to students from a variety of scientific disciplines and not only those planning a teaching career.

TABLE 1. Summary of course structure.

Session	Activity
1	Fish Behavior *
2	Lectured Lesson: Inquiry-based design
3	Designing an inquiry-based lesson; presentation of group ideas. How big is a water drop? *
4	Snail racing * Egg Drop Challenge *
5	Lectured lesson: Open Learning
6	How does a candle burn? *

TABLE 1. cont.'d.

7 + 8	Designing and planning of an inquiry-based science lesson.
9	Teaching of designed lessons to groups of 3 to 5 schoolchildren.
10	Evaluation of taught lessons and course summary

*Inquiry-based activity.

Fishy beginnings

The course begins with a simple observation experiment. In groups of three, students were asked to observe a fish tank which contained either a Dwarf Shell Dweller Cichlid (*Lamprologus ocellatus*) or a Siamese Fighting Fish (*Betta splendens*) and to investigate how each behaved. Students could use a variety of materials, including shells and brightly colored paper, but were not told what to do with these materials or what they should try to find out. The aim of this activity is to introduce students to more open methods of learning. Most students beginning the course are used to doing very structured experiments during science lessons, and expect to receive a list of instructions and be told what results they should expect to find.

Many of the students given this activity are at first perplexed. 'What do we have to do?' 'What are we supposed to find?' were common questions. However, after some time some students started to experiment without being directed. Some placed shells in the fish tanks and observed how the fish swam into them for protection. Others stuck pieces of colored paper onto the side of the fish tank to see what reactions it caused in the fish. Some students began cutting the card into fish shapes and then seeing how the fish reacted to different sizes and colors of cardboard fish. Not everything seemed to work and this worried some students.

The practical work took some time, mainly because of the hesitancy of the students in deciding themselves what to do. At the end of the experiment the idea that in inquiry-based teaching the student decides what to study, what to do, and what the answers mean were discussed. This activity has proved to be a good introduction to open methods of teaching for students.

What is inquiry-based science?

The second session was purely lecture based and introduced the theoretical background of inquiry-based science. Students learned what inquiry-based science was, its characteristics, and its development. They were told that inquiry-based science is an open student centered teaching technique. The different types of inquiry-based science; open, guided or structured, were also discussed. To reinforce the ideas taught in this session students had to design a

simple inquiry-based experimental lesson for homework.

Designing a simple experimental lesson

A good way to find out if students understand what inquiry-based science teaching involves is to ask them to plan an inquiry-based lesson. Groups of students were given a set title and had to use this to develop a suitable inquiry lesson. The lesson plans had to include some kind of practical experiment or investigation, which the schoolchildren themselves design or plan. The themes which the students are given included; dandelion growth, microscopy of human hairs, housefly anatomy, woodlice behavior, and nettle stinging.

Each group presented their ideas to the class in the third session after having a week of preparation time. Ideas were varied. For example, the group tasked with designing a lesson about dandelion growth developed a lesson in which schoolchildren would compare dandelion growth in sunny and shady areas. The group given the title 'woodlice' planned a lesson that contained an experiment where schoolchildren would study whether woodlice preferred diet or regular cola. The housefly group planned a lesson in which schoolchildren would study and draw houseflies with hand lenses and look for differences and similarities.

Each group's ideas were commented on in a class discussion. This proved useful in evaluating and assessing the ideas given. When, for example, one group presented a lesson plan that included no inquiry-based or experimental element, but instead research on the Internet to answer some teacher decided question, the other students were quick to point out that this was not inquiry-based science.

How big is a water droplet?

This activity makes students think about how investigations should be conducted and allows them to practice their inquiry-based skills. Students are simply asked to find the answer to the single question; "How big is a water droplet?" Students are provided with a beaker, water, pipettes, and paper towels. Although this seems a relatively easy question to answer, once you begin studying how

water drips, and the different factors which affect the size of a water droplet, you begin to realize it is much more difficult to answer than you first thought.

There are a surprising number of possible variables that could affect the size of water drops coming from a pipette. When asked students suggested that the height from which water is dripped the size of the aperture of the pipette, the properties of the water, and the surface on which the water is dripped could all have an affect on the final size of a water droplet. They were then prompted to carry out experiments to find out how big a water droplet is, and whether these suggested variables did in fact affect the droplet size.

Some of our students tried weighing droplets from pipettes of different sizes, to see if this affected the size of the water droplet produced. Another group tried adding oil and soap to the water to see if this would affect the water tension and thus the size of droplet produced. One group tried dripping water at different angles from the pipettes. Some groups measured the diameter of the droplets produced as they landed on a non-absorbent workbench, while others measured the size of stain left by a droplet of water on a paper towel. One group counted and collected a large number of water droplets in a scaled beaker, and then divided the total volume of water they had by the number of droplets they had collected to find the size of a single droplet. The fact that there is no correct answer to this problem mirrors many problems in real life science. This exercise can be used as an introduction to a discussion about variables in experiments, how experiments can be made 'fair,' and overall experimental design.

Snail Racing

Another good example of an inquiry-based exercise used in the course was snail racing. Students were asked to bring one or more living snails to class and a 'snail-attracting object' of their choice. Students brought a variety of different things they thought would attract snails, including dandelion leaves, grass, salad, sugary fizzy pop, and even a bottle of beer. In class students were then given the question "How can you make your snail travel fastest?"

Students went about answering this question in different ways. Some students used the various snail-attracting objects to see to which ones snails were really attracted and if it affected the speed at which they traveled. Some other students compared the speed at which snails moved over different surfaces, for example work bench surfaces, newspaper, and plastic sheeting. Some groups set up a 'start line' and 'finish line' and raced their snails from one to the other. Another group, being more exact, timed the distance snails moved in 5 minutes.

Students were not told how to conduct the snail races or how they should find out what affected the speed at which snails traveled. They had to work out ways of finding out these things themselves. Students themselves have to find the solution to problems they encounter. One such problem is that snails rarely travel in a straight line, and sometimes go in totally the wrong direction to that desired. One group decided to 'disqualify' snails that traveled in the wrong direction, while another group ingeniously used pieces of string to measure the exact distance snails traveled regardless of direction. Although different groups might use different methods, this does not necessarily mean one method is better or worse than another, each is valid in its own way.

The Egg Drop Challenge

Students were then challenged to design a way in which eggs can be dropped from a great height without being broken. Only simple materials such as newspaper, sticky tape, towels, cardboard, plastic bags and string were made available, although groups could improvise or use other materials.

Each group came up with a different solution to this problem. One group surrounded its egg with towels and cloth, so that when the egg landed it would be sufficiently cushioned from the ground. Another group designed a parachute like contraption so that the egg would float to the ground. Another group suspended their egg with string in a box, so that the strings would act as shock absorbers and absorb the jolt when the box landed on the ground. One group inflated plastic bags around the egg as a sort of air cushion. This activity caused a lot of activity and interest. Some groups named their eggs and added faces.

Once each group had finished their designs it was time to test them. One member from each group went to a high third story window; everyone else went outside to watch the eggs land. Each egg holder was dropped from the window onto a specified target. Afterwards all the eggs were examined for damage. The group who emerged with an undamaged egg and who had been closest to the target were declared the winners.

Open Learning

After completing a few experiments, we felt that it was important that students heard from teachers who had experience of teaching using inquiry-based methods. One morning the students visited a local school to talk to a teacher who specialized in open teaching techniques as proposed by the German science education specialist Martin Wagenschein (1968). The students heard about the teacher's experiences and ideas, and were shown how one simple lesson could be transformed to make it more open-ended by letting schoolchildren make

the choices and decisions in the classroom instead of the teacher. The teacher emphasized the importance of getting schoolchildren to be active and involved during lessons, and the importance of teacher questioning in promoting schoolchildren to think for them self.

How does a candle burn?

One good example of open teaching is the study of how candles burn (Theophel, 1995). To start this practical activity students were given the question 'How does a candle work? Students were given candles, asked to light them, and then asked to observe and draw a candle flame. A class discussion followed where students described a candle flame. During the discussion the tutor gave the class no direction or information, but used questioning to make students observe the candles more closely and to describe what they saw. Can you see anything else? What about the wick? What about the wax? Although students started out with rather simple descriptions, by this questioning a more detailed description began to be drawn out.

One student observation was 'as the candle burns it gets shorter.' This prompted the question and problem 'Where does the wax go to?' from the tutor. The students were unable to answer this definitively. The tutor suggested some experiments. First the students were instructed to blow their candles out, 'What did you see?' There were sometimes plumes of white smoke, and the students concluded this was wax steam leaving the candle, and that this was what burnt in the candle flame.

Next the tutor suggested that students, with the use of tongs, place a slide over the flame. Students observed that black soot collected on the slides in large patches. The tutor then prompted students to place a slide actually into the center of the flame. Soot collected in a ring shape, with the center of the ring which had been held in the middle of the flame being clear of soot. The students thus concluded that smoke is only produced at the outside of the flame, and not in the middle. One student thought this was because the center of the flame was the hottest and that the soot was simply burnt away without collecting on the slide.

The tutor suggested an experiment using wooden splints, by placing a splint for only a split second in the flame you can see where the wood begins to burn and is hottest. This took some practice, but the students began to see that the wood that was in the outer parts of the flame burned, while that which had been in the center was not burnt; therefore the center of the flame is cooler than the outer part. The tutor then explained that in a candle flame the outside burns hotter because there is more oxygen available to the flame; in the center of the flame there is not as much oxygen and it does not burn as well.

The aim of the practical was to show students that often things that seem simple can be quite complex, and that a good teacher instead of telling students the answer, prompts students with good questions to see, observe, and think of the answers for themselves.

Designing and teaching an inquiry-based lesson

For the final sessions of the course, students worked in groups of three to plan and then teach an inquiry-based science lesson of their own design to a small group of 14 year old students. As the students in our course were training to become teachers, it was important that they gained real first hand experience of teaching in an inquiry way. By having to plan and teach an inquiry lesson themselves the ideas the students had learned throughout the course were reinforced.

Two sessions were set aside to allow students to find an idea and then plan and design their lessons. Members of the staff were in attendance to provide useful suggestions or help if difficulties arose. Students were free to use the sessions how they wished. Some groups used the time to research ideas in the library or on the Internet, other groups used the time as 'group meeting time' to discuss the work they had done individually over the last week, while some groups tried out and practiced experiments they thought they could use.

In week nine a class of 14-year-old school students visited the university and were divided into small groups. Students were allocated a group of schoolchildren that they had to teach in an inquiry-based way for an hour. The schoolchildren were eager to participate in an interesting diversion from normal lessons. This exercise proved extremely useful for the students as it allowed them to confront some of the difficulties with inquiry-based science teaching. A variety of different ideas for inquiry-based lessons were taught, including 'the behavior of stick-insects,' 'can mice follow mazes?' and 'which parts of the tongue taste can taste what?'

The final session was a summary session. First the teaching from the previous week was discussed and evaluated as part of a class discussion, and this was followed up with a discussion about the course in general with final thoughts from the tutors and students.

Anecdotal comments from students about the course are positive. Students comment that they enjoy actually 'doing something' as opposed to simply listening as in traditional lecture courses. Students find the practical activities especially interesting as they are something they can actually use themselves in the classroom when they are practicing teachers. Because the students do the practical work themselves, they feel they better understand what inquiry-based science is, and how

they could teach it themselves. Students were given questionnaires which asked what views they had about inquiry-based and open teaching both at the beginning and end of the course. The results indicated that students would be more willing to incorporate aspects of inquiry into science lessons when they became teachers after they had taken the course.

References

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Conclusion

The course outlined here has proved to be an effective way of introducing prospective science teachers to inquiry-based science. The structure shown here can be used as a template for other similar courses, or could be adapted for courses teaching students scientific investigation skills.

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ACUBE Standing Committees 2007

Membership: Wyatt Hoback, *University of Nebraska-Kearney*

Constitution: Margaret Waterman, *Southeast Missouri State University*

Nominations: Melissa A.F. Daggett, *Missouri Western State University*

Internet: Bobby Lee, *Western Kentucky Community and Technical College*

Awards: William Brett, *Indiana State University*

Resolutions: Marya Czech, *Lourdes College*

51st Annual ACUBE Meeting

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

Oct. 4 -6, 2007

Loras College, Dubuque, Iowa



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

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

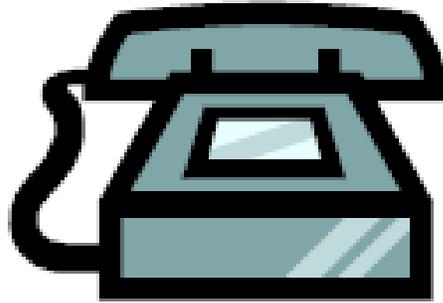
Housing Preview

51st Annual ACUBE Fall Meeting

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

Loras College
Dubuque, Iowa

October 4-6, 2007



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

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

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

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

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

Call for Resolutions

The Steering Committee of ACUBE requests that the membership submit resolutions for consideration at the 2007 Annual meeting to the Chair of the Resolutions Committee. Submit proposed resolutions to:

Sister Marya Czech, Dept. of Biology, Lourdes College, 6832 Convent Blvd. Sylvania, OH 43560,

Email: MCZECH@lourdes.edu

Phone: 419-824-3687

Book Review

The Weather-Makers: How Man Is Changing the Climate and What It Means for Life on Earth. Tim Flannery. Atlantic Monthly Press., New York.2006. 384 pp. Hardback – ISBN: 0871139359. \$24.00.

The Weather Makers: How Man is Changing the Climate and What it Means for Life on Earth by Tim Flannery is one among many recent books on global climate change. Flannery examines climate change from multiple disciplines and perspectives. This account of global climate change is exhaustive, clearly written, and relatively easy read for the lay person. It is not overly lengthy, and the author does an excellent job of breaking up his subject into short, easy to read chapters. His narrative is engaging, and his stories add to the power of his message, being used as pedagogical tools to illustrate the science.

The author brings atmospheric science and the atmosphere alive through his narrative and use of the phrase “the great aerial ocean,” a phrase first used by Alfred Russel Wallace. The Gaia hypothesis is used as a metaphor to explain feedback loops, and Flannery describes well various feedback mechanisms that regulate the average global temperature. While Flannery clearly doesn’t believe the Earth is a living entity, Gaia is a more than useful way to illustrate the interconnections between all things on Earth, and from there, to argue for a holistic approach to solving environmental degradation. It’s also a useful concept to demonstrate how one species can, and does, have an influence on its environment.

The science of climatology can be complex and difficult to understand. Flannery brings it to life by giving us lessons in the history of science, as well as several lessons in the history of Earth. He takes us on a journey back hundreds of years to early discoveries in climate studies, and millions of years to envision what our world’s climate and environment were like. After a lengthy discussion of the variability in our climate, and the drivers of changes, Flannery brings us to the more recent past. We examine the conditions under which human societies developed and our population exploded. We have had an unusually long period of benign climate conditions, and Flannery reviews evidence that suggests that humans have been altering the global environment since the Agricultural Revolution thousands of years ago, by adding methane, a potent greenhouse gas, and indirectly adding carbon dioxide by removing forests and changing land use patterns. These changes were relatively minor in comparison to recent changes.

By asking two questions: how big are the changes, and how fast are they occurring, Flannery conveys the urgency of the crisis. This book is, in part, his personal search for an answer, and we learn

through his exploration of the various topics. Put into historical perspective, the reader is exposed to the mounting evidence that, not only is climate changing, but that humans are major drivers of the changes and that the new conditions are outside of the conditions in which today’s species evolved. A most difficult section for me to read was the section on how climate change is affecting biodiversity, and the predictions for the near and far term reductions in biodiversity that may result. The difficulty lies in reading about the changes that have occurred and the perils that survivors face, from coral reefs to polar bears. It’s not an easy thing for a biologist to contemplate. Nor are the other predicted changes on which Flannery expounds, from water deficits to ocean acidification.

Flannery does a great service in his explanation of computer models and how they work. He discusses predictions for the climate, biodiversity, and humanity, and how much all of the predicted changes and disasters will cost society and the insurance industry. On top of these predictions, he throws in several scenarios, for which computer models have yet to come to a consensus. The collapse of the Gulf Stream could plunge Europe into a persistent cooler period, and the changes could be rapid. The collapse of the Amazon rain forests and methane release from the sea floor are the other two scenarios, both of which illustrate global positive feedback loops.

The discussion of policy is enlightening, in that Flannery compares the Montreal Protocol, which successfully saved the stratospheric ozone layer through an international agreement to limit CFC production and release, to the Kyoto Protocol, which would need to be strengthened 12 times over for it to lead to any meaningful reductions in carbon emissions. Yet, even in its current, mild form, it has had little impact. Flannery helps explain why that is, and offers some insight into the strategies of the vested interests that seek to go about business as usual.

What are the solutions? Flannery takes a look at the feasibility of engineering solutions, weaning ourselves off inefficient fossil fuels, and ramping up renewable technologies. Finally, what can individuals do, and will it be enough to make a difference? Many do not think so, but Flannery shows what you can do that will make a difference. He tells us what he’s done to make a difference. The first thing you can do, if you have not yet started to reduce your carbon emissions, is to read this book.

This book would be an excellent addition to course material for an environmental science or environmental studies course. Flannery’s examination is detailed, interdisciplinary, and concise enough that students will no doubt come away from a reading of *The Weather Makers* with a better

understanding of climate science, conservation, energy, economics, policy, and culture. The book offers many potential issues for further discussion in class or exploration in a class project, such as a term paper or group project. Every educated citizen on the planet should be aware of the issues presented within, and perhaps this should be required reading for all of us.

Christopher Paradise
Department of Biology
Davidson College
Davidson, NC 28035

Honorary Life Member Editorial

Thoughts While Listening to an Old Erroll Garner CD

I am sitting here listening to Erroll Garner. For those of you too young to know Garner, he was a great jazz pianist of the 50's, 60's and 70's, dying too young at 53 in 1977. Most jazz aficionados remember well many of his pieces, most particularly his recording of *Concert by the Sea*, and his amazing recording of *Misty*. I was deeply honored last fall at the meeting at Milliken when my old friend John Jungck and my former student, now Assistant Professor, Laura Salem presented me with an Honorary Live Membership on behalf of ACUBE. Lest this seems a strange way to start a note, in a wonderful way the music of my childhood growing up, and remembrances of 35 years of relationships with the members of AMCBT/ACUBE blend to put me in a very mellow, cheerful and thoughtful mood.

Most of you know that though I have retired from teaching Biology, I have continued to be active in Biology Education, working to help where I can K-16 science education in this country. There are many 'battles' I was a party to, that still need being fought and brought to a successful conclusion. Let me list a few for you to personally 'chew' on, and/or for ACUBE to consider adopting as campaigns or target projects.

1) A national Biology Organization, truly representative of College and University teachers and teaching. NABT has lost membership, become very high school focused, and is ignored by the majority of College and University Professors. I recently suggested to the ACUBE Board to consider at least an affiliation with the Southeast Biological Association, a group similar to ours.

2) A planned national suggested curriculum for all departments, large and small. At the small college level, we often get courses and faculty cut because of 'bottom line' financial decisions, not based on what is needed to produce a good, graduate school-ready student. At the University level, we often allow students to run amok through a "smorgasbord" of

course offerings, taking only courses from their favorite instructors, or do the kind of narrow focusing that should be done in graduate school. In today's modern biology, at least we ought to tell undergraduate students that here are the basic organismal courses you need and here are the basic molecular courses you should have at a minimum, plus necessary Chemistry, Physics and Mathematics. Such lists would allow small Colleges to argue with administrators with some national agreement on what is needed to be taught. Large Universities, will continue to have smorgasbords, but at least some core threads will be covered. If you don't see the need for this, next time you have a hiring search, or talk to the current population of graduate students, see if they have any breadth at all? I currently meet every 2-3 weeks with world class geneticists, Nobel laureate quality researchers, and frankly I am appalled at how little they know outside of DNA and Biochemistry.

3) Standard teaching loads in departments. Because of having national groups to back them, Chemists can refer to ACS guidelines for loads, similarly Mathematicians and Computer Science faculty. Harold Wilkinson of Millikin in the late 80's did a study within ACUBE, and found the range of loads was very inconsistent, with some colleagues teaching so many courses a semester, they never could do real justice to innovation, updating, or any personal research. A model would need to include consideration of reasonable credit and student contact hours. At Rockhurst, we once had an instructor teaching 4 credit hours in a semester, but was meeting with students 3 lectures hours a week, plus 4 labs at 4.5 hours each per week for a total of 21 contact hours. We were told by a Dean that this faculty member was under-loaded. That same semester, we had two chemists who were teaching 3 different preparations at 3 credit hours each, and 12 total hours student contact, and the same Dean said they were teaching an adequate load, perhaps even a little overloaded. We all know 3 preparations versus 1 preparation is different, but was it equivalent to 9 plus hours difference in student contact time?

4) Research support – the available dollars varies hugely across the small college scene. Some small colleges make available an initial stipend for research laboratory equipment and/or facilities, to entice young teachers to come to their institution. Others offer nothing. Yet most colleges still require some amount of publish or perish for promotion and

tenure. When, where, how does the young professor do this, with no or little financial support at the institution? What I have observed recently is many young professors make arrangements with their former doctoral or post-doc mentors to use their lab facilities during summers and holidays. Does this make any real sense scientifically, or more importantly ethically and morally since the institution on one hand demands research and on the other does not support it. And finally, many small colleges' administrators fail to see that science research done well, is very different from History, Philosophy or English research. And what about the fact that

graduate schools are increasingly demanding that applicants show some undergraduate research?

Well the *Concert by the Sea*, has finished, but because I got wound up writing and remembering my frustration over some of these issues, I think I will stop writing, and listen to it again, and return to my mellow mood. Thanks to all for the Honorary Life Membership, and looking forward to seeing old friends and colleagues at many future fall meetings.

Richard Wilson
Ken-A-Vision Mfg.Co.Inc.
Raytown, MO 64133

Editorial

I did not have a very good 2006-2007 academic year. I was at a Christmas party in December when someone asked how the semester went and I gave a blunt and honest assessment. They laughed and said I reminded them of an old disgruntled retiree. That warmed my heart with Christmas cheer and made me look forward to the spring semester. However, spring was even worse.

Why was it so bad? I started the year off by assuming my students across all the courses I taught were weak. I "adjusted" my standards in all of my courses to match my lowered expectations. I allowed rewrites on examinations. I assigned mandatory extra-credit. I let obnoxious behavior such as persistent tardiness, dead grandpa epidemics at test time, and text messaging during lectures, slide unchecked. The result was poor student performance across the board and a miserable instructor.

My initial reaction was to blame the students. Hence, the disgruntled retiree label placed upon me at Christmas. Once my grades were turned in, my reports completed, and my office and laboratory were cleaned, I began to reflect on this past year and how I can address this next year. I also read a book entitled *What the Best College Teachers Do* by Ken Bain (2004), Director of the Center for Teaching Excellence at New York University. This acclaimed book is a must-read for anyone who teaches undergraduates or graduate students. The book suggests that students respond to high standards, provided that they are given ample opportunity to meet the standard prior to having a grade administered. It also indicates that simply putting the information out there and leaving it up to the student to do with it as they will, is not an optimum strategy. A feature of the book that I especially liked is that it did not get into the lecture is bad-lecture is good debate, but encourages a mixture of approaches that fits the instructor's style.

So what will be my strategy for next year? My focus this summer will be on the part of the introductory survey course that I teach. We have both majors and non-majors in our course and we have structured the course to accommodate both groups. Allowing students several opportunities to meet a standard, prior to an examination or administration of some type of grade sounds doable, but also difficult. Do I provide several assignments that I must grade prior to each examination? Do I give frequent quizzes (which I also must grade) to make sure students are keeping up with expectations? Do I curve examinations when the highest grade is only a 70%, even after the students have been exposed to many of the exam questions previously? What about students who openly express contempt for the subject, our institution, or who state a desire to solely focus on extracurricular activities at the expense of their coursework? These students, by the way, are growing in numbers at our institution and at others from what I hear and read.

The last question is the easiest to answer. I plan on not worrying much about those folks, even if they make up a significant portion of the class. I think my attitude this year stems from the fact that I tried to appease them at the expense of the subject and those who are serious about their education. My standards shift meant not giving out as many D's and F's, and therefore not having the pleasure of seeing these folks again next year. But many of these students will not be coming back, regardless of what mark they get in this course. So I shall readjust my standards to meet what I hope will be a majority of students interested in learning biology.

What about frequent quizzes? I gave on-line quizzes this semester so I would not be swamped by grading. I took the sting out of these assignments by allowing them to take the quizzes twice. I also kept them short and focused on assigned reading. But these quizzes did not translate to success on

examinations. The software allows me to do some adjustments not just in quizzes, but other assignments and I'm going to try to use it to the maximum potential. I think students who are not interested in their learning will not take advantage of this opportunity and that should simplify grading at the end.

As for the examinations, I am going to change my testing style in some fashion. Buzz Hoagland at Westfield State College and a long-time member of ACUBE has inspired me to try pyramid-style examinations whereby students make more than one pass at the exam. One of these passes could include a group approach to the questions being asked. I have given examinations with combinations of short answer, short essay, and multiple choice, but this may change as well if I try the pyramid approach.

Finally, I am going to try to do some demonstrations in the classroom to reinforce the empirical nature of biology. The inspiration for this came from an article in this month's *Bioscene* by Kremer *et al.* (p. 19) that describes several inquiry-based learning opportunities. Some of these have sparked some ideas for in-class demonstration to enhance lecture and discussion experiences.

I hope my developing plan for the upcoming year works and allows me to feel better about my teaching and my students. If anyone out there has had similar experiences, I would like to hear from you and feature your experiences in *Bioscene* as a "Letter to the Editor" or "Guest Editorial." I'll keep you informed of what works and what does not over the course of the next year both in this medium and at our annual fall meeting at Loras.

Stephen S. Daggett
Bioscene editor

Call for Reviewers

We are continually looking for persons who are willing to review manuscripts for *Bioscene*. We need reviewers for a wide variety of subject areas. Reviewers should be willing to provide in depth reviews and detailed suggestions for authors concerning revisions necessary to improve their manuscript for possible publication. Reviewers should be willing to provide a rapid turn-around time for the manuscripts they review. If you are interested in reviewing for *Bioscene*, please send an email that includes your phone number, FAX number, and a list of the areas for which you are willing to review to: Stephen S. Daggett, *Bioscene* editor, at stephen.daggett@avila.edu.

Association of College and University Biology Educators 51st Annual Meeting

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

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

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

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

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

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

Proposal Title:

Presentation type (indicate one): Poster, 45 minute paper, or 90 minute workshop

Equipment needed: All rooms are equipped to connect a laptop computer to an LCD projector. Please list any other computer or AV equipment needs, and any special room requirements (multiple computer workstations, wet lab, etc.)

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

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



2007 Annual Meeting Registration Form

Loras College, Dubuque, IA
October 4-6, 2007

Please send registration form and payment to: Dr. Tom Davis
Department of Biology
Loras College
1450 Alta Vista
Dubuque, IA 52004-0178

NAME: _____ DATE: _____

DEPARTMENT: _____

INSTITUTION: _____

STREET ADDRESS: _____

CITY: _____ STATE: _____ ZIP CODE: _____

WORK PHONE: _____ EMAIL ADDRESS: _____

Entire Conference Registration Fee: Circle the correct amount(s).

Membership status	By 9/15/07	After 9/15/07
Regular Member	\$100	\$115
Regular member + 2007 dues	\$130	\$145
New Member (includes 2007 dues)	\$130	\$145
Non-Member	\$130	\$145
Non-Participating guest/spouse	\$ 85	\$ 95
Student (Grad or Undergrad)	\$ 85	\$ 95
K-12 teacher	\$ 85	\$ 95
Friday evening dinner only	\$ 20	\$ 20

TOTAL ENCLOSED (Please make checks payable to ACUBE) _____
Sorry, checks or money orders only.

Special needs (food, facilities, etc.):

Field Trips: Check all field trips you plan to attend.

1. Thursday afternoon 3-5 PM: Visit nationally known Dubuque Arboretum
2. Friday morning 8-10 am: Visit an Ordovician Fossil bed in Graf, IA.
3. Friday afternoon 1:30 - 4 pm: Hike in Whitewater Canyon Park
4. Friday afternoon 1:30-3:30 pm: Shopping in downtown Dubuque at Cablecar Square



Association of College and University Biology Educators

FIRST NAME: _____ INITIAL: _____ LAST NAME: _____ DATE: _____

TITLE: _____ DEPARTMENT: _____

INSTITUTION: _____

STREET ADDRESS: _____

CITY: _____ STATE: _____ ZIP CODE: _____ COUNTRY: _____

ADDRESS PREFERRED FOR MAILING: _____

CITY: _____ STATE: _____ ZIP CODE: _____ :

WORK PHONE: _____ EXTENSION: _____ FAX NUMBER: _____

HOME PHONE: _____ EMAIL ADDRESS: _____

MAJOR INTERESTS

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

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- C. Physiology
- D. Anatomy
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