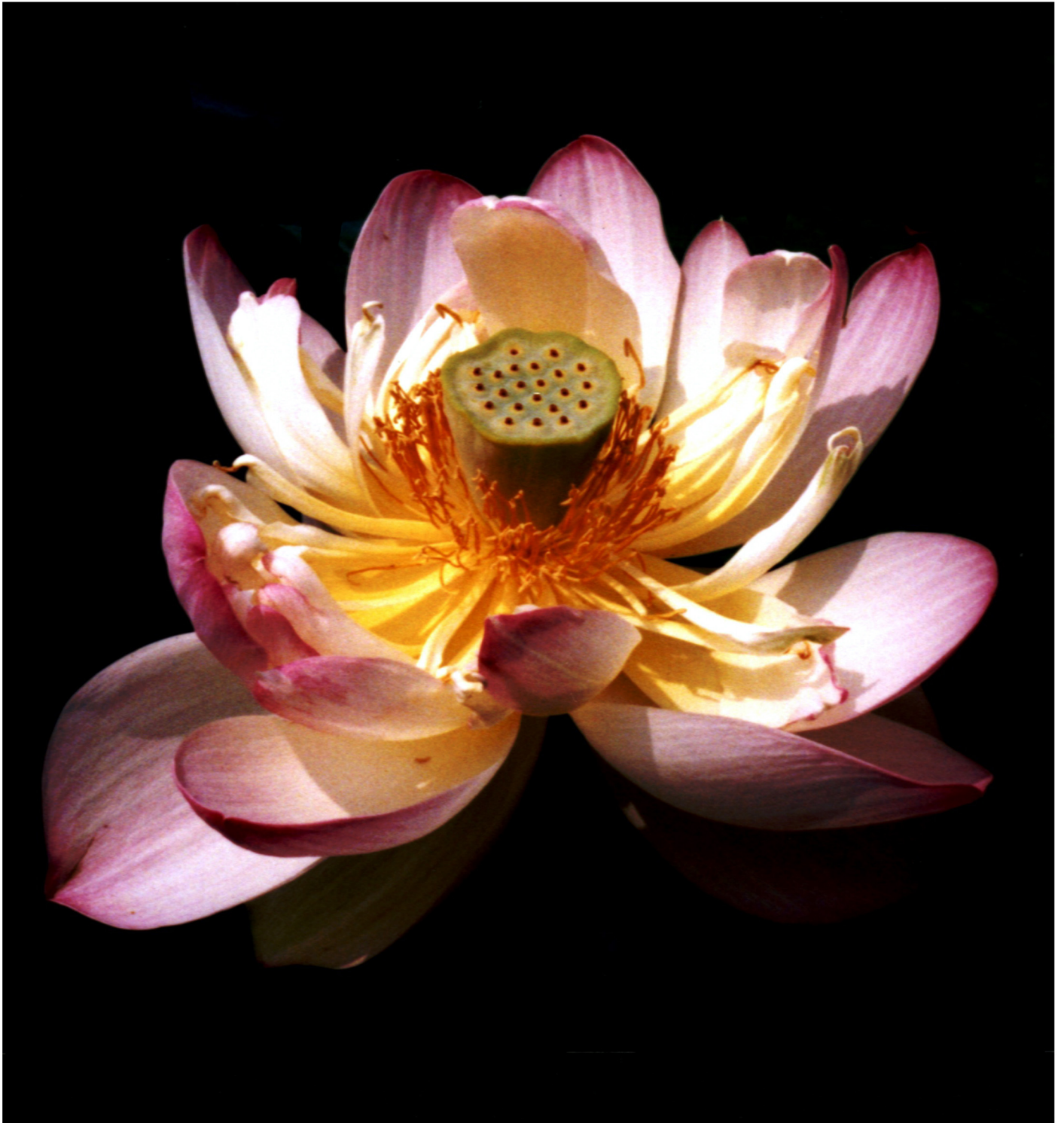


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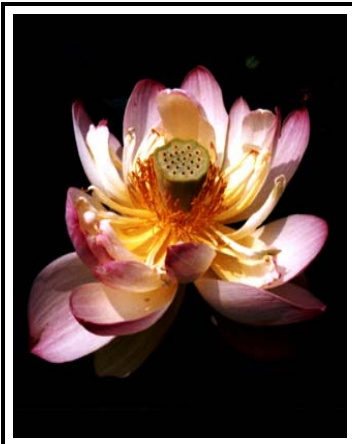
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Bioscene: Journal of College Biology Teaching

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Student Designed Labs in Physiology – What Really Happens?

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ABSTRACT: Is it possible to design a laboratory experience that immerses the students in the scientific method and generates student ownership and enthusiasm of physiological concepts and applications? An example of such a course that uses student designed laboratory experiments is described here. The laboratory periods for this one semester, junior level, 4 cr. Vertebrate Physiology course are arranged into several 3-4 week sections. The first week is a design week in which student groups ask a question, pose a hypothesis and design an experiment. Week 2 is used to implement the design and collect data. Week 3 is used for group presentations where results, statistical analyses, and literature comparisons are combined to accept or reject the original hypothesis. Students reported that they enjoyed this type of lab experience because they are posing and answering questions for which they have ownership. Advantages and pitfalls of using this methodology are also described.

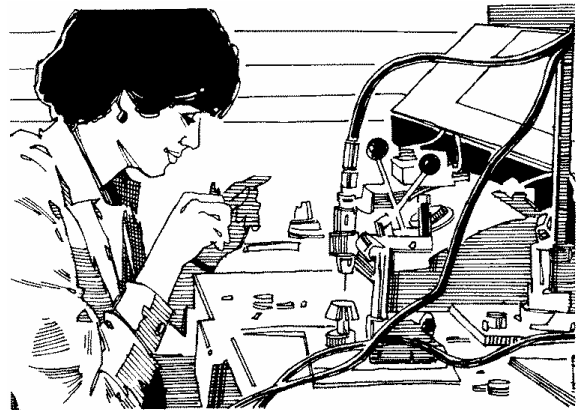
KEYWORDS: student designed laboratories, physiology laboratory, active learning, human physiology, lab planning, scientific method.

INTRODUCTION

The purpose of having a laboratory experience in any biology course is to get students actively involved in doing science, to have them experience first hand the courses of the information that are being presented in lectures and to gain an understanding of how concepts and ideas are applied to help us better understand how the natural world works. Many studies have shown that students develop more personal ownership when they are directly involved in picking the topics for investigations. They develop more personal ownership, increase their own intellectual investment in the projects and ultimately learn more and remember more because of this personal ownership of the experimental process (Cross, 1987; Gilchrist, 1997; Kolkhorst, et al., 2001; National Research Council, 2000; National Science Foundation, 1996; Rao and Di Carlo, 2001). How can we get more student ownership and intellectual investment in laboratory investigations in biology? How can we get faculty intellectual investment in the course topic transferred enthusiastically to the students? The purpose of this paper is to present some ideas and stimulate some risk-taking by Bioscene readers to use students designed labs in their courses.

We all know what kind of methods, techniques and content should be included to help our students learn in a hands-on learning environment. What should they be able to do when they have finished with their laboratory experience? What would be a good set of

laboratory outcomes for biology majors and non-majors? Can a course be designed that includes many of these outcomes and promotes student ownership of concepts and the process of science too?



The Faculty members of the Biology Dept at Doane College in Crete, NE put together a set of desired outcomes for their majors that they call the Doane College Biology Department Statement of Student Outcomes (unpublished; Table 1). In my opinion it is an excellent list of not only outcomes for Biology majors but also a checklist for individual courses. Can many of these be included in a course to help our students learn concepts and apply them to experimental situations in an active-learning laboratory?

Table 1. Doane College Biology Department Statement of Student Outcomes (with permission from the Biology Department Faculty at Doane College, Crete, NE)

1.	COMMUNICATE EFFECTIVELY IN SCIENCE	Written, Oral, Leadership Skills, Collaborative Learning
2.	USE AND UNDERSTAND THE SCIENTIFIC METHOD	Problem Recognition, Hypothesis Generation, Experimental Design, Data Collection, Data Analyses, Interpretation of Results, Use of Scientific Literature.
3.	KNOW AND APPRECIATE THE MAJOR CONCEPTS IN BIOLOGY	Biodiversity, Systematics, Ecology, Evolution, Form and Function, Cell Theory, Energetics, Homeostasis, Inheritance, Development, History/Philosophy of Science.
4.	USE THE TOOLS AND TECHNIQUES OF SCIENCE	Appropriate Instrumentation, Computers, Statistical Methods, Observational Skills, Safety Techniques.
5.	BE SCIENTIFICALLY LITERATE	Environmentally Aware, Health Conscious, Appropriately Skeptical, Knowledge of the World of Science.

The laboratory schedule in a physiology course that is described here attains many of these outcomes including scientific writing, oral presentation, team learning and cooperation, all aspects of the scientific method as mentioned in Table 1, use of equipment, computers, statistical methods, and observation skills.

COURSE DESCRIPTION

This course is a 4 cr., one semester, 15-week, junior level, Vertebrate Physiology course. It usually has an enrollment of 20 – 32 students. The students take one of the two, 2 hr laboratory sections that meet one day per week. An outline of the lab schedule for this course is shown in Table 2. The first two lab periods in the semester are used to introduce ideas and practices that are a part of student designed labs. Many students are not used to designing lab experiments. Standard introductory material is discussed, i.e. how to write a lab report, how to use basic statistics, and how to plot data using Excel. Also in the second lab period

they practice designing a lab experiment that addresses a specific hypothetical hypothesis. (For example: Vasoconstriction happens quicker and with a bigger decrease in volume pulse in athletes compared to non-athletes; or Blood pressure and heart rate increase and decrease faster in smokers compared to nonsmokers; or leg muscles are stronger than arm muscles in short vs tall people.) They pick their lab teams (a minimum of 2 and maximum of 3 people per group; 3 work better) and spend about 30 minutes discussing what they can do to test the hypotheses. They discuss equipment, sample size, techniques, and come up with a plan that they present to the other groups in this lab period. The other groups and the instructor critique the experimental design for strengths and weaknesses as well as limitations for experimental procedures and available equipment. Through this exercise they get a better feeling for what is expected of them next week when they must design an experiment and actually carry it out the succeeding week.

Table 2: Outline of Lab Schedule for Vertebrate Physiology

Week 1:	Introduction to Laboratory; How to Write a Lab Report; Statistics Review; Basic Physiological Processes and Terminology
Week 2:	Lab Design Critique Sessions
Week 3:	1 st hour: Planning Experimental Design for Next Week: Skeletal Muscle Physiology 2 nd hour: Physiology Current Events Discussion
Week 4:	Execute Week – Students do the experiment planned the preceding week
Week 5:	Re-execute Week –Students redo the previous experiment with improvements (Written Draft of 1 st week results due)
Week 6:	Report Week – Each team gives informal oral report on experimental results
Week 7:	1 st hr: Planning/Experimental Design for Next Week: Cardiovascular Physiology 2 nd hr: Bioethics Discussion: Animals in Research (Formal Written Lab Report Due with results from 2 nd week)
Week 8:	Execute Week - Students do the experiment planned the preceding week

Week 9:	Report Week – Each team gives informal oral report on experimental results (Formal Written Lab Report Due with results)
Week 10:	1 st hr: Planning/Experimental Design for Next Week: Respiratory Physiology 2 nd hr: Current Events Discussion: Enhancing Athletic Performance
Week 11:	Execute Week - Students do the experiment planned the preceding week
Week 12:	Report Week – Each team gives informal oral report on experimental results (Formal Written Lab Report Due with results)
Week 13:	Planning and Initial Topic Selection for Final Powerpoint® Pathophysiology Talk
Week 14:	Further Team planning/instructor consultation for Powerpoint® talks
Week 15:	Teams present PowerPoint® Talks

The next four weeks in lab are spent on skeletal muscle physiology. The first two units (Introduction to Laboratory and Lab Design) are not repeated and students spend the first week designing the experiment. Early in this planning period, they are presented with a “Stimulating Ideas” list. This list contains some possible topics, which they could use to design an experiment. The idea sheets used for muscle and respiratory physiology are shown in Table 3.



These sheets also contain citations for some published papers, most of which are from the *Journal of Applied Physiology*, that the students can use to get ideas of what methods others have used, what sample data might look like and a discussion of their meaning as well. JAP can be searched easily online by going to <http://jap.physiology.org>. It is suggested that they look at a few of these papers and topics before they come to the first planning session so they may have some ideas to start discussing with the instructor. These idea sheets are also posted on the Blackboard so students can access them prior to coming to class. They are presented a list of possible equipment to learn about skeletal muscle function as well as what kind of animals might be available for their use. The group

uses a planning sheet (Table 4) to help them write out the questions and hypotheses to be tested, equipment to be used, exact sampling protocol, sample size and what each team member will do in preparing and carrying out the design. This process is done in close conferencing with the instructor who approves their experimental design. This is also a good time for the instructor to demonstrate the use of the equipment so they will know how to use it next week.

The second week is the ‘execute’ week. Students collect data during regular lab time and “outside of class” during times it is convenient for subjects to be sampled. But they must collect data that week. For many of these students, it is their first attempt at designing lab exercises especially in physiology. They usually have some problems, but do manage to get some data. Analyzing the results of their experiment helps them identify weaknesses, so the 3rd week is a “repeat-the experiment-with-modifications” week. They also consult with the instructor after their first attempt and talk over the needed modifications to be more successful and get better data. The data from the first execute week are put into a lab report draft. The instructor reads the draft and gives them feedback about their writing and ability or inability to follow standard, scientific-writing, report format. The 4th week of this first lab sequence is used for group presentations. Experimental hypotheses, methods and results including statistical analysis are summarized on a one page transparency or PowerPoint® slide and presented to the rest of the class. Class members ask questions, suggest improvements and learn some physiology from other groups. The formal, written lab report is due the next day. Thus, any suggestions or modifications received during the presentations can be included in the lab report for the next day. This sequence is repeated for the rest of the semester. Cardiovascular and respiratory labs are performed in 3 week sequences: one week for design, one week for execution and one week for presentations (Table 2). They are only given an additional execution week for the first muscle lab sequence. By the time the third lab sequence is undertaken most teams can design a sound experiment, collect good data and present results in a meaningful way.

Table 3. Stimulating Ideas for Planning Skeletal Muscle and Respiratory Physiology Lab Experiments

TOPICS TO GET YOU THINKING ABOUT SKELETAL MUSCLE PHYSIOLOGY:

- Test and compare isolated frog, toad or salamander muscles.
- Compare maximum contraction tension in relation to rest time, effects of stimulus voltage, stimulus frequency, tetanus, fatigue, injection of chemicals, active vs. passive tension in different muscles or antagonistic muscles, and affects of muscle load on contraction strength.
- Test in vitro vs. isolated frog nerve and muscle prep –nerve stimulus vs muscle stimulus.
- Compare latency, contraction, and relaxation time in different muscles.
- Human muscle testing - antagonistic muscle strength, fatigue, diet effects
- Isotonic vs isometric lifting, endurance vs strength; compare different groups of athletes in muscle tests or effects of practice; end of season vs beginning of season; muscle diameter or length vs strength or agility.
- Effect of lower blood flow on muscle exercise in forearm using a bp cuff.
- Sarcomere length and volume comparison between muscles, between animals.
- Time of appearance of fatigue between right and left side muscles.
- Effects of STIM voltage, frequency or skin position on motor points in arm or leg muscles.
- Temperature effects on muscle function.

Papers in J. of Applied Physiology (JAP) to read for ideas: (Search JAP on line at <http://jap.physiology.org/>)

Strength induced enhancement of mechanical work production in frog single fiber and human muscle. JAP 83: 1741-1748, 1997.

Length dependence of active force production in skeletal muscle. JAP 86:1445-57, 1999.

Reduced reflex sensitivity persists several days after long-lasting, stretch-shortening cycle exercise. JAP 86:1292-1300, 1999.

Shortening of muscle relaxation time after creatine loading. JAP 86:840-844, 1999

Role of extracellular Ca in fatigue of isolated mammalian skeletal muscles. JAP 84: April 98.

TOPICS TO STIMULATE THINKING ABOUT RESPIRATORY PHYSIOLOGY:

- Role of CO₂ in control of breathing: effects of hyperventilation & hypoventilation
- Effects of smoking on lung volumes; variations in Forced Expiration. Volume (FEV)
- Broncho-inhaler effectiveness
- Asthmatic breathing and volumes
- Variation in forced expiratory reserve
- Temperature effects on breathing
- Humidity effects on breathing
- Height, weight, sex, athletic background correlations
- Oxygen consumption rates in small animals; construction of a thermal neutral zone or upper and lower critical temperatures in mammals; compare exothermic and endothermic animals' responses to temperature change
- Variation in rate of CO₂ production using Fyrite apparatus
- Pattern of breathing with exercise; measurement of alveolar CO₂ and dead space volume
- Measurements of rib cage changes in humans with different breathing – estimates of volume
- Relationship of metabolic rate to body wt and surface area in mice or rats

Papers in Journal of Applied Physiology to read for ideas:

Moderate exercise increases post exercise thresholds for vasoconstriction and shivering JAP 85:1357- 1362; October, 1998.

Increasing duration of smoke exposure induces more severe lung injury in sheep JAP 64:1107 – 1113, 1988.

Smaller lungs in women affect exercise hyperpnea JAP 84: 1872-1877, 998.

Chest wall motion during tidal breathing JAP 83:1531 – 1537, 1997.

A technique to measure the ability of human nose to warm and humidify air. JAP v87: 400.

Table 4. Lab Planning Sheet

Names of Group Members (2 or 3 students/group):
<ul style="list-style-type: none">• Specific question or hypotheses to be tested by your group experiment:• General plan/ experimental design of experiment;• Equipment needed:• Types and number of animals / people needed and how many experimental repetitions:• Outline a detailed timeline sequence: What is going to be done in each experimental unit and team members responsibilities:• Experimental group treatment:• Control group treatment:
Comments, Questions or Anticipated Problems:

DISCUSSION

Advantages of Student Designed Labs

Students in these labs truly take ownership of their experiments. Initially, they are rather slow at coming up with a testable idea but with guidance, they select plan they like. It is mentioned above that the first exercise of data collecting is frustrating. However, after they learn about their own limitations and the limitations of the equipment and test subjects, they proceed enthusiastically collect some valid data. Because of this enthusiasm, many students take more time to delve into published literature and specialized physiology textbooks to get specific answers to the questions that their results have generated. It gives them a chance to apply basic physiological concepts that they have been presented in lecture and other more detailed physiological references from the literature. It makes writing these reports, and making sense of their results a personal and group challenge. Some of the explanations presented by students that bring concepts and applications together have been rewarding.

Another advantage is that group work is emphasized and required. Almost all the groups, staying together for the entire semester, cooperate well. It is suggested that they take turns writing the sections of the lab reports and most groups do this. In these groups they learn how to collect data efficiently, analyze, plot and assess it, and reflect on the results in relation to the original hypothesis. It is a good example of students teaching students, each student benefiting from the experiences of other members of the group.

Another important aspect of this kind of lab is that most of the equipment is durable, easy to operate, and inexpensive to use. With the exception of the 6 Sure-Step Blood Glucose meters which utilize strips that cost \$40 for 50, all the others (strip chart recorders used for muscle physiology, volume pulse measurements, EEGs, EMGs, ECGs, and breathing volumes) meet these criteria. Digital blood pressure cuffs by A&D Medical are portable and easy for the students to use. Respiration belts, heart rate monitors and temperature probes made by Vernier (<http://www.vernier.com>) can be connected directly to student laptop computers so that the laptops become chart recorders and data storage stations.

One other aspect of this lab planning sequence is that most student groups can adequately plan their experiment, discuss it with the instructor and attain approval in about 75 minutes. This leaves the rest of the two-hour lab available for the students to “sit around and talk physiology”. Often students do not get a chance to informally apply some of the topics presented in lecture to everyday situations. Each period a student brings in a magazine or newspaper article that includes some aspect of physiology that has been discussed or that they have questions about and the group discusses it informally. In another lab session, students bring in articles, rumors or questions about the physiology of enhancing athletic performance. Good discussions are generated between students who are athletes or students who may be interested in a daily workout plan and how it will affect them. Another important topic that is discussed in these post lab-planning sessions is the use of animals and humans in research. Possible alternatives to dissection and use of frog gastrocnemius muscles are discussed. The use of humans in clinical trials and the advantages, disadvantages and implications of placebos, gender and sample sizes are discussed. Ethical questions including when human life ends and what measurable signs of life are needed to keep an individual on life support have sparked heated discussions in the past. It gives the students a chance to ask questions, hear opinions of others, and further develop their own background knowledge and opinions on some important everyday issues in physiology and bioethics.

Pitfalls of Student Designed Labs

It is necessary to enforce the rule about the minimum number of experimental units per group. They must have a minimum of 3 units so that minimal comparative statistics can be performed. When the minimum sample size is used, the statistical tests may return the verdict of “no statistical difference between groups”; therefore, they must be urged to use as large a sample size as possible. Many students have had previous experience in which they obtained no significant difference and interpreted this to mean that they didn’t obtain reliable results or that the experiment was useless. Sometimes this may be correct but many

times students must be asked to look again to see the reason the treatment produced no significant difference.

Usually each semester complaints surface about some members not contributing equally to the group. It is necessary to monitor group activity closely during the semester and determine, by the quality of the lab reports, which members have not been performing adequately. This has continued to occur in about 10% of the groups over the past 5 years. It is difficult to prevent.

Another problem is synchronizing lecture material with its use in lab. Sometimes due to the timing of lecture, the background information that they need to design a thoughtful, effective experiment has not been covered in lecture by the time the lab planning session arrives. Alleviation of this problem can be accomplished by giving specific background information on the suggested topics in the beginning of the lab planning sessions. It is best if at least 3 lectures on the physiological topic are given before the students plan the lab on that topic.

A challenging aspect of this type of lab is suggesting new twists or variables in an experimental design. This takes imagination by the instructor, but including an unknown in the design makes the experiment more challenging and fun. For example, one of the "low energy" groups might design an experiment to test the hypothesis that "when we run

uphill, our heart rate will increase" Some variables that can be included in testing this hypothesis are utilizing people of different ages, genders, heights, leg lengths, leg diameters, before and after drinking a 16 ounce can of Mountain Dew, before and after a cigarette, or on a 75°F afternoon vs. a 25°F afternoon. Including some unknown variable, whether or not students can find specific references to it, makes it more of a challenge, and introduces them to aspects of physiology that might not have occurred to them.

CONCLUSIONS

Student designed labs at Loras College have immersed the students in the scientific method to a greater degree than any other type of lab environment in which the author has participated or discussed with other biology instructors. The teamwork, critical thinking, problem solving, data interpretation, and hypothesis-posing give the students the chance to think for themselves and use the physiological concepts in an applied context. It does increase student learning by increasing student ownership of not only the information but the process of scientific investigation. A discussion of any aspect of the lab planning sequence mentioned above or answers to any questions can be obtained by contacting the author at 563-588-7767 or tdavis@loras.edu

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Biology for Contemporary Living



A Research-Oriented Approach to Digestive Physiology to Replace Traditional Enzymatic Laboratories.

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ABSTRACT: The current trend in research-oriented education offers an opportunity to revitalize physiology laboratories. Physiology laboratory manuals have traditionally adopted a demonstrative format that typically reinforce concepts describe in lecture. This format proves to be especially limiting in digestive physiology laboratories. The initial goal of the proposed laboratory is to localize digestive enzymes within the digestive tract of cockroaches, and to develop general conclusions about their similarities to mammalian digestion. Students prepare homogenates of digestive tract segments from cockroaches and perform assays for protein, lipid, and carbohydrate digestion. This approach not only demonstrates the practicality of lecture material, but also provides a springboard for independent research opportunities.

KEYWORDS: Cockroach, Digestive Physiology, Invertase, Amylase,

INTRODUCTION

With the current focus on research-based education, physiology laboratories have to go beyond classical demonstrations to inductive approaches to physiology. The focus of laboratories and manuals alike has been on demonstrations of human physiologic concepts described in lecture using “classical” techniques and technology. This demonstrative laboratory format does substantiate lecture material, but leaves students with little more than validation of the physiologic litany from class. Traditional digestive physiology laboratories exemplify the demonstrative format currently found in many manuals. These laboratories typically involve assays of digestive enzymes purchased from a chemical supply company or involve the collection of salivary amylase from students. The former provides a good indicator of a student’s attentiveness in lecture, allowing them to confidently predict that a protease described in lecture digests proteins, amylase digests polysaccharides, and so forth. The latter’s collection of saliva in a test tube provides the same problems associated with the use of other human bodily fluids, such as blood, in a student laboratory. The following laboratory exercise describes a research-oriented approach to digestive physiology through the localization of enzymatic activity within the digestive tract of cockroaches. This laboratory not only provides students with practical application of a knowledge base developed during their undergraduate tenure, but also

acts as a springboard into independent-research projects.



Being around since the early Paleozoic Era, insects were the first animals to successfully adapt to life on land (Gordon, 1996). Undergoing adaptive radiation, a plethora of anatomical and physiological

adaptations evolved among insects that occupy copious niches on land. Considered a living fossil, cockroaches first made their evolutionary appearance 340 million years ago, during the Carboniferous Period. During this period cockroaches were suspected to be so numerous that they represented 40% of the insect life. Today there are 3,500 species of cockroaches found on every continent except Antarctica. Truly representing the diversity of insects, the cockroach family provides excellent models for anatomical and physiological investigations.

Facing the same environmental challenges as man, cockroaches share many similar anatomical and physiological features with us, as well as adaptations unique to insects (House, 1965; Barnes, 1980). Comparing the digestive organs of cockroach and mammalian systems, both share salivary glands, liver (fat bodies), esophagus, intestines, and rectum. The crop and proventriculus of the cockroach provide storage and mechanical processing of food similar to the mammalian stomach. Pancreatic contribution to digestion in mammals is shared with the gastric ceca and ventriculus of the cockroach. Enzymatic similarities between humans and cockroaches within the digestive tract include protease, lipase, and carbohydrase activities (House, 1965; Chippendale, 1978). The pH of the gastrointestinal contents of insects ranges from 5 – 8. This range precludes the physiologic activity characterized by the mammalian stomach. Rather than pepsin-like enzymatic activity, insect protease activity is characterized as being trypsin-like. Like protease activity, lipase activity also functions within specific pH ranges. Cockroach lipase has an optimal pH of 8. This optimum is typical of the cockroach midgut, however, regurgitation of gastrointestinal contents from the midgut into the crop with a pH of 5 inactivates lipase activity. Carbohydrase activity in insects is estimated to include up to 30 different enzymes, each specific for a carbohydrate substrate (House, 1965). This estimate arguably may include enzymes that cleave specific glucosidic bonds rather than specific substrates, falsely inflating the number of carbohydrases in insects. Despite years of investigation, it is also unclear where specific enzymes occur in the cockroach digestive tract (Barnes, 1980). Due to the diversity of cockroaches, and insects in general, the location and activity of digestive enzymes vary. The initial goal of the purposed laboratory is to attempt localization of digestive enzymes to specific digestive organs, and to develop general conclusions about their similarities to the functions of the mammalian digestive system. This approach to investigating the physiology of digestion not only demonstrates the application of lecture material to practical research endeavors in a controlled environment, but also provides an opportunity for independent research at the undergraduate level.

METHODOLOGY

Investigation of the function of the cockroach digestive tract can be anatomically divided into three regions (House, 1965; Barnes, 1980; Gordon, 1996), the foregut (stomodaeum), the midgut (mesenteron), and the hind gut (proctodeum). The foregut includes the mouth, esophagus, crop, and proventriculus, whereas the midgut includes the gastric ceca and ventriculus. The hindgut consists of the intestine, rectum, and anus. Anatomical sites designating the junctions between the three regions include the proventriculus dividing the foregut and midgut, and pylorus with diverticulating malpighian tubules dividing the midgut from the hindgut. Because entomology is under-represented in most undergraduate curricula, students must first become familiar with the organization of the cockroach's digestive tract prior to dissection (see Figure 1).

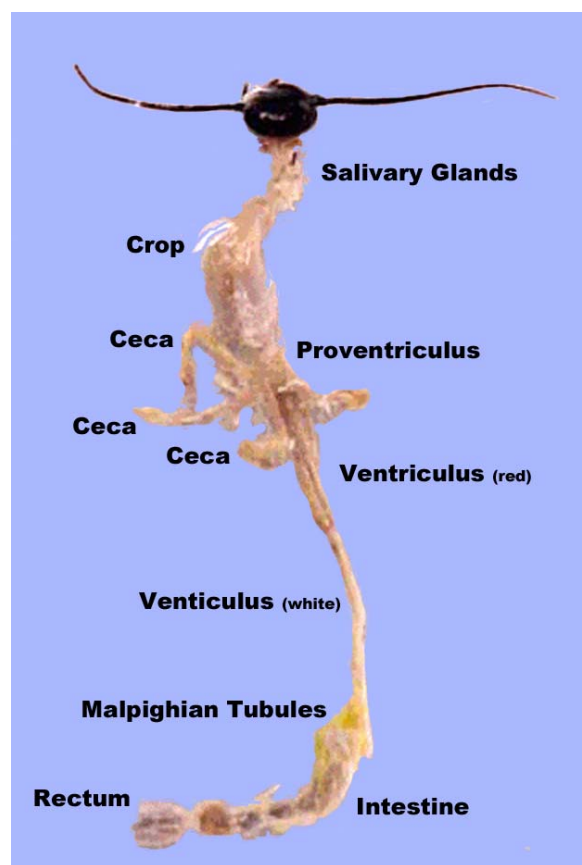


Figure 1. Anatomical organization of the cockroach digestive tract.

Cockroaches can be anesthetized using an ether or carbon dioxide chamber. Once completely anesthetized, scissors' points are placed between the junction between the third and second to last tergites. Tergites are the dorsal plates of the chitinous exoskeleton, whereas sternites are the ventral plates. Two incisions are made along each laterally arranged spiracles, continuing through to the thorax. Once the

tergites are freed from the underlying connective tissue they can be removed in one piece. By grabbing the head with a forceps and cutting the surrounding neck chitin, the entire digestive tract can be removed by gently lifting the head and freeing the attached tract moving caudally toward the anus. When the entire digestive tract is removed, it should immediately be submerged in a Petri dish containing a 0.9% NaCl solution.

After each segment of the digestive tract is positively identified, the segments can be sequentially removed for homogenization. Fat bodies (liver) intermingled with the remaining organs can also be removed and homogenized for assay. Beginning with the esophagus and attached salivary glands, the segments are placed in a Dounce homogenizer with 1.0 ml of 0.9% NaCl solution. The homogenized segments are poured into 1.5 ml centrifugation tubes, labeled, and spun down for five minutes. The pellet is discarded and the supernatant is retained for the digestive enzyme assays given below (if time does not permit assays, the supernatant can be frozen at -70°C without losing activity).

Five sets of centrifugation tubes for each nine digestive tract segments are required. Two sets of tubes will be required for protein digestive assays that consist of ninhydrin and Biuret tests. One set of tubes is necessary for a lipid assay, and two sets are needed for sucrose and starch digestion assays. The segments to be assayed are salivary gland, crop, proventriculus, ceca, ventriculus (red), ventriculus (white), intestine, rectum, and fat bodies. The ventriculus can be divided into red and white segments in Madagascar hissing cockroaches, *Gromphadorhina portentosa*, based on a clearly demarcated color change midway along the ventriculus.

Assay Procedures:

Proteins (Woodring and Dietz 1992):

- 1) Mix 100 μl of tissue solute with 100 μl of a 1.0% egg albumin solution into two sets of tubes.
- 2) Incubate both sets of tubes for 1.5-2.0 hours at 37°C .
- 3) *To one set of tubes, add 200 μl of 0.1% ninhydrin, and boil for 5-10 minutes.
- 4) **To the second set of tubes, add 200 μl of a 10.0% NaOH solution, then add an additional 200 μl of a 1.0% CuSO_4 solution.

*Ninhydrin tests positive for amino acids when purple.

**Biuret tests positive for protein when blue.

Lipids (Tharp 1997):

- 1) Mix 100 μl of tissue solute with 200 μl of litmus cream* into one set of tubes.
- 2) Incubate for 1.5-2.0 hours at 37°C .

Litmus cream tests positive for lipase when pink-pinkish blue, demonstrating a change in pH.

* Litmus cream is prepared by mixing a 0.1% aqueous litmus solution with heavy cream until a pale blue color is achieved, if too dark additional incubation time is required.

Carbohydrates (Welsh and Smith 1960):

- 1) Mix 100 μl of tissue solute to 100 μl of a 2.0% sucrose solution and place into 1 set of tubes.
- 2) Mix 100 μl of tissue solute to 100 μl of a 1.0% starch solution (sufficiently cooled after boiling) to the second set of tubes.
- 3) Incubate both sets of tubes for 1.5-2.0 hours at 37°C .
- 4) To the sucrose set of tubes add 4 drops of water, one of Fehling A solution*, one of Fehling B solution**, and then boil for 5-10 minutes.
- 5) To the starch set of tubes add two drops of iodine solution.

Sucrose digestion by invertase is indicated by an orange precipitate. Starch digestion by amylase is indicated by a brown color and lack of purple precipitation.

*Fehlig A solution: Copper sulfate, 17.3 grams, in 250 ml of distilled water.

**Fehlig B solution: Sodium potassium tartrate (Rochelle salts), 86.5 grams, in 125 ml of distilled water.

Controls:

1. Ninhydrin assay: An aqueous solution of glycine mixed with the ninhydrin solution
2. Biuret assay: The egg albumin solution mixed with the 10.0% NaOH and 1.0% CuSO_4 solutions.
3. Lipid assay: Litmus cream solution diluted with distilled water to replace the tissue solute.
4. Sucrose digestion assay: Replacement of tissue solute with a glucose solution.
5. Starch digestion assay: Substitution of distilled water for tissue solute.

RESULTS

Overall, the data collected from students reflect general trends in insect digestion (Table 1). Statistical contrasts of data collected over a two-year period tested the following null hypotheses using a Chi square test ($\chi^2_{0.05,8}$):

- 1) Digestion of protein, sucrose, and starch did not occur, therefore representative polymers were present in each gastrointestinal segment.
- 2) Protein and lipid digestion occurred in all gastrointestinal segments, which is indicated by the presence of amino acids and pH change, respectively.

Both null hypotheses were rejected, with the most striking contrast occurring between tests for amino acid and protein in the salivary gland, proventriculus, rectum, and fat bodies. Each of the mentioned gastrointestinal segments demonstrated a high incidence of protein and low incidence of amino acids in tested samples. This indicates little to no protein digestion occurred in these segments, however, the crop, ceca, ventriculus (red and white), and intestine equally exhibited both amino acids and proteins. This latter trend indicates active protein digestion in those segments.

Similar to mammalian salivary glands, those in the cockroach begin the process of carbohydrate digestion. Unlike mammals, the salivary glands of the cockroach appear to also have lipase activity. This

phenomenon is not uncommon amongst many insect families, as well as amongst different species within insect families (House 1965). The ceca and ventriculus demonstrate the pancreatic ability described above, contributing to the break down of protein, lipids, and carbohydrates. Significant histological features have not as yet been identified to explain the color difference between the red and white regions of the ventriculus. Although trials that are more experimental are required, the present trend suggests a tapering in enzymatic digestion in the white segment of the ventriculus that continues with the proceeding intestinal and rectal segments. This is indicated by the declining activity noted in the amino acid, lipid, sucrose, and starch assays (Table 1).

Table 1. Summary of results from 23 cockroach (*Madagascar hissing cockroach, Gromphadorhina portentosa*) experiments performed over a two-year period. The ninhydrin and Biuret tests were used to detect the presence of amino acids and protein, respectively. Lipid, sucrose, and starch digestion were detected via pH change, precipitation of monosaccharides, and color change, respectively. Chi square test ($\chi^2_{0.05,8}$) performed on data reject null hypotheses: 1) Digestion of protein, sucrose, and starch did not occur, and 2) Protein and lipid digestion occurred in all gastrointestinal segments.

Region	Presence		Digestion		
	Amino acid	Protein	Lipid	Sucrose	Starch
Salivary Gland	0	21	11	13	9
Crop	16	16	14	16	15
Proventriculus	5	17	7	17	14
Ceca	14	18	9	17	14
Ventriculus (red)	19	14	13	23	17
Ventriculus (white)	17	20	11	17	9
Intestine	10	13	2	7	11
Rectum	1	13	6	3	8
Fat Body	5	15	8	8	8

Further contrast amongst carbohydrates and its monomers is necessary before definitive statements about carbohydrate digestion can be made. Future laboratory experiments will include Benedict's test on aliquots taken from the starch homogenates. This will allow contrast between starch and its monomer glucose, in a similar fashion to that made between amino acid and protein assays above. Since the lipase activity is indicated by a pH change, direct assay of the breakdown of lipid into glycerol and fatty acids is not practical, nor cost effective.

Pooling of data from students enrolled in the physiology laboratory introduces a certain degree of error into the cockroach digestive laboratory. Student's dissection skills, ability to aliquot samples, laboratory experience, and degree of ongoing socializing all contribute to error in reporting precise results. Likewise, the cockroach's digestive physiology also contributes to this error. Chyme from the ventriculus can be regurgitated through the

proventriculus into the crop (House 1965, Barnes 1980). Regurgitated chyme and its accompanying ventricular enzymes stored in the crop not only permits more time for digestion to take place, but may also account for the digestive activity demonstrated by the assays performed on the crop. Variability of digestive activity in the crop, as well as other organs, may be accounted for by the students thoroughness in washing away potentially regurgitated chyme, reproductive status of the roach, or the roach's diet. Enzymatic activity along insect digestive tracts has been noted to change in response to altered metabolic demands of gamete production, as well as substrate availability based on the composition of the roach's current food.

CONCLUSION

The digestive protocol discussed above was incorporated into the physiology laboratory (Bio 464) at the University of Detroit Mercy for the last two years. Comparison of grades from students

participating in the cockroach laboratory was on average slightly higher than those of students participating in the traditional digestive laboratory or not enrolled in the laboratory. The slight difference in students' percentage grades on lecture exams made the difference between a B and B- for overall class averages for the research-based laboratory student group and traditional laboratory/ no laboratory student group, respectively. This trend, although not statistically significant, may be attributed to the additional effort required of students to search the library and internet for information on insect and mammalian digestive physiology necessary for comparative analysis for their laboratory reports. The guideline for the students' laboratory reports is taken from the *American Journal of Physiology's* author's guide. Exposure to research-based laboratories and report format has not only provided an impetus for undergraduate students to develop independent research projects, but has also aided our graduates in their professional pursuits. Anecdotes from graduates pursuing careers in medicine, dentistry, and research claim that this format prepared them on a professional level for the research expectations required of them. The trend toward research-based laboratory is not only replacing the traditional demonstrations of systemic physiology, but offering a variety of opportunities for students that is limited only by ingenuity.

QUESTIONS TO ASK:

1. How does the pH of the digestive tract's regional contents vary between humans and cockroaches?

2. What does the variety of digestive enzymes discovered indicate about the diet of the cockroach species studied?
3. Are there similarities in the sequence of enzymatic activity along the digestive tract between humans and cockroaches?
4. Is there a correlation of the functions of the mammalian GI tract organs and glands with those of the cockroach.

FURTHER RESEARCH:

1. Determination of different pH optima of localized enzymes or homogenates.
2. Contrast homogenate enzymatic activity with gut content (chyme) activity.
3. Tract motility with carmine or carbon powder, altering it with various parasympathetic/sympathetic agonists and antagonists to time passage rate.
4. Starved versus fed (altering diet content) contrast.
5. Contrast male and female distribution patterns of enzymes. Many female insect species have additional enzymes along the GI tract apparently to meet the metabolic demands of egg production.

ACKNOWLEDGMENTS:

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Call for Nominations

President-Elect, Secretary & Steering Committee Members

ACUBE members are requested to nominate individuals for the office of President-Elect and two at large positions on the ACUBE Steering Committee. Self-nominations are welcome.

If you wish to nominate a member of ACUBE for a position, send a Letter of Nomination to the Chair of the Nominations Committee: Dr. Janet Cooper, Biology Dept., Rockhurst University, Kansas City, MO 64110, (816) 501 4237, janet.cooper@rockhurst.edu.



ACUBE 47th Annual Meeting

Truman State University

Kirksville, MO

October 9-11, 2003

Biology for Contemporary Living

Call for Abstracts

Living in the contemporary world requires an ever-increasing need for biological information and understanding. Students are facing issues such as emerging diseases, spread of invasive species, stem cell research, loss of habitats and species, and implications of the human genome project. How are we meeting the need to educate students in a biocomplex world?

Presentations and workshops addressing other topics are welcome; here are some examples of potential presentations:

Bioinformatics

Research with students

Using case-based learning and current issues

Labs that work/Field courses that work

Characteristics of our students as learners

Curricula: content/method/delivery/assessment

Preparing K-12 teachers/biologists/citizens etc.

Interdisciplinary courses and problem solving

Influencing public policy as informed by science

Approaches to teaching evolution

Many of you have addressed these issues in creative ways. Please consider sharing your ideas and techniques at the ACUBE 47th Annual Meeting at Truman State University in Kirksville, MO in 2003.

Please email your 200 word abstract AND mail a hard copy of the abstract with the completed form BEFORE May 31, 2003 to

Lynn Gillie, Division of Math and Natural Science, One Park Place, Elmira College, Elmira, NY 14901

Ph: 607-735-1859 Fax: 607-735-1947 email: lgillie@elmira.edu

Proposed Title: _____
(please print clearly)

Presentation type: _____ 90 minute workshop _____ 45 minute paper _____ Poster
(rank your choice)

Equipment/facility needs: _____ 35 mm slide projector _____ Overhead projector
_____ Macintosh projection system _____ Macintosh computer lab
_____ PC projection system _____ PC computer lab
_____ Other: (explain)

Name of presenter: _____

Work address of presenter: _____

Phone No. presenter: _____ email _____

Please include names and contact information for additional presenters on back.

The Bacterial Ribonucleic Acid (RNA)

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ABSTRACT: This article discusses the bacterial RNA cycle in soil from the perspective of persistence of extracellular RNA in soil and RNA as a nutrient source for other microorganisms.

KEYWORDS: RNA nucleic acid, cycles, microorganisms, nutrient, persistence, soil

INTRODUCTION

What happens to RNA (ribonucleic acid) when a bacterial cell dies and releases its cellular contents into the soil environment? Do extracellular RNases degrade it? Do other microorganisms use the RNA as a nutrient source? We will discuss these questions in this paper.

The major role of RNA in the bacterial cell is protein synthesis, and the site of protein synthesis is the ribosome. The bacterial ribosome is composed of two subunits, the 30S (Svedberg units) and 50S. Each subunit contains proteins and specific ribosomal RNAs (rRNA). The bacterial 30S subunit contains approximately 21 proteins and 16S rRNA, while the bacterial 50S subunit contains a 5S and 23S rRNA and about 34 proteins. Transfer RNA (tRNA) brings the individual amino acids to the ribosome where the messenger RNA (mRNA) sequence is translated into a protein sequence. Protein synthesis at the ribosomal site follows four steps, initiation, elongation, termination-release and polypeptide folding (Madigan *et al.*, 1997).

Of the three RNAs, tRNA and rRNA are the most stable. However, they are not as stable as chromosomal DNA and are replaced during the lifetime of a bacterial cell. Messenger RNA has a half-life measured in minutes. Transfer RNA and ribosomal RNA account for 90-95% of the total amount of RNA in the bacterial cell, the remainder being mRNA (Kjeldgaard 1967). The cellular content of RNA is closely tied to the growth and physiology of the bacterial cell.

RNA CYCLING IN SOIL

Persistence of extracellular RNA

When a bacterium in soil lyses, what happens to the RNA? Does it degrade or can RNA persist outside the bacterial cell? There has been some research on the persistence of extracellular DNA in soil but little is known about RNA. DNA and RNA are similar in that both possess a negative charge and both are composed of nucleotides, differing only in the sugar and one base. DNA is double stranded while RNA is single. Despite these minor differences, factors affecting persistence in soil could be the same for both macromolecules.

In general, nucleic acids (RNA and DNA) released from dead cells are quickly digested by RNases and DNases, respectively, in soil, sediment and aquatic environments (Greaves and Wilson, 1970; Novitzky, 1986; Paul *et al.*, 1989; Romanowski *et al.*, 1992, 1993). However, various studies have shown that DNA, and most likely RNA, do persist in the soil environment for varying lengths of time (Greaves and Wilson, 1970; Recorbet *et al.*, 1993; Romanowski *et al.*, 1992, 1993). Extracellular DNA can form complexes with soil particles (Lorenz and Wackernagel, 1994) protecting it from enzymatic degradation. An anionic polymer, which could be DNA or RNA, will adsorb to negatively charged soil and sediment particles via cation bridging. Results from experiments by Demanèche *et al.* (2001) suggested that nucleases also become bound to clay particles, separating the DNA and enzymes physically so that the nucleases cannot degrade the DNA. If the sites on the clay particles become saturated with nucleases then the DNA is no longer protected.

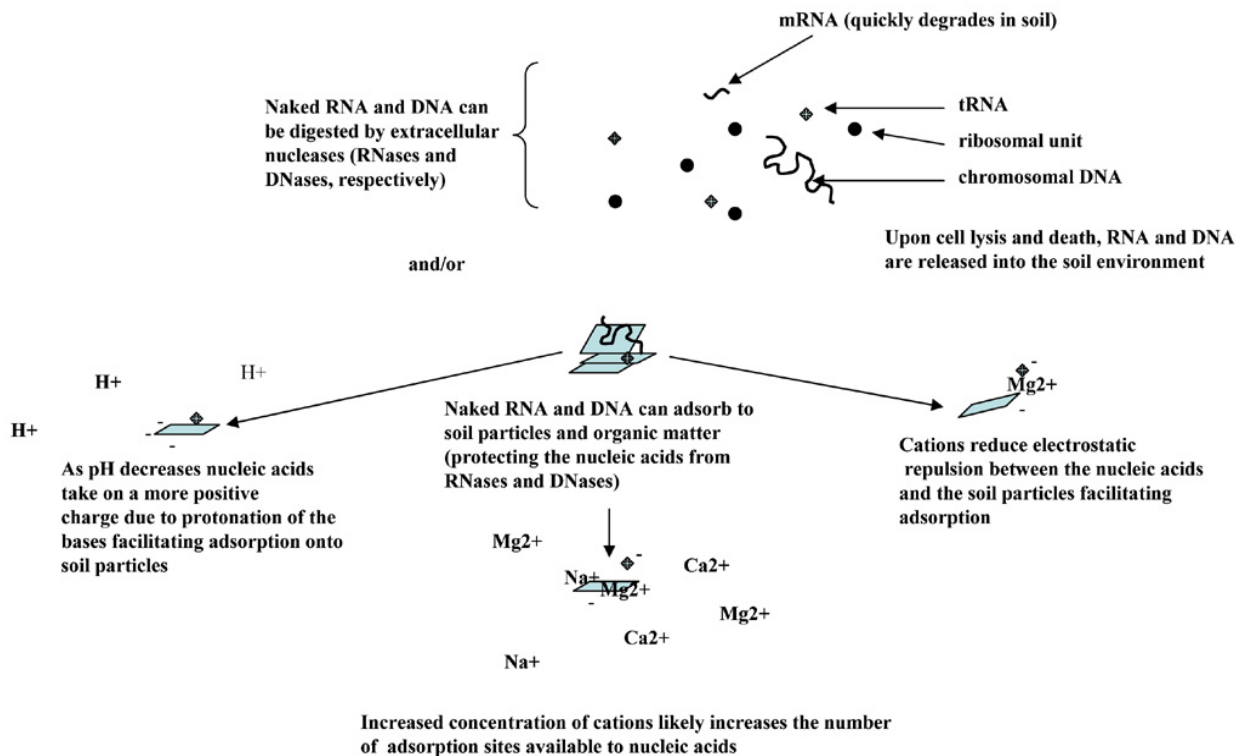


Figure 1. Factors affecting the persistence of nucleic acids in soils.

Numerous factors affect the rate and extent of adsorption of nucleic acids, and in turn may affect the persistence of DNA and RNA. These factors include the pH of the bulk phase, valence and concentration of cations and type of mineral in the soil (Lorenz and Wackernagel, 1994). The capacity of various soil minerals to adsorb DNA varies. Lorenz and Wackernagel (1992) reported that although bentonite clay made up only 0.6% (wt/wt) of the mineral material in a sand-clay microcosm, 60% of the DNA was adsorbed to the bentonite. Research has shown that adsorption of nucleic acids to soil particles increases with decreasing pH (Greaves and Wilson, 1969; Ogram *et al.*, 1988; Romanowski *et al.*, 1991; Khanna and Stotzky, 1992). As the pH decreases, nucleic acids take on a more positive charge due to protonation of the bases, resulting in an increased attraction to negatively charged soil particles (Greaves and Wilson, 1969). Divalent cations have been reported to increase the adsorption of nucleic acids to montmorillonite and sand more than monovalent cations (Greaves and Wilson, 1969; Lorenz and Wackernagel, 1987; Romanowski *et al.*, 1991; Paget *et al.*, 1992). In addition, increasing the concentration of cations has been observed to increase adsorption (Lorenz and Wackernagel, 1987; Romanowski *et al.*, 1991; Paget *et al.*, 1992). Cations, whether mono-, di-, or multivalent, act as cationic or positively charged bridges between the anionic or

negatively charged nucleic acids and soil particles (Theng, 1979; Hesselink, 1983).

Is there any evidence that RNA persists in the environment? Extracellular RNA has been found in concentrations of 6.67 to 192.8 µg/l in coastal and estuarine waters and 4.03 to 13.9 µg/l in open ocean waters (Karl and Bailiff, 1989).

RNA as a nutrient source in soil

The presence of naked or extracellular bacterial RNA in soil originates from bacterial cells upon lysis and death. Bacterial ribosomal and transfer RNA may be present in higher concentrations in soil than messenger RNA due to the higher concentration of the former in the cell. As mentioned previously, extracellular nucleases often digest naked RNA producing short oligonucleotides. The oligonucleotides can undergo hydrolysis by nucleoside-catabolizing enzymes to yield nucleosides that are actively transported across the bacterial cell membrane into the cells (Stewart and Carlson, 1986).

Most bacteria can synthesize their own nucleotides; thus, what is the reason they transport nucleosides into the cell? Bacteria may use nucleosides for something other than nucleic acid synthesis. Once inside the cell the nucleosides undergo either hydrolytic or phosphorolytic cleavage separating the sugar (ribose) from the base (Hammer-Jespersen,

1983). The sugar is catabolized and the bases are either catabolized or reincorporated into nucleic acids (Stewart and Carlson, 1986). Bacteria use the products as sources of nitrogen and carbon. Purines, pyrimidines, ATP (adenosine triphosphate), NAD⁺ (nicotinamide adenine dinucleotide) and FAD (flavin

adenine dinucleotide) are examples (Madigan *et al.*, 1997). The phosphate molecules left behind in the soil, after the nucleosides are transported across bacterial cell membranes, may enter the soil phosphorus cycle. Figure 2 is a schematic representation of the RNA cycle in soil and its role as a nutrient source.

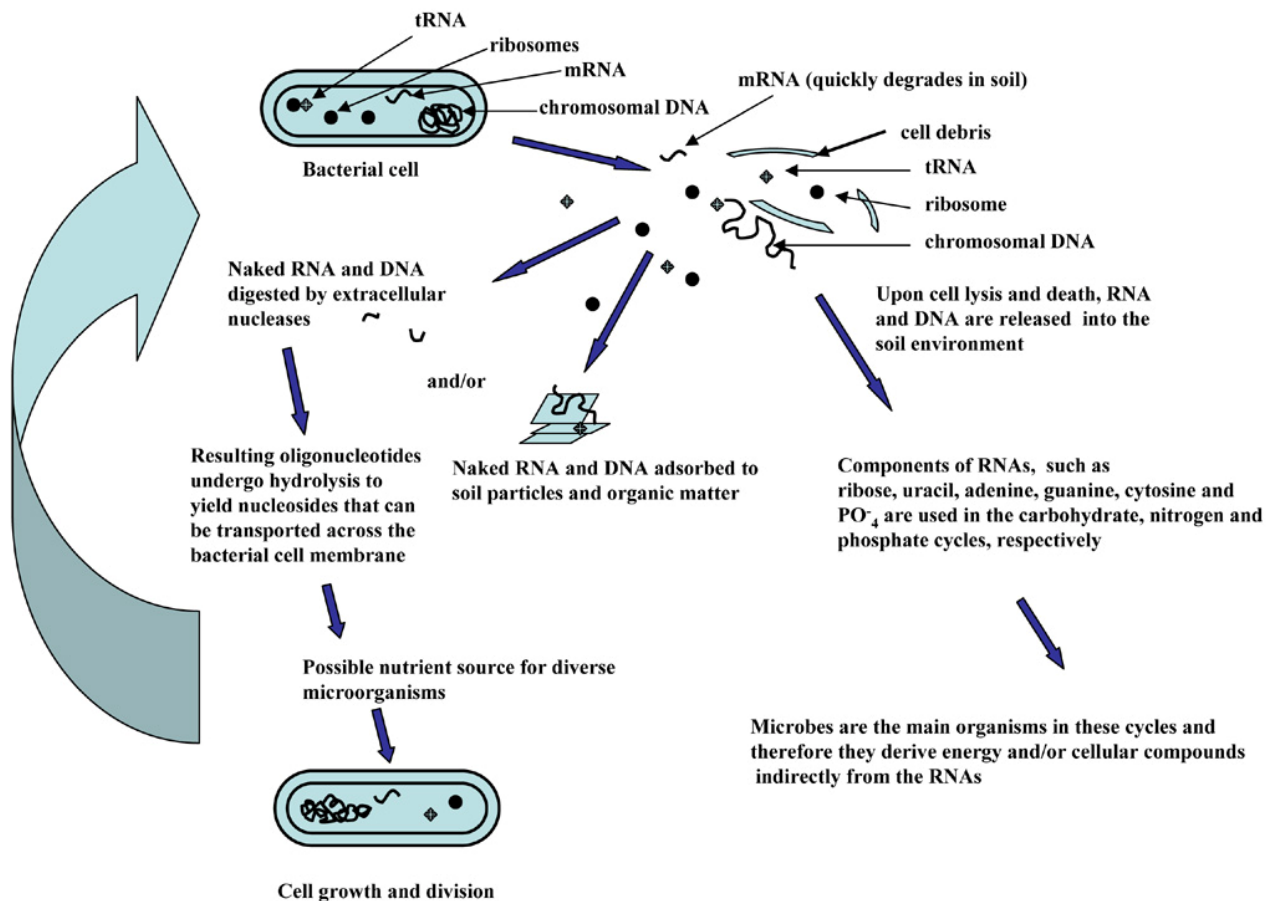


Figure 2. RNA cycle in soil.

RNA nucleosides, not taken up by bacterial cells, and RNA phosphate molecules can enter the carbon, nitrogen, and phosphorus cycles. Microbes are the primary organisms in these cycles and therefore they derive energy and/or cellular compounds indirectly from the RNAs.

It is possible that other microbes also utilize RNA as a nutrient source. Protozoa, amoebae in particular, are abundant in soils and actively seek bacteria, other protists and detritus as food sources.

SUMMARY

Nucleic acids have long been looked upon as sources of nitrogen, phosphorus and carbon in the soil.

They play a part in nutrient cycling (Lorenz and Wackernagel, 1994). The two major factors limiting microbial activity in soil are water and nutrients. In some soils, inorganic nutrients such as phosphorus and nitrogen are the limiting nutrients (Madigan *et al.*, 1997).

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Call For Resolutions

The Steering Committee of ACUBE requests that the membership submit resolutions for consideration at the 2003 Annual meeting to the Chair of the Resolutions Committee. Submit proposed resolutions to: Dr. Richard Wilson, Dept. of Biology, Rockhurst University, 1100 Rockhurst Rd., Kansas City, MO 64110, Phone (846) 501-4048, wilson@vax1.rockhurst.edu

Faculty Assumptions about the Student Characteristics Required for Success in Introductory College Biology

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ABSTRACT: The transition from secondary to post-secondary science courses is characterized by low student retention rates (fifty percent). First-year college student difficulties may be related to an incongruity between secondary student preparation and post-secondary faculty requirements. The purpose of this study was to learn how well matched secondary and post-secondary teacher assumptions were about the student characteristics required for success in introductory college biology courses. Faculty participants were interviewed, engaged in focus groups, developed tables of specifications for student requirements, and responded to surveys. The results of this study indicate that secondary and post-secondary faculty have differing assumptions about the importance of certain student characteristics. The study further showed that communication improved the agreement on some assumptions between the two groups. The results point to future research possibilities and to educational implications for retention.

KEYWORDS: Science Education, Higher Education, Instructional Design, Faculty Expectations, Science Curriculum Development, Retention in Science, Transition to College, Faculty Requirements, Higher Education Retention, Assessment in Science.

INTRODUCTION

Cultural Transition

First-year college students are incorporated into a culture of learning qualitatively different from their secondary schools' (Upcraft and Gardner, 1989; Tinto, 1993). The cultural change from secondary to post-secondary education causes social and academic student difficulties (Tinto, 1993; Razali and Yager, 1994; Seymour and Hewitt, 1997). The transition to college is characterized by academic problems for first-year students that contribute to deleterious effects on undergraduate first-year student retention rates (Tinto, 1993).

The Leaky Pipeline

The academic difficulties students face in the sciences are a national concern. The National Research Council (1996) points out a twenty-five year decline in freshman interest in choosing majors in undergraduate science, with potential majors particularly dissatisfied during the transition from high school to college science programs. The highest risk of loss of student science majors occurs at the end of the first year of college, when only about half of high school seniors

who declared science majors remain majors (Seymour and Hewitt, 1997; National Research Council, 1996). Moreover, very few students transfer into science majors after college enrollment and there is always a net loss (Hilton and Lee, 1988). Thus the sciences have the highest attrition rates of any undergraduate major and also the lowest rates of recruitment of any other major (National Science Foundation, 1996).

The consequence of the difficulty in improving retention rates, particularly among first-year college biology (life science) majors, may produce a variety of harmful effects on the society. For example, leaks in the science student pipeline are linked to declines in scientific literacy for adults (National Research Council, 1996). Such declines also contribute to reduced numbers of qualified individuals available for life science teaching, research development, and technological advancement.

Introductory Courses

The introductory science courses have the poorest student retention rates in undergraduate sciences. They offer the first opportunity for students

to face the academic demands of college science (Mitchell, 1990). Therefore, students must enter introductory courses with the prerequisite knowledge, skills, and dispositions to enable them to successfully engage in the required activities of these courses.

Post-secondary teachers design their introductory courses with certain assumptions about the characteristics of their incoming students (Mitchell, 1990). Current research also documents that secondary school science teachers intend to base their instructional and curricular goals on requirements of college instructors of freshmen students (Yager, Snider, and Krajcik, 1988; Mitchell, 1990). The K-12 science education is, therefore, inherently linked to undergraduate education; for “a sound curriculum in the college years cannot be developed unless students are given a solid elementary and secondary science background on which to build” (National Research Council, 1996, p. 35).

The clear and effective matching of faculty requirements with incoming student characteristics is strongly related to undergraduate student success (California Higher Educational System, 1984). Although a variety of instructional factors have been cited in the literature that contribute to low retention rates among biology majors, an obvious determinant for student success is the degree of match between introductory course expectations and incoming student preparation.

“There are many myths about what colleges expect” and about “what experiences in high school make a difference in college” (Yager, 1986, p. 24). Improved communication between secondary and post-secondary faculty might dispel the myths and smooth student transition from high school science courses to college life sciences. However, related research shows few empirical studies exploring communication between secondary and post-secondary biology faculty and their relative assumptions about the preparation needed for success in college biology.

Do Faculty Assumptions Matter for the Transition to College?

Differences may exist between what post-secondary faculty assumes about their incoming students’ characteristics and what the secondary preparation actually produces in terms of student characteristics. The current poor retention rates among first-year college biology majors may result from an inability of instructors to determine the appropriate learning goals for their incoming students (Seymour and Hewitt, 1994; Barrowman, 1996). If post-secondary teacher requirements do not match what they assume entering students actually know and are able to do, there would be an inherent obstacle to success.

This study shows that secondary and post-secondary teachers have different assumptions about the academic student characteristics required for success in introductory college biology. This

difference may result in a lack of agreement on what constitutes good preparation for college. The disparity in preparation may be a reason for the academic culture shock students experience during their transition from secondary to post-secondary education (Tinto, 1993; Chaskes, 1996).

Although serious deficiencies in biology education have been recognized by the scientific community, few research studies have addressed the importance of specifying faculty assumptions about the student characteristics required for success in post-secondary life science courses. Therefore, the purpose of this study was to document high school biology teachers’ assumptions about the knowledge, abilities, and dispositions required for success in introductory college biology courses and the degree to which their assumptions match those of faculty who teach these courses.

THE RESEARCH QUESTIONS

This research study measured the congruence of secondary and post-secondary faculty assumptions about the student characteristics required for success for first-year college biology students. Specifically, the study sought to answer the following questions:

1. What are secondary biology teachers’ assumptions about the knowledge, abilities, and dispositions required for success in introductory college biology (life science) courses?
2. What are the post-secondary biology teachers’ assumptions about the knowledge, abilities, and dispositions required for success in introductory college biology (life science) courses?
3. Are secondary biology teachers’ assumptions about the knowledge, abilities, and dispositions required for success in introductory college biology (life science) courses the same as those of post-secondary biology teachers’?

METHODOLOGY

Overview

This study utilized an ethnography-based methodology that employed open-ended questioning in interviewing participants based on Glesne and Peshkin (1992) and Seidman (1998), focus group interactions according to recommendations by Edmunds (1999), and a data analysis procedure based on Strauss and Corbin (1998). First, faculty were interviewed individually and the results of the interviews summarized. Then faculty participants met in cohort focus groups to discuss the summary data. During the final focus group meeting, all participants ranked and rated their expectations on a student characteristics survey. An overview of the methodology is given in Appendix B.

Participant Selection

Participants were identified and recruited based on their willingness and availability to take part in the

study. These convenience samples consisted of seven life science faculty who teach introductory biology, three from two high schools, two from a two-year college, and two from a four-year college. All institutions were located in the Northeast. The term used for the sequence of educational institutions in this study is a "feeder unit", which instructs a population of students through successive stages of secondary and post-secondary curriculum.

Interviews

Because a main objective of this study was to identify what student characteristics are perceived as important for introductory college biology courses, a researcher-developed set of open-ended interview questions was prepared (Glesne and Peshkin, 1992; Seidman, 1998). The same ten questions were asked of each participant individually during a 45-minute period. The aim was to facilitate later discussion of faculty requirements in relation to preparation for and retention of first-year college students in introductory college biology courses. The questions are given in Appendix C.

Focus Groups

The same interviewed participants were then asked to participate in group interviews focusing on their assumptions about the student characteristics required for success in first-year college biology. This interaction is termed a "focus group" and is described by McMillan (1999) as "...most useful for encouraging subjects, through their interaction with one another, to offer insights and ideas about a concept, idea, value...about which they are knowledgeable" (p. 221). The focus group interactions followed the recommendations by Edmunds (1999) for focus group procedures. A list of prompt questions for focus group meetings was one outcome of the interviews and was included in the discussion guide for the focus group to facilitate discussion. The specific focus group protocol used in this study is given in Appendix D.

Three focus groups were conducted; a) only the secondary faculty, b) only post-secondary faculty, and c) both groups of faculty, all seven participants. Each focus group's interactions lasted about ninety minutes.

A survey of student characteristics (developed from interview responses) was ranked and rated by the participants at both the beginning and end of the heterogeneous focus group. The survey is given in Appendix E. During the heterogeneous focus group, participants also composed a table of specifications for student characteristics important for success in introductory college biology courses. The table is given in Appendix A.

Data Analysis

The analysis of interview and focus group transcripts used a coding system to classify and categorize the data as recommended by Strauss and Corbin (1998). A coding system is defined as the

formal classifying and categorizing of data to produce form and possible meaning (Glesne and Peshkin, 1992). The data analysis required conceptualizing defined categories (or codes) for the data, and refining those categories in terms of their properties (characteristics of the categories) and dimensions (the intensity of that characteristic along a continuum) to build theory. "Events, happenings, objects, and actions/interactions that are found to be...similar or related in meaning are grouped under...categories" (Strauss and Corbin, 1998, p.102) and in this study, faculty assumptions about student characteristics comprised the central codes.

A researcher-developed codebook organized the codes so that each data piece received a code name and number to identify a central idea or concept. The code book was used to identify and categorize relevant data. A reexamination of the codes and data were performed after each stage of the study to determine the range of potential meaning of the data, as suggested by Strauss and Corbin (1998).

As a final step in the analysis, a simple frequency count of the coded themes was taken to identify the relevant trends. A visual representation of the participants' responses was also developed using a matrix. This aided in the triangulation of the findings from the interviews, focus groups, and tables of specifications (Glesne and Peshkin, 1992).

Match of Research Questions and Methodology

The focus of this ethnographic approach was on collaboration and participant communication, a main benefit of matching this methodology with the research questions. Because the related literature attributes the mismatch of student science preparation between high school and college to a lack of communication among faculty, this kind of ethnographic methodology sought to ameliorate the problem at the local level. The methodology fostered communication among participating faculty members as a first step in bridging the gap between secondary and post-secondary life sciences. It compelled faculty to come to consensus on the importance of certain student characteristics within their cohort groups and then to confront their viewpoints with another group. It thereby required secondary and post-secondary participants to develop group positions and relationships and then to defend their assumptions in a possibly disagreeable environment. Simple communication among faculty might have been less effective in uncovering the degree to which the secondary and post-secondary group assumptions did or did not match.

RESULTS

Results of this study are divided into four sections: 1) The frequency with which secondary and post-secondary faculty mentioned student characteristics; 2) Faculty rankings of student characteristics; 3) Table of Specification for Student

Characteristics (Appendix A); and 4) Themes emerging from the research.

Frequency of Faculty Responses

Frequency of faculty-mentioned assumptions about the student characteristics important for success in introductory college biology is depicted in Figure 1. The data suggest that secondary faculty valued most highly: reading comprehension, grasp of biology vocabulary, interpersonal communication, self-discipline, and Latin as requirements for introductory college biology students. On the other hand, the data show that college faculty valued most highly: writing ability, integrating biology with other courses, mathematics skills, and an ability to ask questions.

Faculty Rankings of Characteristics

Participants individually ranked a list of student characteristics (Appendix E), in order of importance, for students entering introductory college biology. Participants ranked the list twice, the first ranking before and the second ranking after the heterogeneous

focus group meeting. The secondary faculty group ranked higher (by over five points compared with the post-secondary group) these characteristics: perseverance, self-confidence/self-esteem, time management, independence in studying, and delay of gratification. The post-secondary faculty group ranked higher (by over five points) these characteristics: basic mathematics, algebra, writing, chemistry knowledge, physics, and problem solving.

The relationship of secondary and post-secondary group mean rankings of characteristics for the first exercise is shown in Figure 2. A regression analysis comparing secondary and post-secondary group rankings reveals an r-squared value = 0.1501. This indicated that before the heterogeneous focus group experience, faculty shared a 15% relatedness overall in their ranked assumptions about the importance of listed characteristics for students entering introductory college biology

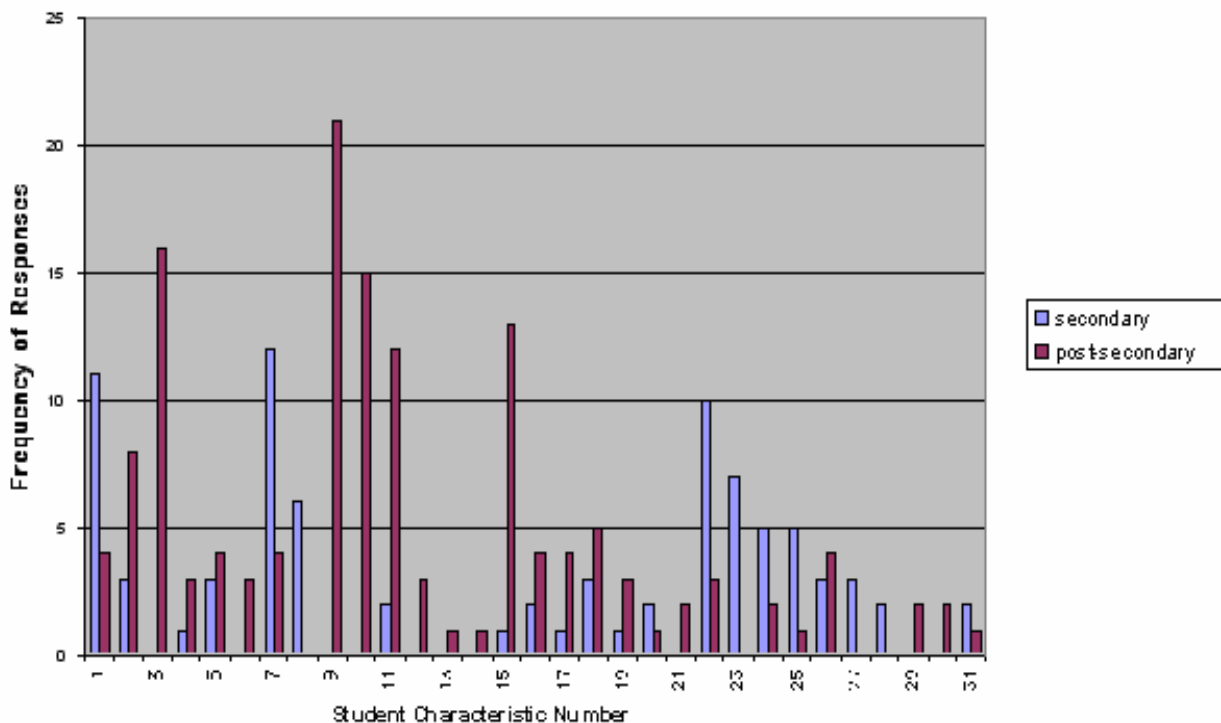


Figure 1. Frequency of Interview Mention. Note. Student Characteristic Number: 1. Definitions of biology terms; 2. Knowledge of biology concepts; 3. Integration of biology within subject and across curriculum; 4. Applying biology to real life; 5. Basic Hands-on lab knowledge and abilities; 6. Chemistry knowledge; 7. Reading Comprehension in science; 8. Knowledge of Latin; 9. Writing Skills; 10. Math to decimals/fractions; 11. Math to algebra; 12. Math to statistics; 13. Math to calculus; 14. Physics knowledge; 15. Asking questions; 16. Studying in groups; 17. Explaining biology to others; 18. Organization of information; 19. Separating Information; 20. Notetaking; 21. Time management; 22. Communication; 23. Self-discipline; 24. Perseverance; 25. Self-Confidence/Self Esteem; 26. Enthusiasm; 27. Independence; 28. Delay of gratification for results; 29. Critical Thinking; 30. Problem solving; 31. Computer skills.

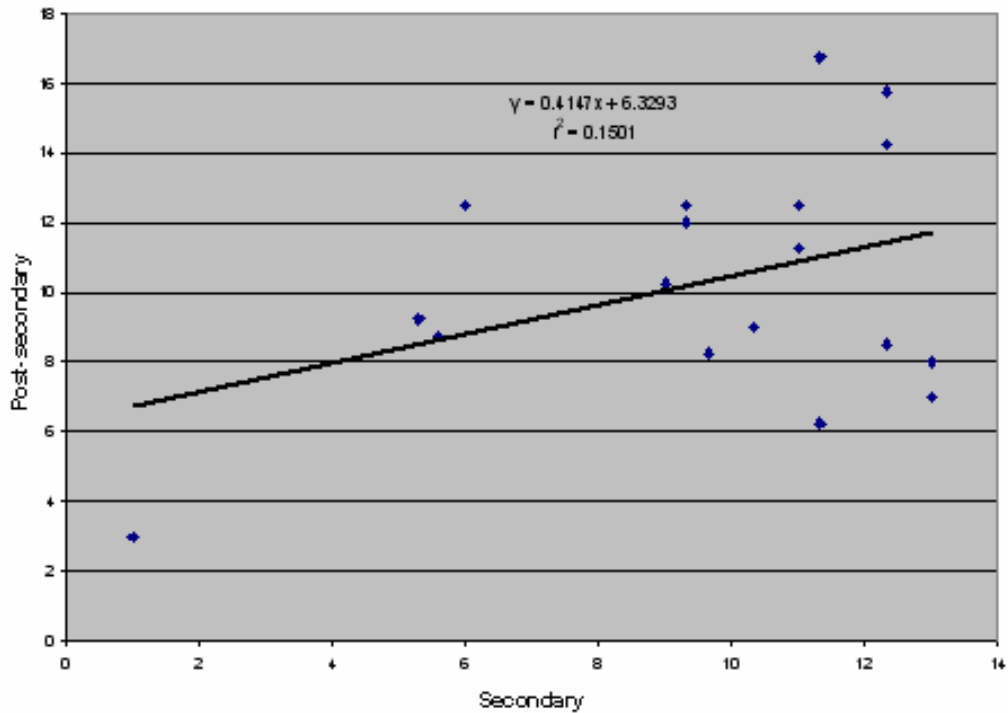


Figure 2: Relationship of Secondary/Post-secondary Pre-Heterogeneous Focus Group Rankings. A regression analysis comparing the secondary and post-secondary group rankings for the second exercise reveals an r-squared value = 0.3429. This value indicates a relatedness of 34% in the scores between the two groups after the heterogeneous focus group meeting. Comparing pre- and post-heterogeneous focus group scores shows an increase in relatedness of rankings by 19%.

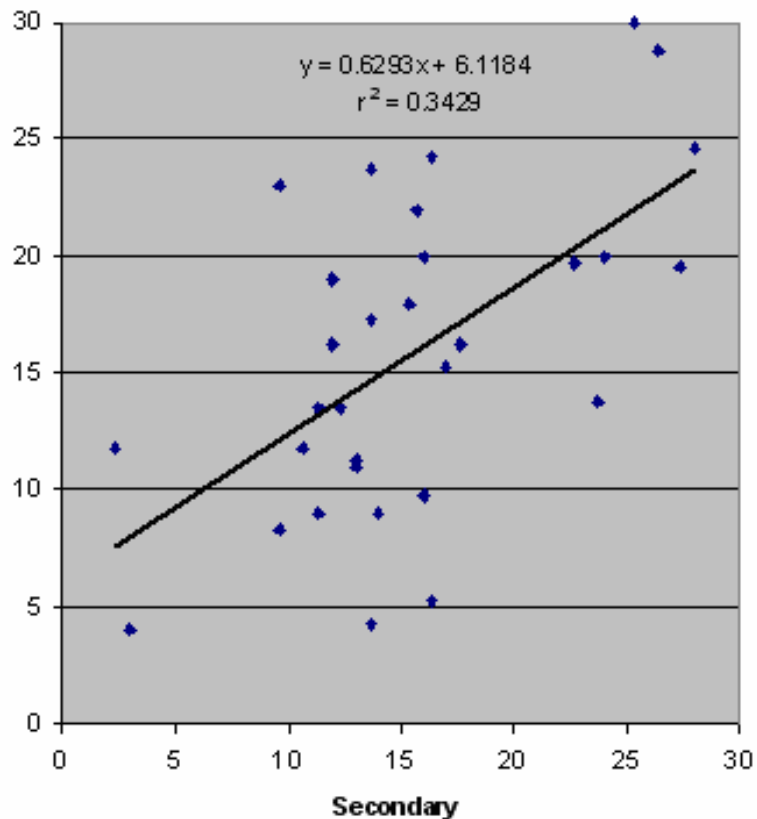


Figure 3. Relationship of Secondary/Post-Secondary Assumptions in Post-Focus Group Rankings.

Table of Specifications for Student Characteristics

A product of the heterogeneous focus group interaction was the cooperative development of a table of specifications of characteristics important for student success in introductory college biology. The table is a list of characteristics that includes those agreed on by the secondary and post-secondary participants to be important knowledge, abilities, and dispositions for students entering introductory college biology. The table of specifications is shown in the Appendix A. They are not listed in order of importance, and each student characteristic is followed by specific enumeration of the parts that should comprise each characteristic.

Themes Emerging From The Research

Although the faculty collectively produced a table of specifications for their assumptions about the student knowledge, abilities, and dispositions important when entering introductory college biology, there was disagreement as to the relative importance of many student characteristics. This section includes the four themes emerging from the study: ***Isolation of the Secondary Faculty, Blame Placed on Secondary Faculty by Post-secondary Participants, Epistemological Differences Underlying Faculty Expectations, and Communication for Bridging the Gap.***

Isolation of the Secondary Faculty

During the study, secondary participants consistently expressed uncertainty about what post-secondary participants expect of the students being prepared for introductory college biology. When asked by the researcher about what knowledge and/or abilities were important for students to have when entering introductory college biology, one respondent first answered, "I don't know since I'm not a college teacher..." and another expressed that he was "... so far away from [college biology]. When I graduated, it was years ago. I am not up with technical aspects of today." When asked about study skills requirements for introductory college biology, the secondary participant who taught an AP biology course first answered, "I wish I knew." This isolation was demonstrated as secondary participants placed high importance on characteristics that post-secondary participants considered outdated, namely Latin knowledge, vocabulary learning, and note-taking skills.

In the interviews, all secondary participants mentioned the importance of Latin knowledge as a necessary academic characteristic for future college biology students. Its importance was based on nomenclature and vocabulary learning, with comments offered by secondary participants such as, "words are thrown at you in college, and with Latin you can probably figure out where they are coming from" and "it can be useful for scientific names." Another recognized that the prerequisite may have changed by stating, "I found it disappointing when colleges

stopped requiring it for biology majors," but continued to express its importance for contemporary students. When the post-secondary faculty confronted secondary members with comments such as "I don't think it has any value in today's courses...there's very little taxonomy for its use" and "not important", the secondary group offered little of their previous position except for a dismissed comment, "It shouldn't be a requirement but it's very beneficial." The post-secondary participants considered the secondary emphasis more or less out-of-date, indicating a temporal isolation of secondary faculty from current requirements.

The secondary faculty also stressed biology vocabulary knowledge as an important characteristic during the interview and focus group interactions. In numerous statements, every secondary faculty participant described good preparation for college biology as the successful learning of a common vocabulary. The post-secondary faculty however showed a low frequency of mention for this characteristic during the same interactions (see Figure 1).

A difference in emphasis on biology vocabulary between secondary and post-secondary faculty was most clearly demonstrated during the heterogeneous focus group interaction. A secondary participant stated that "sometimes a communication of ideas is pretty difficult without a vocabulary." Another secondary group member added that "there should be an underlying assumed body of knowledge if [the student] passed the Regents...". To this a post-secondary participant stated that "the terminology can be learned [in introductory college biology], it changes, uh, new terms come up as technology and knowledge advances. I'm less hung up on the student's understanding of a strong vocabulary as I am on the second issue, the concepts." The third secondary faculty member then retorted that "vocab is vocab... concept or not, I would like a kid going to college biology to have a clue about what photosynthesis is..." The post-secondary member disagreed stating, "I don't find a lack of understanding of biology vocabulary to be an impediment to success in my course...whether they can understand the word roots or the vocabulary itself... I don't see it as a major issue in my teaching." Another post-secondary member defended this stand, expecting students to enter introductory college biology with "the skills so they can utilize resources so they can learn those kinds of terminologies."

During the homogeneous post-secondary faculty exercise, participants spent little time emphasizing vocabulary as an important student characteristic. While one gave weak support for it stating that "a little bit of fundamental knowledge of basic prefixes, suffixes, and roots could contribute to their success" another immediately countered with "sometimes a little knowledge is a bad thing. Kids are resistant to tackle

new terminology, new vocabulary if they think they already know it”, after which all post-secondary faculty de-emphasized vocabulary importance.

Secondary faculty also emphasized note taking as an important student characteristic both during the interview process and in their rankings. This prerequisite was drawn from their memory of student experiences in college classes as students. However, during the heterogeneous focus group, the importance of this characteristic was contested by a post-secondary member. His comment illustrated the change in requirements for note taking in contemporary introductory college biology courses,

Well a number of my colleagues have taken into the practice of providing the students with good flushed out outlines of the lectures so they're not looking at the top of the students' heads while they lecture. Instead they're making good eye contact and trying to draw the students into the discussion.

When a secondary participant retorted, “if you take good notes then you can formulate how you need to remember it”, another post-secondary member ended the discussion with, “Its not an important skill. With information increasing, we are required to hand out notes in the interest of time.” No agreement was reached by the end of the process.

Clearly the isolation of secondary faculty, in terms of current post-secondary course requirements, was revealed both implicitly and explicitly. The disagreement on requirements such as Latin knowledge, vocabulary content knowledge, and note-taking skills indicate a temporal isolation of secondary faculty from current post-secondary instructional practices in introductory biology courses.

Blame Placed on Secondary Faculty by Post-secondary Participants

Post-secondary participants blamed secondary participants for low student success in their introductory courses, citing high school instruction as a main cause of student mis-preparation. They believe high school faculty over-teach biology content and over-emphasize affect development (e.g. self-esteem and enthusiasm) and under-emphasize integration of themes (e.g. writing and mathematics).

During the interview process, each post-secondary faculty member made comments that de-emphasized conceptual biology knowledge as an important pre-requisite to success in introductory college biology. One participant's statement, “I don't care what biology you know” reflected this sentiment. Another participant said, “It's not knowledge but more skills that I'm concerned with...that students should have in mathematics --plotting, interpolation, algebra, and writing skills--the ability to communicate properly on exams.” Another added that “in most cases [the students] lack the skills even though they have good backgrounds” and that “secondary teachers should put less emphasis on knowing biology when they come in

and more on math and writing skills.” Conversely, secondary participants emphasized conceptual knowledge in biology as an important requirement during the interviews and focus groups. The idea that “you need a base of knowledge to do well in college science” was expressed by each secondary participant. Each participant group adhered to their core beliefs about the relative importance of content acquisition and there was no agreement during the heterogeneous focus group.

The lack of student abilities to integrate biological knowledge with other content areas was another characteristic emphasized by post-secondary as detrimental to student success. One post-secondary faculty member stated that the introductory college biology course “expects them not to just learn some terms, like they do for their high school teachers, but putting it into context... try to carry it in other areas.” Another mentioned this during the interview stating, “if you can relate the information with other subjects, I think it facilitates the learning process...” and that a good lab “forces the student to use a variety of resources and content areas to synthesize information and analyze this...[so that] they see the solution to one problem generates other questions. Without this ability it'll be hard for [students] to do well in the course.”

During the interviews, concurrent themes of emphasizing integration across the curriculum and blaming secondary faculty were coupled with retention issues. One participant stated that students “... who do poorly compartmentalize information, where they can't recognize it and apply it to another course...and they learn to compartmentalize in high school.” Another asked, “Why don't [students] learn that subjects are connected...you can't do well in my course without knowing that math is at its base.”

When confronted with these comments during the heterogeneous focus group, secondary participants blamed the standardized secondary assessment (naming the NYS Regents examination in Biology), as requiring knowledge as a set of facts. Secondary participants offered contradictory statements regarding the importance of mathematics as a prerequisite for introductory college biology. During most of the discourse on integrating mathematics, the secondary faculty did not participate and all three secondary participants expressed surprise to hear that knowledge and abilities in algebra and statistics would be important student characteristics for introductory college biology.

Writing ability was given a high priority by post-secondary faculty as a characteristic for students entering introductory college biology and they blamed secondary faculty for deficiencies in writing among incoming college science students. All post-secondary participants posited numerous comments concerning this emphasis. One faculty member stated that “...we find that there is generally a lack of ability or

knowledge for writing a scientific paper. They're not adequately trained in APA or MLA style. Not trained in doing citations." Another commented, "What are the students doing in high school? Don't they write papers and learn basic writing skills?" Another drew a link between writing and success in introductory college biology stating that "there is a disparity in those that can write and express themselves and those that can't and don't succeed" and in terms of their assessment "students may know the concepts but can't put it into words on the short answers on the exam."

Writing ability was not mentioned at all by high school faculty. When confronted with their omission of this characteristic, secondary faculty again referred to assessment requirements as not demanding writing. They cited the NYS Regents examination in biology "as an almost completely multiple choice test." The blame for student mis-preparation again went from college teachers to high school teachers to state assessment. One secondary participant emphasized self-discipline; "... it's the discipline, the self-esteem, the belief in one's self... the belief that there is not always an easy out and some things have to be learned the hard way." Another asserted, "a good student has enthusiasm, a positive outlook on life" and should be "smiling, bright, talking. The college teacher looks for this." Another claimed that in college biology students must have "a self starting attitude, making the choices to study independently" and "having the self-confidence to go into the lab, look up some terms on their own... to do a lab on their own." Post-secondary faculty mentioned these characteristics very infrequently. When confronted with this emphasis during the heterogeneous focus group, post-secondary participants were silent. However, during the interviews, they mentioned, "...students have too much self confidence...coming to class thinking that they know biology and are rudely awakened." This sentiment was expressed by all of the post-secondary members, citing concerns that, in general, secondary faculty "pamper the students" and that this keeps them from "adjusting to the demands of a college course".

Epistemological Differences Underlying Faculty Expectations

Participant groups appeared to differ in their view of knowledge and knowledge construction. During their interviews, secondary faculty viewed as important students' understanding that, "there are right and wrong answers to questions..." and "that there are some things you need to look up in a book—learning to do that." Another elaborated that "you can be successful without being analytical" in introductory college biology. These statements are consistent with an epistemological view of learning that is conclusion-based and according to the King and Kitchener (1997) hierarchy of knowledge, based on authority. The secondary group also demonstrated this perspective during the heterogeneous focus group, so that when

asked about the mechanism of how critical thinking and analytic skills contribute to success, one commented that "those skills build as students get more and more immersed in what they're reading...they learn more vocabulary."

In contrast, post-secondary faculty consistently demonstrated, during interviews and focus group meetings, an evaluation-oriented view of knowledge and knowledge construction. Numerous comments showing that they expect students to "... critically think to realize that solutions are not always black and white" manifest an epistemological level of uncertainty consistent with the hierarchy offered by King and Kitchener (1997). When discussing the importance of the ability to ask questions, a characteristic emphasized by post-secondary faculty, an emphasis on open-ended questions was prevalent. One participant stated, "the best question a student can ask me is why." Post-secondary faculty de-emphasized facts and factual knowledge with one participant commenting that he expected students to consider that "... an understanding of science is not just facts, but a process of understanding uncertainty; frustration." The certainty of facts and vocabulary knowledge emphasized by secondary faculty juxtaposed the uncertainty of knowledge expressed by post-secondary faculty. To illustrate, a post-secondary faculty member commented that students should be able to view results with "... a general knowledge that there's uncertainty."

Communication for Bridging the Gap

The discussion and clarification between faculty regarding certain student characteristics led to some agreement by participants. Consensus was reached on: 1) laboratory skills best taught in high school biology; 2) chemical principles; 3) meanings of terms and 4) the importance of reading ability. This overall consensus building was reflected in regression analyses (see Figures 2 and 3) showing increased agreement after faculty groups actually interacted.

At first, disagreement between groups was exhibited regarding the laboratory skills required for incoming college biology students. Some faculty members were uncomfortable with what they saw as a repetition of effort when post-secondary faculty repeated high school laboratory exercises, for instance, use of the microscope. Early on participants contended that time was being wasted by a duplication of efforts. As discussion ensued, there was agreement among faculty members that the reinforcement of certain skills, such as use of the microscope, was an important preparation for post-secondary requirements of skill level in the college biology laboratory.

Disagreement about what chemistry knowledge and abilities students should have coming into college biology appeared during the heterogeneous focus group discussion. When macromolecules, atomic structures, reactivity, and periodic table knowledge were expressed as necessary chemistry knowledge for the

table of specifications, the secondary faculty pointed out that this had been taken out of the NYS Regents examination and that students not taking chemistry would lack such knowledge and abilities.

After agreement from both levels that chemistry knowledge was essential to success in understanding concepts for introductory college biology, faculty discussed their plan of action to close a possible gap in student chemistry preparation. One post-secondary participant commented, "I do less chemistry... but now I may need to change things." The desire to change post-secondary curriculum, based on the new information about the lack of high school chemistry preparation, was expressed by each of the post-secondary participants. They each indicated a need to accommodate students who lack knowledge and abilities in chemistry areas due to the changes in NYS Regents requirements.

Clarification and some redefinition about certain prerequisite student characteristics also resulted from the faculty group's interaction. For example, while secondary faculty viewed self-esteem/self-confidence in terms of an ability to meet introductory course requirements, post-secondary members appeared to have a different interpretation of the terms. One participant stated that self-esteem/self-confidence was "a very different issue--to be able to come to a conclusion intellectually and stand ground on it whether you didn't get the expected conclusion on an experiment". Faculty groups also came to consensus on the definition of critical thinking and were then able to specify the actual components necessary for the critical thinking expectation.

During the heterogeneous focus group discussion, faculty also came to consensus on the importance of reading ability. At first, secondary faculty commented that high school biology courses did not prepare students to read because their assessment was based on notes taken in class. One secondary member commented that, "It's really dumb what we do; they don't have to read to pass the Regents. We give them all they should know but that won't help them in college biology" and "in a high school class I wouldn't dare say read chapter 12 -- you wouldn't." Another secondary member added, "in college, most of the tests were from the readings and not the lectures." A college faculty participant contested both statements, saying "you can't expect it [students to read assignments] at the college level either." Another added, "That may have worked thirty or forty years ago, but not anymore."

Elaborating on the importance of reading ability, faculty came to an agreement that reading was important for preparation to follow a lecture but that most of the assessment came from notes at both secondary and post-secondary levels. While secondary faculty commented that they relied on the instruction typical of their experiences in introductory college

biology, all the participants agreed that change had occurred. Both groups, therefore, agreed that reading ability was a characteristic that had diminished over time.

The methodology in this study therefore allowed for a consensus building that emerged from communication about contemporary teaching methods employed in introductory college biology.

DISCUSSION

Process Contribution to Bridging Gap

This study heightened the awareness of participants about the congruence of their assumptions with other faculty groups. The methodology chosen was uniquely effective in impelling faculty to first come to consensus on the importance of certain student characteristics within their cohort groups and then to confront their viewpoints with another group. Simple discussion among faculty might have been less effective in uncovering the degree to which the secondary and post-secondary group assumptions did or did not match. At first, the secondary group believed their teachings were effective in preparing students for college biology and the post-secondary group deemed their instruction appropriate for the assumed knowledge, abilities, and dispositions of their incoming students. Both groups, however, were compelled to alter this complacency, when confronted with alternative data about the academic transition students face between secondary and post-secondary biology.

The study thus showed that communication between secondary and post-secondary groups improved the overall congruence of participant assumptions about the knowledge, abilities, and dispositions required for student success in introductory college biology. As evidence, the regression analysis of rankings by faculty before and after the heterogeneous interaction indicated an improved relatedness between group assumptions of over 19% (from an r -squared = 0.1501 to 0.3429) (see Figures 2 and 3). Heterogeneous focus group interaction also involved faculty groups defining terms (e.g., self-esteem/self-confidence), specifying differences in curricular requirements, clarifying misunderstandings about student characteristics, and coming closer to agreement on reading comprehension and writing skills needed for success. Thus, as would be expected, an improved congruence in assumptions was achieved through the process of bringing secondary and post-secondary faculty together. It is naïve to presume that a few ninety-minute focus groups are sufficient for ameliorating the disparity that exists between viewpoints of secondary and post-secondary faculty.

Secondary Participant Frustration

Secondary faculty emphasized specific student characteristics that were unacceptable to the post-

secondary group, such as Latin knowledge, reading comprehension, and note-taking. Secondary participants communicated a feeling that is best described as isolation in the time-dimension from contemporary introductory college courses. This is expected because of a secondary reliance on old curricula and instructional techniques for introductory college biology as the reserve from which these faculty draw their ideas about preparing students for college. Given the limited exposure secondary faculty have to introductory college courses, the results were not surprising (Razali and Yager, 1994). Such limited exposure may be a result of a lack of communication with either post-secondary faculty or established standards. With the lack of clearly defined national and state-level guidelines for post-secondary life science course requirements and pre-requisites, a vacuum is left in secondary faculty links to the college biology courses for which they are supposed to be preparing their students (Daempfle, 2000).

The vacillation and disagreement over mathematics requirements further illustrated both the isolation secondary faculty have from post-secondary life sciences and the frustration that the process of updating their preparation of students caused the secondary participants. While basic mathematics and algebra were the most frequently discussed characteristics by post-secondary faculty, high school teachers were confused about the degree to which mathematics mattered for success in introductory college biology. It may be that secondary faculty did not realize that biology had become more mathematical since their coursework ended, particularly statistical, with the addition of new methods of research (e.g., ecological modeling, molecular biology, genetic engineering).

Incongruence of State Standards with Post-Secondary Assumptions

Disagreement on the emphasis secondary participants placed on content knowledge may be a result of the curriculum being so heavily concentrated on content and vocabulary knowledge, as established by the New York State Biology Content Standards and Regents Examination. Lack of instructional freedom may have contributed to the frustration the secondary participants displayed during the process. While post-secondary faculty have greater academic freedom to contend with the increased volume of content in contemporary biology, secondary faculty do not have that luxury. This constant-volume problem of content, discussed by Willeford and Clapp (1961), appears to have been dealt with by the college participant assumptions through their emphasizing skill development to enable students to acquire content independently. However, secondary faculty curricula may not be as flexible, which would help explain the reluctance secondary faculty expressed for accepting the post-secondary participant recommendations.

Links to Chemistry Expectations Research

Results of this study support work done on chemistry faculty expectations (e.g., Ogden, 1975; Stuart, 1977; Mitchell, 1990; Razali and Yager, 1994). Chemistry education literature revealed incongruence in chemistry assumptions between secondary and post-secondary faculty. Razali and Yager's (1994) results on faculty assumptions in chemistry showed that while secondary respondents significantly emphasized content knowledge characteristics, undergraduate instructors favored other qualities.

Similarly, post-secondary faculty, in the supporting literature and in this study, recommends that secondary teachers should increase integration of prior knowledge with other content areas (Razali and Yager, 1994). Both the results of this study and the chemistry findings show that high school teachers who are confident that the student characteristics they assume are important in their students' preparation for college are, in fact, concentrating on something that college professors do not value highly in college science courses. However, in this study, an improved congruence in rankings, ratings, and communicated faculty assumptions between the secondary and post-secondary groups attests to the importance of communication in diminishing the disjuncture in student preparation across the secondary/post-secondary interface.

Implications for Educational Practice

This study offers a set of prerequisite student characteristics for the reader, which, in conjunction with the related literature, can be used to develop curricula that more efficiently prepare students for their transition from secondary to post-secondary life sciences (see Appendix E). To illustrate, based on this study, it might be prudent for secondary biology instructors to increase their preparation of students in terms of writing and mathematics skills. Post-secondary faculty in this study might focus on helping students without such preparation to meet their requirements.

The kinds of changes advocated should be determined within local feeder units based upon their own results. Changes should be considered in terms of improvement in the curricula at both secondary and post-secondary institutions. Based on the findings, curricular improvement could involve a different approach to text usage and assessment, the clarification of prerequisite requirements, improved instructional and curricular preparation to help pre-college biology students meet college faculty demands, and institutional action.

Communication of Requirements to Students

It is not enough that faculty define their requirements for college biology courses. These requirements should also be communicated effectively to students and the course assessment measures should reflect these academic demands. Barrowman (1996)

claimed college faculty requirements often were not clearly communicated to students and that assessments often surprised first-year college students.

Improvement in Preparation

The results of the study should also help faculty to better understand the possible gaps in student preparation for the transition from secondary to post-secondary biology. Chemistry and biochemistry knowledge, writing, and mathematical abilities, and the ability to integrate biological topics with other subjects, were examples of post-secondary faculty requirements for which secondary students may not be prepared (within the feeder unit or in general).

Institutional Action

On an institutional level, an active research program, perhaps tracking non-persisting students in biology and exploring their reasons for leaving, would be beneficial to retention. Because a potential incongruence in student preparation is an institutional problem, safeguards against student loss should be implemented. These might include: remedial courses or workshops to lessen possible academic deficiencies caused by inconsistencies in preparation, counseling services to help students cope with academic adjustments during their transition to college biology, and recruitment of faculty willing to participate in research and communication that improves student preparation.

Implications for Research

This study of a particular feeder unit involving four institutions is limited in its external generalizability to other institutions. However, the purpose of this study was to analyze a particular organizational infrastructure. It attempted to achieve an understanding of an existing relationship between

secondary and post-secondary faculty assumptions about importance of certain student characteristics. The local social significance of the results is important in improving the student's transition within this feeder unit. The results do not purport to advise other institutions to do this or that, but attempt to increase understanding about the current state of affairs that may exist between secondary and post-secondary life sciences. It is the ultimate goal of this research that the incongruence found in faculty assumptions in this local study will increase awareness that such a dynamic can exist and should be further researched in other localities.

CONCLUSIONS

It is hoped that the results of this study, and the possible uses of its methodology to implement future research, will: 1) heighten the awareness of faculty regarding the importance of communication with faculty at other institutions; 2) increase the match between secondary and post-secondary faculty assumptions about the student characteristics required for success in introductory college biology; 3) help to create educative experiences for students that help them to meet faculty requirements and to succeed in introductory college biology; and 4) stimulate additional research to study secondary and post-secondary requirements, both assumed and actual.

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Appendix A: Specifications for Faculty Assumptions About Student Characteristics Important for Success When Entering Introductory College Biology: As Developed by Heterogeneous Focus Group

- | | |
|--|--|
| <p>1- Definitions of biological terms</p> <p>2- Understanding of word roots/word parts</p> <p>3- Understanding of Biological Concepts:
 Cellular Biology
 Genetics
 Evolution
 Diversity of Life
 Ecology
 Energy Release
 Regulation
 Biochemistry
 Organ Systems</p> <p>4. Integration of Biological Knowledge with other subjects:
 microbes and biochemistry
 sociobiology
 medicine
 ecology/environmental issues
 bio-economics
 bio-politics
 application of biological concepts to real life
 conceptually
 in lab experiences</p> <p>5- Hands-on Lab Skills
 measurement
 metric system
 observation skills
 microscopy
 balances
 rulers
 graph paper</p> | <p style="padding-left: 20px;">pipettes</p> <p>6- Chemistry knowledge
 knowledge of the four categories of macromolecules
 endothermic/exothermic reactions
 oxidation-reduction reactions
 solutions
 pH
 enzymes
 atomic structures
 atomic structures and reactivity</p> <p>7- Reading comprehension
 reading comprehension in science</p> <p>8- Knowledge of Latin words and word roots</p> <p>9- Writing skills
 exam essay writing
 laboratory report writing</p> <p>10- Communication with others
 explain ideas in class
 ask questions
 sharing interest with others
 group sharing of ideas</p> <p>11- Decimals/Fractions
 percentages</p> <p>12- Algebra
 X-Y system plotting
 equation manipulation</p> <p>13- Statistics
 X-Y system plotting on distributions
 Chi Squared general purposes
 mean, median, mode
 knowledge of use in polling</p> |
|--|--|

- knowledge of use in showing uncertainty of results
- 14-Calculus**
- 15-Physics knowledge related to living systems**
 laws of conservation of matter and energy
 first and second laws of thermodynamics
 law of gravity
 light wave relationship of energy to frequency
- 16- Asking questions**
 why based questions
- 17- Group studying**
 for problem solving
- 18- Explanation of biological concepts to peers**
- 19- Organizing information**
 for lab report writing
 to follow conventions/procedures within the laboratory
- 20- Separating important from unimportant information**
 in text reading
 in internet searching
- 21- Note-taking**
- 22- Time management**
- 23- Problem solving**
- 24- Computer skills**
 word processing

- email/internet navigation
 spreadsheets
 graphing
- 25- Discipline in classroom**
 non-disruptive conversation in the classroom
- 26- Perseverance**
 perseverance during research projects
 perseverance in building skills
- 27-Self-confidence/Self-esteem in general**
 self-confidence/self-esteem to overcome failure or defeat
 self-confidence/self-esteem during biological research process
 self-confidence/self-esteem in defending results
- 28- Enthusiasm**
- 29- Delaying gratification for the results**
- 30- Independence in studying**
- 31- Critical thinking**
 critical thinking to link an observation to an evaluation of data
 critical thinking to integrate biological knowledge within the subject

Note. Calculus was excluded by both faculty groups; Latin was included by secondary faculty and excluded by post-secondary faculty. Number and “-“ indicates original expectation. Indentation indicates specification of each original expectation above.

Appendix B: The Summary of the Methodology

PHASE	PARTICIPANTS/ SETTING	DATA COLLECTION METHODS	DATA ANALYSIS/ PRODUCTS
Interviews	3 secondary faculty 2 two-year college faculty 2 four year college faculty	Interviews	Development of focus group prompts; tape recordings of interviews; survey on student characteristics
Focus Groups	3 Secondary faculty 2 two-year college faculty 2 four-year college faculty	Focus groups→ tables of specifications development/rankings	Tape recordings of focus group interactions; data on faculty assumptions
Follow-up	All participants	Phone interview	Transcripts

Appendix C: Interview Questions: All Asked of Participants

1. What academic knowledge/or qualities should students have to be successful in Introductory College Biology?
2. What academic knowledge/or qualities do students often lack which would help them to be successful in Introductory College Biology?
3. What study skills help students to be successful in Introductory College Biology?
4. What study skills do students often lack which would help them to be successful in Introductory College Biology?
5. What personal characteristics (about the individual student) help students to be successful in Introductory College Biology?
6. What personal characteristics (about the individual student) do students often lack which would help students to be successful in Introductory College Biology?

7. What other characteristics of an entering college student would help him or her to be successful in Introductory College Biology?
 8. What kinds of high school preparation do many of our students have which help them to be successful in Introductory College Biology?
 9. What kinds of high school preparation do many of our students lack which would help them to be successful in Introductory College Biology?
 10. What can the college or the instructor do to enhance student success in Introductory College Biology?
-

Appendix D: *Specific focus Group Protocol*

(10 min.) Introduction

- Greeting
- Purpose of Focus Group
- Ground Rules
 - role of researcher
 - confidentiality of comments/responses
 - recording equipment (explanation that it will be used)
 - importance of individual opinions (no right or wrong answers)
 - speak one at a time and as clearly as possible
 - Icebreaker Exercises (participant names, institutions, courses taught, areas of interest).

(65 min.) Assumptions About Student Knowledge, Abilities, and Dispositions Required for Success in College Biology Courses

1. A list of prerequisite student knowledge, abilities, and dispositions assumed to be important by faculty for success in introductory college biology (as developed from the interviews) was presented to the participants. “Are there any other knowledge, abilities, and dispositions not on this list?” (asked by researcher). A tally of the number of times each item on the list was mentioned during the interviews was kept and was displayed on a visual aide in the room.
2. “Why do each of the knowledges and abilities on the list contribute to student success in introductory college biology?” (“How do you think the mechanism of knowing or having a particular prerequisite ability contributes to the success of the student in introductory college biology?”). (Asked by researcher)
3. “Please give specific example(s) of these expectations and why they contribute to student success in introductory college biology.” (asked by researcher) The reasons each of the items link with success and the specific examples of each reason will be written on a visual aide in the room.
4. “Tell us a story or describe a particular incoming college student who has had all of the knowledge, abilities, and dispositions to succeed in your course. Did they succeed? Why or why not?” (Was asked by researcher to both faculty groups as a facilitator of discussion).

(10 min.) Ranking/Rating of Expectations

“Develop a group ranking order, from most important, of the student knowledge, abilities, and dispositions you expect of incoming college biology students.” (Directed by researcher) (A list of student characteristics survey (Appendix E) was displayed on poster-boards in the room. The survey of student characteristics was developed from homogeneous focus groups to be important knowledge, abilities, and dispositions for students entering introductory college biology).

Participants were asked to rank, from #1 (most important) to #31 (least important), the characteristics provided on the poster-boards. Participants also rated each characteristic immediately before and after the heterogeneous focus group, on a Likert scale, with #4 (very important), #3 (moderately important), #2 (mildly important) and #1 (not important). This ranking and rating served as a basis for the quantitative comparisons in the results.

A major goal of the focus group interactions was to develop a table of specifications of the student characteristics life science faculty assumed were important for success in introductory college biology. The stakeholders were asked to develop a series of required student characteristics to be placed by the researcher in the form of a table of specifications. Through the table of specifications, “the focus group covers ...topics on an issue...that might otherwise be left out of a survey” (Edmunds, 1999, p. 4).

In this study, the table of specifications was a list of characteristics that consisted of each of the student characteristics agreed upon by both the secondary and post-secondary groups to be important knowledge, abilities, and dispositions for students entering introductory college biology. It included the original characteristic plus the specifications enumerated as the parts comprising each characteristic.

(5 min.) **Closing Comments**

- **Final Suggestions/Comments**

Conclusions: were based primarily on the majority of responses, but unexpected comments/dissensions allowed for further analyses.

Appendix E: Student Characteristics Survey

(Participants ranked (both pre- and post-heterogeneous focus group) the importance of each of the following student characteristics for its contribution to success in introductory college biology course.

Biology Category

1. Definition of biology terms
2. Knowledge of biology concepts
3. Basic hands-on lab knowledge and abilities

Non-biology Category

4. Chemistry knowledge
5. Reading comprehension in science
6. Knowledge of Latin
7. Writing skills
8. Math to decimals/fractions
9. Math to algebra
10. Math to statistics
11. Math to calculus
12. Physics Knowledge
13. Computer skills

Study Skill Category

14. Asking Questions
15. Studying in Groups
16. Explaining Biology to Others
17. Organization of Information
18. Separating Information
19. Note-taking
20. Time Management

Personal Category

21. Communication
22. Discipline in the classroom
23. Perseverance
24. Self-confidence/Self-esteem
25. Enthusiasm
26. Independence in studying
27. Delay of gratification for results

Application Category

28. Critical thinking
29. Applying biology to real life
30. Problem Solving
31. Integration of biology within subject/across curriculum

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Using a Computer Simulation to Teach Science Process Skills to College Biology and Elementary Education Majors

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ABSTRACT: The *Lateblight* computer simulation (Arneson and Ticknor, 1990) has been implemented in the general biology laboratory and the science methods course for elementary teachers to reinforce the processes of science and to allow the students to engage, explore, explain, elaborate and evaluate the methods of building concepts in science. The students develop testable hypotheses and then use the program to run experiments and collect data. In addition, they research relevant background information and subsequently present their results in a poster during class.

KEYWORDS: Hypothesis testing, computer simulation, protist, constructivist teaching methods, cooperative learning

INTRODUCTION

Many students experience difficulty in science courses due to the lack of understanding of the methods of science (McPherson, 2001). Various approaches have been used to introduce students to the processes by which scientists find answers to questions about the natural world. Mulnix and Penhale (1997) successfully used the collaborative model to simulate the activities of scientists when conducting research projects, searching published literature, and communicating findings with peers.

The increasing availability of computer simulations that represent complex processes, and yet allow users to interact with the dynamics of a model system, creates a unique way of helping learners conceptualize (Windschitl, 1996). Windschitl and Andre (1998) contend that computer simulations used in a constructivist approach afford learners the opportunity to freely create, test, and evaluate their own hypotheses in a more richly contextualized environment. Furthermore, a well-designed simulation allows learners to choose their mode of informational representation on the computer screen and it allows them to develop hypotheses about phenomena that accommodate their way of solving problems (Windschitl & Andre, 1998).

Objectives of the Study

Constructivist teaching methods have been reported to be more effective in improving the learning

of biology concepts, reasoning skills, and positive attitudes toward science at the college level than traditional expository modes of instruction (Windschitl & Andre, 1998; Faryniarz & Lockwood, 1992). A typical classroom using constructivist pedagogy displays students actively engaged in the learning experiences as they work individually and in cooperative groups. As mentioned earlier, computer simulations also allow students to construct testable hypotheses, thus actively applying the principles of constructivist instruction. The researchers applied Vygotsky's social constructivist view emphasizing the development of shared knowledge through social interaction and cooperative learning (Mintzes, Wandersee, & Novak, 1998). The instructional material used in this study to teach science process skills was a computer simulation, *Lateblight*, introduced by the BioQUEST Curriculum Consortium (Arneson and Ticknor, 1999). In this qualitative study, the researchers are concerned with the process by which students build abstractions, concepts, and meaning out of the experience with the computer simulation in a cooperative learning environment.

This study was conducted to answer the following questions:

- What are the students' attitudes toward learning science process skills using a computer simulation?

- Did the cooperative learning environment help students learn the science process skills while working together on the problems provided in the computer simulation?
- Were the students able to transfer their knowledge of science process skills to an open-ended, long-term investigation?

This study represents inductive qualitative research subsumed within a larger reform effort in the freshman biology program and science methods course for elementary education majors at a southeastern university. The results of this study will inform our assessment of the program, in addition to adding to the body of knowledge regarding the effectiveness of constructivist teaching methods and educational technology in enhancing student learning.

METHODS

The computer simulation was used in the second introductory biology laboratory course, *Principles of Biological Science II Laboratory* and in *Science Methods for Elementary Teachers*. The subjects were 187 freshman students majoring in biology and other science areas and 46 junior and senior students enrolled in the science methods course for elementary teachers. The objective of the biology course is to study biodiversity, comparative biology, and biology as a process of knowing in a constructivist learning environment. The science methods course emphasizes the content, attitudes, and science process skills in the context of constructivist instruction for the elementary teachers. The tasks for this activity included the following: (1) learning and using the *Lateblight* computer simulation, (2) conducting library and online searches, (3) formulating hypotheses, (4) testing the hypotheses, (5) making generalizations and conclusions, (6) preparing a poster presentation to be used in the discussion of the results of the experiment, and (7) critiquing and evaluating one another's poster presentations. The nature of the data collected in this research is not suited for quantitative measures; therefore, the approach to data collection, analysis, and interpretation follow procedures for qualitative research.

The computer simulation in this study depicts the story of the potato famine in Ireland in the 1800's. The organism responsible for the famine is a fungal-like protist, *Phytophthora infestans* (McGraw, 2000). The zoospores become airborne and attach to the potato foliage forming lesions, and then spread rapidly to the tubers. The severity of the pathogenic infestation, referred to as blight, depends upon 1) weather conditions, 2) fungicide application, and 3) placement of discarded rotten potatoes. The pathogen grows best in cool (<24°C), moist conditions (Fry & Goodwin, 1997). When fungicide is applied to potato plants, the percentage of blighted tubers decreases (Stanley, 1997). Because zoospores rapidly disperse in moisture,

spores from infected tubers that have been discarded too close to the field may easily infect new potato foliage, thus spreading the pathogen.

Library and On-line Search

Students worked in groups with the *Lateblight* computer simulation and conducted library and online searches to obtain information pertaining to late blight or *P. infestans*. The biology majors used the electronic search of the university holdings on scientific journals and the Internet during the scheduled three-hour laboratory period. Students worked in groups of four with two laptop computers. The teaching assistants serving as instructors for the course guided the students in conducting electronic searches, answered questions about searches, helped students access sites, and viewed students' search results. However, the students in the science methods course had only 70 minutes per class period two times per week. Therefore, they started the on-line search in class and continued during their own time at a computer laboratory on campus or on their own home computer. The library search was performed as an assignment. Like the biology majors, they were required to submit at least three related articles from scientific journals.

Formulating hypotheses

Utilizing the information obtained from their literature searches and the problem scenario presented in the computer simulation, students worked in groups of four to form a testable hypothesis that would enable them to obtain a high net profit. They also explained the purpose for doing the experiment. The instructor provided students with a preliminary worksheet to guide them in identifying the variables to be manipulated (weather, fungicide spray, harvest season and resistance level of potatoes). The program generated graphs and reports of completed seasons. Students interpreted the graphs to draw conclusions and related them to the hypotheses they had formed. Students then followed guidelines provided by the instructors to write a paper and create a poster presentation for the class that was evaluated by the instructor using a scoring rubric (see Appendix 1).

Poster Presentation

Students worked on their poster presentations over the span of two weeks. Each presentation contained the following sections: Introduction, Materials and Methods, Results, Discussion, and Literature Cited. During the presentations, each group of students stood by their poster while a designated reporter explained the experiment. A 15-minute time limit was enforced. The teaching assistant and their classmates asked questions about the results of the experiment and evaluated the poster presentation using a rubric. Upon completion of the presentations, students responded to a questionnaire designed to reveal their attitudes toward the use of computer simulations, poster presentations, cooperative learning,

and the potential to apply what they learned about science process skills to another problem. To answer the last question posed in this study, the investigators also assessed student performance in a subsequent open-ended, long-term investigation.

Data Analysis and Findings

This study collected data on the students' perceptions about their experiences using the computer simulation, *Lateblight*, as a tool in learning the processes of science. Data sources consisted of an evaluation of the students' laboratory reports, instructor evaluations of poster presentations, group grades in the

laboratory exercise, and students' responses to a questionnaire regarding attitude toward the use of a computer simulation. The investigators triangulated data from these sources (Creswell, 1994). Triangulation is a method of combining methodologies when studying same phenomena or programs (Creswell, 1994 & Patton, 1990) providing validity to students' responses. The instructors and the researchers discussed and evaluated student progress in this laboratory activity during weekly meetings. Table 1 shows the frequency of the variables selected by both groups of students.

Table 1. A list and tally of variables in *Lateblight* computer simulation selected by students.*

Variables	Biology majors	Elementary education majors
Weather:		
Cool wet	63	7
Hot dry	44	20
Moderate dry	28	15
Moderate wet	26	8
Fungicide spray:		
Once a season	58	20
More than once a season	58	34
Harvest season:		
Beginning	5	12
Middle	35	15
Late	5	19
Resistance level of potatoes:		
Low	18	12
Medium	30	8
High	47	26

* The numbers did not add up to 187 or 46 for biology and elementary students respectively because in order to run the program, students had to choose a weather condition. However, some groups actually chose weather as the variable to manipulate; therefore, the number of students changing the weather condition was inflated. Other groups did not manipulate weather, but still recorded a weather condition, since that is required to get results. At the same time, a few groups manipulated other variables (i.e., fungicide spray, harvest season, etc.); therefore, the total number of variables manipulated did not equal 187 or 46 respectively for the two populations.

Library and Web-based Searches

The biology majors performed both library and web-based searches during the three-hour laboratory period. Students liked this convenience because they were able to access the university holdings on-line, and download articles from scientific journals without physically going to the library. Fifty-two percent of the elementary education majors used the on-line library search at a site other than the library. Thirty percent used the on-line search in the library. Ten percent did both. And the remaining eight percent did not use the online search but instead used the traditional literature search at the library. When asked about the amount of materials they found related to the topic, 46% of the biology majors reported that there was more than an adequate amount of information available in journals on-line and on the web, 19%

judged the amount of information available as moderate, and 4% reported that there were few materials available for the topic. However, 85% of the elementary education majors reported that more than an adequate amount of information was available to them.

Computer Simulation and Learning Science Process Skills

Student attitudes regarding the use of a computer simulation as a learning tool was generally positive. Attitude was ranked on a scale of 1 to 5, with 1 as low (less positive) and 5 as high (most positive). Using rankings 4 and 5 as an indication, 40% of the biology majors (BSC) and 85 percent of the elementary education majors (SCE) indicated that the simulation helped them understand science process skills (Fig. 1).

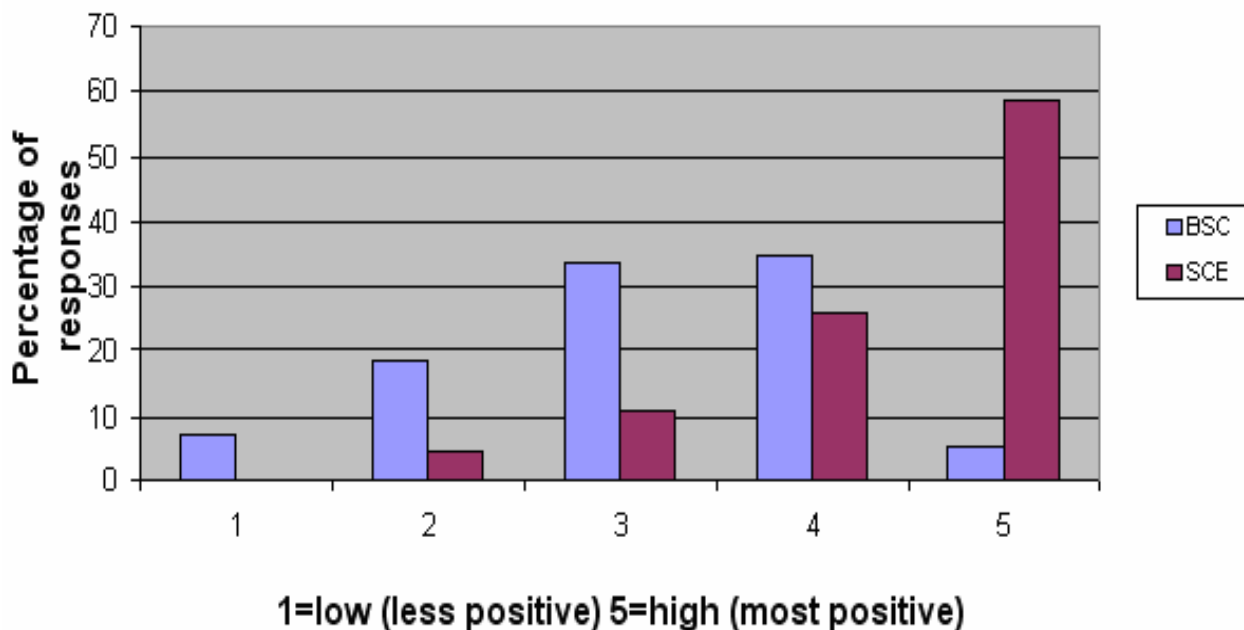


Figure 1. *Computer Simulation and Learning the Science Process Skills.* Distribution of the attitude scale for both populations using the percentage of students responding on the 5-point scale attitude questionnaire administered at the end of the activity. BSC = biology majors; SCE = elementary education majors.

Students expressed the advantages of computer simulation in the following ways:

“You get results faster.”

“It allowed us to run many different variables in a short time.”

“It is a form of hands-on learning on variable manipulation.”

“The use of this technology is great for learning methods of studying problems in science.”

Computer Simulation and Cooperative Learning

Table 2 presents the attitudes of both populations toward the cooperative learning approach used in the computer simulation. Regarding cooperative learning, 69% of the biology majors and 96% of the elementary education majors said “they enjoyed working as a team because they were able to work with more ideas contributed by members”, “there was better thinking on the problem”, and finally, “it built teamwork”. Those who did not enjoy working in cooperative learning

groups (26% of the biology majors and 6% of the elementary education majors), gave these reasons: “prefer to work alone”, and “the time schedule did not allow working together, thus, one person got stuck with the work”. When asked to rate the quality of their cooperative work, 72% of the biology majors and 93% of the elementary education majors expressed satisfaction. Benefits cited by students included: “more ideas are shared”, “get a lot more done”, “like to get others’ feedback”, “understood better with help from group members”, “having different perspectives”, and “it is a real life situation...working as a team”.

Students generally gave positive responses regarding their satisfaction on the quality of the cooperative work and their poster presentations. Table 3 displays the responses of both populations when asked about the quality of their work in a cooperative learning environment.

Table 2. *Attitudes of biology majors and elementary education majors toward cooperative learning*

Attitude	Biology majors N=187	Percent response	Elementary education majors N=46	Percent response
Like	139	74.33	43	93.47
Dislike	48	25.66	3	6.52

Table 3. Students' perception on the quality of their work in a cooperative learning environment

Scale of 1-5 1=low, 5=high	Biology majors N=187	Percent response	Elementary education majors N=46	Percent response
1	2	1.06	0	0
2	21	11.23	1	2.17
3	35	18.72	1	2.17
4	55	29.41	8	17.39
5	74	39.57	36	78.26

Students' Attitude Toward Poster Presentation

When asked about their attitudes toward poster presentations, there was a large variation between the responses of the two populations. Fifty-six percent of the biology majors and 93% of the elementary education majors liked the presentations. Their responses included:

"Poster presentations communicate results better."

"Visuals make me learn faster."

"Poster presentations are informative because I get to know the results from other groups' experiments."

Forty-four percent of biology majors who did not like the presentations gave various reasons, such as the following:

"It is nerve wrecking."

"It is hard to schedule to work together as a group."

"I don't like public speaking."

When asked what lessons they learned when preparing their presentations, it was revealed that many students did not know how to present a scientific report despite the guidelines provided by instructors. Based on the evaluation of the poster presentation by the instructors, 87% received satisfactory performance. The high percentage may be deceiving because the assessment was made for groups rather than for individuals. This percentage does not reflect the number of students who did not comprehend the elements of a good presentation. During the evaluation when instructors gave comments about unsatisfactory presentations, some students exclaimed that, "I did not know that is what you wanted". This response accounts for the under-reporting of procedures and results of the experiment due to perceptual filters operating on students' consciousness. Students tend to use what they perceive is expected by the instructor rather than the elements of a good scientific report. Campbell et al. (2000) reported a similar problem with the communication of laboratory investigations by university students in South Africa.

Transfer of Knowledge of Science Process Skills

When questioned about subsequent investigations in which the students have to use their knowledge of science process skills, 69% of the biology majors felt they would be able to apply what they learned to

another problem. These students indicated that the knowledge they gained would enable them to test different variables in an experiment and to better understand and enjoy working on an experiment. Other reasons cited were: "now I know where to begin when conducting a science investigation", and "the lab activity in the computer simulation made me focus my thinking on the problem." Using the data source from the instructors' evaluation of the individual students' report on the subsequent investigation, *Plant Growth and Development*, 75% were able to write a satisfactory report. The reports included an introduction, a statement of the problem and hypothesis, description of materials and methods, data presented in tables and graphs, accurate interpretation of the results, and citation of literature. This evaluation provides a more accurate indicator of students' ability to transfer the knowledge and skill about the processes of science learned with the computer simulation. Ninety-eight percent of the elementary education majors felt that they would be able to teach the processes of science to their students after learning from this simulation.

CONCLUSIONS AND IMPLICATIONS

Several national reports on undergraduate science education have been published since 1995, which express a strong concern and determination to improve this level of education in American universities (NSF, 1996; NRC, 1999). A common theme of these reports suggests that the instruction should go beyond improving the knowledge base to developing critical thinking, problem-solving, and decision-making skills of students. The Boyer Commission report (1998) suggests, "that the first year of a university experience needs to provide new stimulation for intellectual growth and a firm grounding on inquiry-based learning and communication of information and ideas." In this study, the use of an investigative laboratory activity delivered via computer simulation and conducted in a cooperative learning approach was used as a test case. Although it is a limited study, findings about students' attitudes toward learning science process skills using a computer simulation in a cooperative learning environment and the transfer of learning to another investigation, contribute to the knowledge base about improving undergraduate biology education.

A computer simulation is a powerful tool to enhance learning by providing opportunities for learners to develop skills in problem identification, seeking, organizing, analyzing, evaluating, and communicating information (Akpan, 2001). The choices of different variables in the problem scenario of the *Lateblight* computer simulation allowed learners to practice as cooperative learning groups with a variety of situations that resemble “real-life” problems.

Students realized the benefits of cooperative learning in promoting positive interdependence, group accountability, and social interaction. However, group work has its drawbacks. Students who did not favor group work complained of the difficulty in scheduling meeting times. In general, students became aware of the nature of the work of scientists that they emulate in solving problems in the computer simulation.

The literature search and the poster presentation in this study are testimonies to the students’ diligence and understanding of the problem presented in the computer simulation. Although students were generally positive about the poster presentation, a small number suggested that they would prefer to use presentation software such as Corel Presentation or Microsoft PowerPoint. In line with the premise of multiple intelligences (Gardner, 1983), posters prepared by cooperative groups should promote the expression of students’ various forms of intelligence. Those students with communication intelligence can appropriately deliver the groups’ oral report, the artistic students can

share their keen perception of visual spatial dimensions in the lay-out of the poster, and the student with well-developed logico-mathematical intelligence can provide the analysis and interpretation of the results. In short, the poster presentation provided many opportunities for students to express their intelligences.

Although this study is limited in scope, there are important pedagogical implications of computer simulations used in a social constructivist-learning environment. The two populations, the biology students and the elementary majors, both testified that this experience was beneficial to learning science process skills. The elementary students learned the skills so well that they felt empowered to effectively teach what they learned. On the other hand, the biology students proved that they transferred the knowledge in a similar investigation. The investigators discovered that in future use of this simulation, there is a need to require students to identify the manipulated variables versus the ones held constant. Because the computer simulation provides quick results of the experiment, students overlook the importance of designating the variables in an experiment. Despite the efficiency of computer simulations, the instructors must provide guidance in using and learning science process skills. As computer simulations mimic the problem in real-life, this instructional tool is also powerful in developing problem-solving and decision-making skills in biology issues. It is hoped that these skills will be applied when bioethical issues impact real-life context.

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Appendix 1

GRADING SCALE FOR LATE BLIGHT COMPUTER SIMULATION PROJECT

Late Blight Presentation	Possible Points	Points Accrued	Comments
Procedure			
Title	1		
Correct Format	2		
Each section included	2		
Introduction			
Background Information	3		
Hypothesis	3		
Materials & Methods			
Explain variables manipulated	3		
Procedure outlined	3		
Results			
Graphs and tables	3		
References to graphs	2		
Explanation of graphs	3		
Discussion			
Results Interpreted	4		
Conclusion made	3		
Literature Cited			
3 references	2		
Proper citation	2		
Sources cited in paper	2		
Proper internal citation	2		

Your score:			
Total possible points	40		



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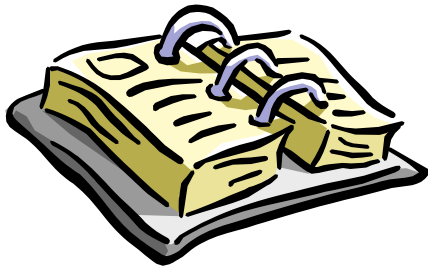
Call for Nominations

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If you wish to nominate a member of ACUBE for this award, send a Letter of Nomination citing the accomplishments/contributions of the nominee and a *Curriculum Vita* of the nominee to the chair of the Honorary Life Award committee:

Dr. William J. Brett, Department of Life Sciences, Indiana State University
 Terre Haute, IN 47809, Voice -- (812) 237-2392, FAX (812) 237-4480
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Housing Preview

47th Annual ACUBE Fall Meeting

Truman State University

Kirksville, MO

October 9-11, 2003

Lodging: Blocks of rooms has been reserved at the Days Inn and Shamrock Inn for meeting participants; remember to request the ACUBE block and rate. **IMPORTANT:** Please note there is a Bluegrass Festival in Kirksville on the same weekend, so PLEASE BOOK EARLY

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Most rooms \$75 and up (plus tax) per night

Thousand Hills State Park Cabins

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Note - these cabins overlooking the lake and book very early; cabins typically have two double beds, some with kitchens.

Camping

For the adventurous, this are camping sites available at the Thousand Hills State Park

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

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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:

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- 1. Biology
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