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Cover image: Cover image of young, green iguana, was taken by Neal Haave.

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The 63rd Annual ACUBE meeting will be held at Syracuse University Friday October 18th – Saturday Oct 19th in Syracuse, NY.

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- incubate new and innovative teaching ideas;
- involve student research in the biology curriculum;
- advise and mentor students in and out of the classroom;
- enhance scholarship through our nationally, peer-reviewed journal, *Bioscene*.

ARTICLES

The Development of an Inquiry-Based Laboratory Module Exploring the Pathophysiology of Diabetes

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Abstract: Histotechnology is commonly used in medical research, pathological testing, and pharmaceutical development. We designed a three-week, inquiry-based laboratory module that helps prepare students for biomedical careers by teaching them tissue sampling, processing, and imaging. Rats were treated with streptozotocin (a known diabetogen) while control rats were injected with buffer solution. Rats were sacrificed one week following treatment. Pre- and post-injection weights were compared and blood samples were collected for glucose analysis and insulin determinations using an enzyme-linked immunosorbent assay (ELISA). Pancreatic tissue was collected, preserved in Bouin's fixative, embedded in paraffin, and sectioned using a microtome. Students then performed hematoxylin/phloxine staining. The number of islet beta cells were compared between control and treated rats. Blood glucose measurements demonstrated that treated rats had significantly higher blood glucose levels and lower beta cells numbers, while the ELISA tests indicated that treated rats had lower blood insulin concentrations. Following this module, students presented an individual poster with images and quantitative data analyses that included insulin concentrations, blood glucose levels, and histological images of pancreatic islets, in addition to beta cell quantification. Overall, students gained hands-on experience with hypothesis testing and an understanding of the pathology of diabetes.

KEYWORDS: Rat, diabetes, insulin, β cells, pathophysiology, enzyme-linked immunosorbent assay

Introduction

The National Science Foundation (2011) Vision and Change document calls on scientific educators to actively involve students in their learning process, rather than make them passive learners. Therefore, there is a need for an inquiry-based scientific education (IBSE) where students learn to acquire knowledge on their own, through hands-on experiences. This provides them with an increased understanding of the scientific method, increased scientific literacy, and direct practice in the processes of hypothesis testing (NSF 2014; Riga et al. 2017; Russell et al. 2007). Undergraduate students that participate in inquiry-based laboratory courses are more likely to be retained and prepared for graduate degrees and professional positions in biomedical sciences (Gregerman et al. 1998; Science 2011; Weaver et al. 2008). Further, participation in an inquiry-based laboratory experiences by women and underrepresented minorities demonstrably increases the likelihood that they will pursue a graduate or professional programs by 14-17% (Eagan et al. 2013; Gregerman et al. 1998). Including a research component in required coursework can also help increase diversity in scientific research careers, especially when independent research lab positions are not available (Bangera and Brownell 2014). Therefore, reform efforts in undergraduate STEM have focused on shifting to a learner-centered and applied, hands-on learning environment (NSF 2014; Woodin et al. 2010).

We developed an inquiry-based research experience that affords students the opportunity to follow the scientific method, formulate hypotheses, perform experiments and collect, interpret and present the scientific data they collected. We used a rat model and induced diabetes using streptozotocin (STZ; a known diabetogen). STZ destroys β cells in the pancreas and induces type 1 (insulin-dependent) diabetes (Szkudelski 2001). Using this diabetic model, students in our physiology laboratory course were involved in a research experience where they were able to collect both histological and physiological data. This three-week laboratory module allows students to link changes in tissue morphology, blood glucose and insulin levels and body weight with the destruction of pancreatic β cells. Specifically, students are able to visualize the pathophysiological effects of diabetes on the endocrine portions of the pancreas, specifically by examining islet morphology and measuring insulin levels. Additionally, students can also examine changes in weight and blood glucose levels. This lab affords them to opportunity to learn laboratory techniques while examining the clinical manifestations of type 1 diabetes.

Diabetes mellitus, type 1 diabetes, results from the inability of the pancreas to produce insulin and accounts for 5-10% of all cases of diabetes. It is characterized by a loss of pancreatic β cells, known to produce insulin and is classified as either immune-mediated or idiopathic (Atkinson et al. 2014).

Becuase there is a loss of pancreatic β cells, there is a decline in insulin production and release. Insulin is a peptide hormone that is one of the main anabolic hormones of the body. Due to the lack of insulin production during type 1 diabetes, there is a subsequent hyperglycemia as insulin does not activate 'insulin sensitive' Glut 4 receptors and allow for the uptake of glucose into the cell. This results in increases in thirst and poly- and glucosuria. A decrease in glucose uptake by the cells leads to ketosis and lipolysis and subsequent weight loss (Sonksen and Sonksen 2000). Clinical manifestations of diabetes can thus be investigated by students in lab. This allows students to link the changes they see with the destruction of pancreatic β cells.

The rat serves as an excellent model organism to study the pathophysiology of diabetes. One week following STZ injections, blood and tissues can be collected for analysis by students in the lab. Specifically, blood glucose levels can be analyzed and treated and control animals can be compared. Blood plasma can also be collected and an enzyme-linked immunosorbent assay (ELISA) can be used to determine blood insulin levels. Lastly, pancreatic tissues can be preserved in Bouin's fixative, embedded in paraffin, sectioned, and stained with hematoxylin-phloxin to identify and count β cells in pancreatic islets. This laboratory module allows students to make hypotheses based on what is known about the pathology of type 1 diabetes. They can then test these hypotheses using blood and tissues collected from the rat. As a final exercise in scientific data interpretation, students generate research posters in order to provide the opportunity to solidify background knowledge, use primary research references, and relate collected data to the pathophysiology of type 1 diabetes. Overall, this laboratory research activity provides exposure to biological practices such as tissue fixation, histology, tissue staining, performing an ELISA, hands-on hypothesis testing, statistical analyses, and the interpretation and scientific presentation of data.

Materials & Methods

Animal Treatments

Male Sprague Dawley CD rats (*Rattus norvegigicus*) weighing mean (± standard deviation) 235.2 ± 7.7 grams were obtained from Charles Rivers Laboratories International, Inc. (Wilmington, Massachusetts). The rats were housed in groups of four in the animal care facility at the University of Detroit Mercy, and were fed rodent chow, given water *ad lib*, and cages were cleaned every three days or more frequently as needed (IACUC approved by the University of Detroit Mercy Institutional Animal Care and Use Committee; June 2017). All treated animals were weighed and given an intraperitoneal (IP) injection of 60 mg/kg of STZ. A stock solution of STZ was prepared by dissolving 15 mg/mL of STZ in citrate buffer (pH 4.5). Control animals were given an IP injection of the buffer only (Ahmed et al. 1998). All animals were given distinctive tail markings using a marker. These were refreshed as needed.

Six days following the STZ or control treatment, rats were fasted overnight and each rat was euthanized the following morning using an overdose of CO_2 (AVMA 2013). The rats were then weighed and blood was collected from cardiac puncture and stored in vacutainers containing EDTA in order to preserve blood and collect blood plasma for the insulin analysis. Blood glucose readings may be obtained immediately by placing one drop of blood into a blood glucose monitoring system (e.g. ONETOUCH Ultra2, Lifescan). Blood, collected in the EDTA vacutainers, can also be preserved for future blood glucose recordings by transferring the blood to microcentrifuge tubes, flash freezing it in liquid nitrogen and storing in a -20ºC freezer. Plasma required for performing the insulin analysis was obtained by centrifuging the vacutainers for 10-15 minutes (1,000-2,000 x g) in a refrigerated centrifuge. Lastly, the pancreas of both control and STZ-treated rats was removed by the course instructors, cut into small pieces (~5 mm x 15 mm) and placed in Bouin's fixative for at least 24 hours before embedding the tissue.

Student Exercise:

Students are initially given a lecture on the endocrine system anatomy and physiology. This includes information on the pancreas with specific information on the role of insulin in glucose metabolism. We also introduced students to the use of appropriate experimental or "sham" controls. Students were expected to formulate hypotheses and expectations based on background information from both textbooks and primary literature. Given the appropriate background information, students are then required to generate a working hypothesis on what anatomical and physiological changes they expect following the delivery of STZ, a known diabetogen that is selectively toxic to pancreatic β cells (Szkudelski 2001). While the instructors of the course perform the IP injections and euthanasia, students are informed of the procedure and husbandry in addition to pre- and post-injection weights. The physiological data collection and histological analyses take three to four laboratory sessions (or weeks) depending on the histology preparation. To conserve time, the teaching assistants and professors may complete the tissue embedding and sectioning. Tissues were prepared for paraffin embedding by treating tissues for 15 minutes with 50% ethanol, 75 % ethanol, 95% ethanol, 100% ethanol, 100% xylene, and paraffin (three replicates of each). Pancreatic tissue was embedded in a paraffin mold and allow to

cool. The molds were place in the freezer overnight to fully solidify the paraffin (Bancroft and Stevens 1990; Carson and Cappellano 2015).

Student Lab Week 1

Students formed groups of four and were provided with paraffin embedded tissue blocks from control and STZ-treated rats. They were also provided with a microtome, water bath and slide warmer. After being instructed on how to cut a ribbon of paraffin embedded tissue, students were shown how to float the 5 µm sections on the water bath (~50ºC) and collect them on slides. Following the collection, the slides were dried on a slide warmer (~60ºC). Following the instruction, student groups collected sections from control and STZ-treated rats on labelled microscope slides, floated on the water bath, and allowed to dry on the slide warmer for at least 30 minutes.

For the hematoxylin/phloxin, a standard procedure (Bancroft and Stevens 1990) was followed where slides with pancreatic sections were put through a descending xylene and ethanol series (100% xylene, 100% ethanol, 95% ethanol, 75% ethanol, 50% ethanol, water; 2 of each for 1 minute each in coplin jars). Slides were treated for 1 minute with 0.3% potassium permanganate/0.3% sulphuric acid mixture, decolorized with a 5% solution of sodium bisulphite, and washed with running tap water. Slides were then placed in a coplin jar containing chrome hematoxylin solution for 10-15 minutes until microscopic evaluation shows β cells to be deep blue. The slides were then rinsed with water and differentiated in 1% acid alcohol for 1 minutes to remove background staining. Then, they were washed in tap water until section is clear blue and stained with 0.5% aqueous phloxine for 5 minutes. Slides were rinsed again in water, treated with 5% phosphotungstic acid for 1 minute, washed in running tap water for 5 minutes when the section should regain its red color. Tissues were differentiated in 95% ethanol. If the sections were too red and the α cells are not clear, the sldies were rinsed for 10-20 seconds in 80% ethanol. Lastly, the slides were dehydrated with 100% ethanol, cleared in xylene and mounted in DPX (with coverslip). The slides were allowed to dry (~20 minutes).

Student Lab Week 2

In week 2, students completed their staining and viewed and imaged their sections using a microscope (Nikon Eclipse E200 with a DAGE-MTI colored camera). Images were collected using the Magic App program (400x magnification). Students also captured images of stage micrometers so that they could provide scale bars on the images they presented. Additionally, they counted the total number of cells present in each islet and determined the percentage of β cells present for both control (N= 3) and treated rats (N =3). They reported and compared the average (mean) and standard error (S.E.) for control and STZ-treated animals using an unpaired t-test.

Student Lab Week 3

Students were provided with a sample of recently thawed blood from control (N=3) and STZ-treated (N=3) rats. They placed one drop of blood onto a blood glucose test strip and monitoring system to obtain blood glucose results. The mean (± S.E.) was calculated and compared using an unpaired t-test. Additionally an insulin ELISA (Invitrogen Rat Insulin ELISA kit, ThermoScientific, Frederick, MD) was performed following the instructions provided (Scientific 2015). This ELISA was started by the professor before the lab period began as it takes >5 hours to perform and each lab period is only three hours in length. For the assay, initially, the plate and solution were brought to room temperature. Then, standards and samples were prepared, loaded into the appropriate wells, and allowed to incubate for 2.5 hours at room temperature with gentle shaking. The solution was then discarded and the wells were washed 4 times with 300 µL of wash buffer using a multi-channel pipette. The plate was then inverted and blotted against a clean paper towels. Biotinylated antibody (100 µL) was added to each well and incubate for 1 hour at room temperature with gentle shaking. The solution was then discarded and washed again. Streptavidin-HRP solution (100 µL) was added to each well and incubated for 45 minutes at room temperature with gentle shaking. The solution was discarded and the plate was washed again. Lastly, TMB substrate (100 µL) was added to each well and incubate for 30 minutes at room temperature in the dark with gentle shaking. The plate was then evaluated after stopping the reaction. The mean absorbance was determined for standards and unknowns using an ELISA plate reader (Versa max microplate reader with Softmax Pro 5 software) set at 450 nm and 550 nm. The readings from 550 nm values were subtracted from the values obtained at 450 nm values to correct for optical imperfections in the microplate. Instructors performed all initial steps in the procedure, but the students were able to add the Streptavidin-HRP solution and continue to the end of the assay.

Each student generated a standard curve by plotting the average absorbance (450 nm minus 550 nm) obtained for each standard concentration on the vertical (Y) axis versus the corresponding Insulin concentration on the horizontal (X) axis. Microsoft Excel was used to generate a graph and determine a line of best fit. The equation of the line was used to determine the insulin values of the control (N=3) and STZ-treated rats (N=3). Students obtained and average (± standard error) and compared the control and treated groups using an unpaired t-test.

Assessment

Formative assessment of learning outcomes were evaluated by means of a research poster. Each student submitted and presented a poster with an introduction, methods, results, discussion, and reference section. They also provided an appendix where they included all of the raw data they collected in addition to the micrographs and standard curve. The poster afforded students the ability to use primary research references and relate collected data to the pathophysiology of type 1 diabetes. Instructors can choose to have students present their posters in a research-style symposium or have them individually present material to their laboratory class or instructor.

Results

Initial results exposed students to early indicators of the clinical manifestations of diabetes mellitus, those being weight loss and hyperglycemia. One week after STZ exposure, students noted that control rats gained significantly more weight than STZ-treated rats (Fig. 1, paired t-test, $p = 0.005$, $n = 3$ per treatment). On average control rats gained 39.7 ± 5.7 (mean ± S.E) more grams that the STZ-treated rats, which gained only an average of 1.0 ± 4.4 grams. After weight determinations and prior to preparation of blood samples for the ELISA, plasma glucose concentrations were determined. Students observed a four-fold increase in blood glucose levels in the STZ-treated rats (Fig. 2, unpaired t-test, $p = 0.002$, $n = 3$ per treatment), with mean (± S.E) glucose concentrations of 499.7 ± 58.0 mg/dL compared to 99.00 ± 9.0 mg/dL in control rats.

Hematoxylin/phloxine histochemical staining of prepared pancreatic tissue by students allowed them to visualize islets of Langerhan and identify pancreatic β cells that stain a deep magenta within the islets (Fig. 3). Analysis of images allowed the students to quantify the number of pancreatic β cells and contrast differences between control and STZ-treated rats (Fig. 4). Using an unpaired t-test, STZ-treated rats had significantly lower percentages of pancreatic β cells ($p < 0.0001$, $n = 6$ per treatment). When compared to control rats, the STZ-treated rats had 51.8 % lower pancreatic β cells (mean ± S.E. was 72.3 ± 6.6 % and 20.5 ± 15.6 % for control and STZ-treated rats, respectfully). Although not quantified, qualitative observations of STZ-treated rats by students noted these rats to have smaller islets, and remaining pancreatic β cells to appear "vacuolated", most likely due to the effects of STZ.

Quantified pancreatic β cells comparisons allowed students to link histologic data with physiologic data resulting from the insulin determinations from the ELISA (Fig. 5). ELISA results suggest an average decrease of 8.2 µIU/mL of plasma insulin levels in STZ-treated rats from that of control rats (mean ± S.E. was 11.4 ± 5.4 µIU/mL and 3.2 ± 2.6 µIU/mL for control and STZ-treated rats, respectfully).

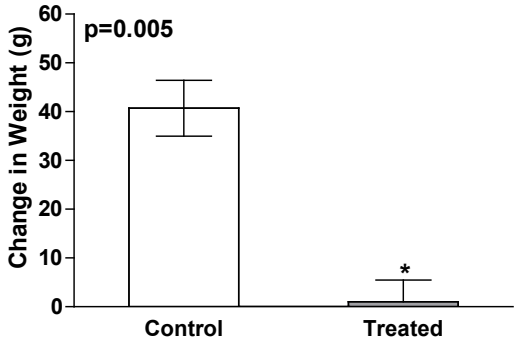

Fig. 1: One week after exposure to STZ, pre- and post-treated weights were compared. The STZ-treated rats gained significantly less weight than the control rats (unpaired t-test, $p = 0.005$, $n = 3$ per treatment).

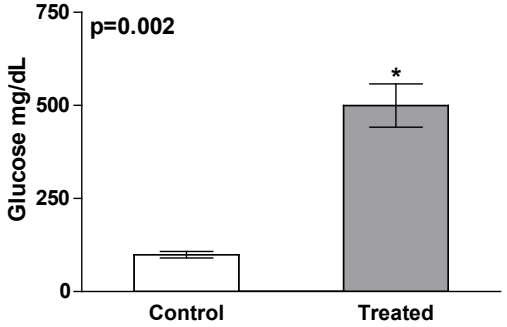

Fig. 2: Following treatment with STZ, STZ-treated rats demonstrated a significantly higher plasma glucose concentration than the control rats using the ONETOUCH glucometer (unpaired t-test, $p = 0.002$, $n = 3$ per treatment).

Discussion

We have developed a three week, hands-on, inquiry-based laboratory module that allows students to gain insights into the cause and effects of type 1 diabetes. Overall this module provided BIO 4640 (Physiology Laboratory) students with a deeper understanding of the physiology of the pancreas, as an essential organ in the abdominal pelvic cavity with both exocrine and endocrine functions. The exocrine functions of pancreas are performed by glands that secrete enzymes which aid in the process of. digestion, while its endocrine functions are a result of release of hormones that regulate the levels of blood glucose (Atkinson et al. 2014). The endocrine portions of the pancreas are composed of group of cells called islets of Langerhans or just islets. Pancreatic islets are composed of three types of

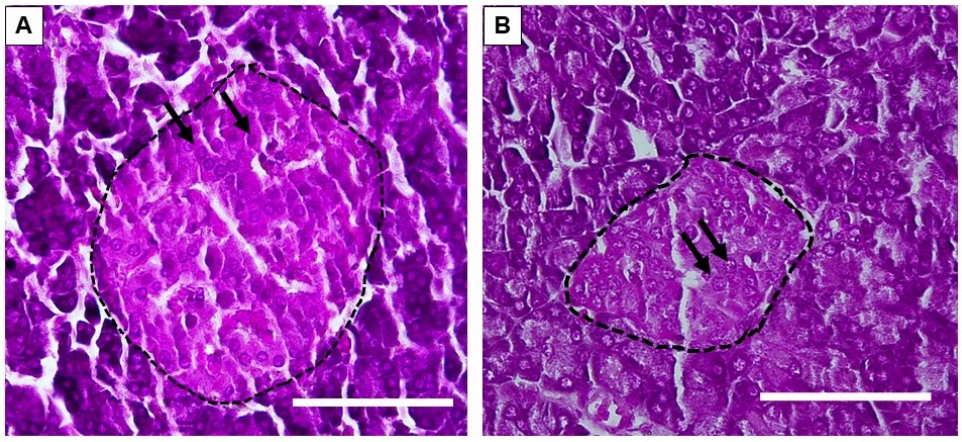

Fig. 3: Following sectioning students stained and imaged pancreatic islets (dashed outlined) from control (A) and STZ-treated (B) rats. Arrows indicate pancreatic β cells (mag. 400x, scale bar = 100 μm).

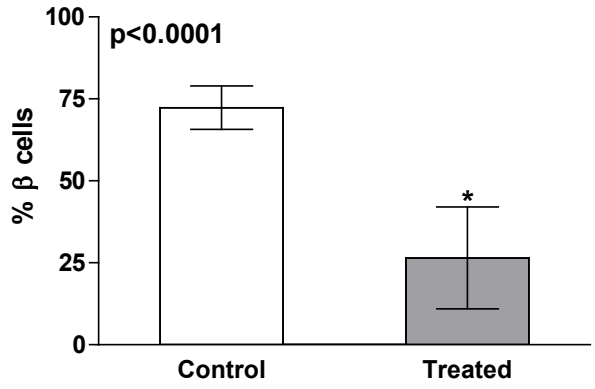

Fig. 4: Students analyzed images of pancreatic islets in control and STZ-treated rats and calculated the percentage of pancreatic β cells. There were significantly more β cells in control rats (unpaired t-test, $p < 0.0001$, n = 6 islets counted per treatment).

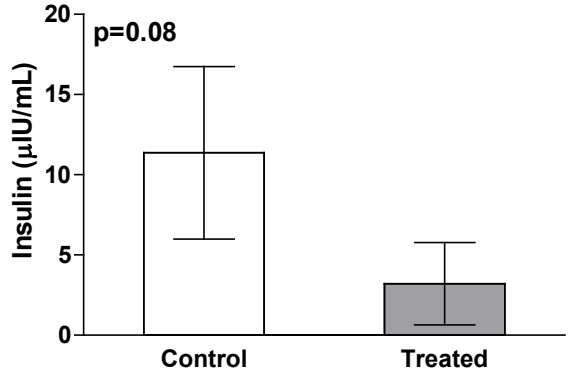

Fig. 5: Student ELISA results indicate control rats have slightly higher insulin concentrations than their STZ-treated counterparts (unpaired t-test, $p = 0.08$, n = 3 per treatment).

hormone secreting cells including alpha (α), beta (β) and delta (δ) cells. The hormone somatostatin is produced and secreted by δ cells and is involved in regulating growth hormone (Brereton et al. 2015). Hypoglycemic conditions stimulate α cells secrete glucagon leading to gluconeogenesis and increased blood glucose levels while hyperglycemic conditions lead to the release of insulin from β cells (Taborsky Jr 2010). Insulin-secreting β cells make up the majority of the cells found in pancreatic islets (~80% of islet cells). Insulin is a hormone that lowers the levels of blood glucose by activating GLUT4 receptors, subsequently increasing absorption of blood glucose for use in cellular respiration and storage in tissues (Saltiel and Kahn 2001). Type 1 diabetes and its subsequent pathologies are manifested after an immune system attack and destruction of insulin-producing pancreatic β cells (Atkinson et al. 2014).

ingIn this lab, we induced type 1 diabetes in a rat model by exposing treated rats to the known diabetogen STZ for one week. STZ has been successfully used to induce diabetes in rat models as it selectively targets and destroys pancreatic β cells. STZ enters β cells using a glucose transporter (GLUT2), leading to subsequent alkylation and damage of β cell DNA and production of free radicals (e.g. hydrogen peroxide and hydroxyl radicals) and by liberating toxic amounts nitric oxide. Overall, this causes β cell necrosis and a subsequent decrease in insulin production and release (Szkudelski 2001). The use of a STZ-injected rats allowed our students to investigate the physiological manifestations of type 1 diabetes. They were able to gain a deeper understanding of the physiology of pancreatic islets by using STZ-induced diabetic rat models and comparing the results with control rats. Students examined and linked various endpoints of diabetes with one another. Initially, students observed that

weight loss and hyperglycemia in STZ-treated rats when compared to the control rats. The weight gain in control rats is directly attributed to the normal functioning of the insulin hormone, secreted by pancreatic β cells as insulin is known to stimulate glycogen synthesis by stimulating a pathway that activates protein phosphatase 1 (Berg et al. 2002). However, the weight loss observed in our STZ-treated rats was attributed to hyperglycemia, which was quantified using a glucometer. Students then hypothesized that pancreatic β cells may not producing and secreting insulin.

To further investigate these clinical symptoms and determine if hyperglycemia observed in the STZ-treated rats was due to disrupted insulin production or function, student's sectioned paraffin embedded pancreatic tissues from control and STZ-treated rats. The histological analysis using a chrome alum hematoxylin-phloxin staining protocol on pancreatic tissue allowed students to easily visualize the β cells, located within the pancreatic islets. β cells appeared vacuolated in the STZ-treated rats when compared to the normal deep magenta β cells in the control pancreatic islets (Fig. 3). Further the percentage of β cells occupying the islets was determined by the students. They did this by quantifying the number of β cells and expressing them as a percentage of total cells found in the pancreatic islets. By using a t-test, students were able to show that islets of STZ-treated rats contained significantly less β cells than islets of control rats (Fig. 4). Further, students were able to link the morphological characteristics of the β cells and the reduction in the number of β cells in STZ-treated pancreatic islet tissue with the hyperglycemia and subsequent weight loss. The results obtained in this laboratory module are supported by several studies that have shown that disruption of β cells leads to increased blood glucose levels (e.g. Honka et al. 2014; Meier et al. 2008; Bonner-Weir 2000). In week three of this lab, students were able to directly link the histological data with the physiological function of β cells by performing an ELISA. After performing the ELISA, obtaining the data using a plate reader, preparation of a standard curve and calculation of a line of best fit using Excel, students were able to convert optical density for unknown control and STZ-treated rats to insulin concentrations. Students were able to show that control rats had more insulin than the STZ-treated rats, though this result was not significant (Fig. 5).

In summary, students who completed this three-week laboratory module were able to experimentally investigate the clinical symptoms of type 1 diabetes which include weight loss, increased blood glucose and decreased insulin levels and relate them to the underlying physiological cause, the destruction of pancreatic β cells. Here the students were able to apply their knowledge from preliminary coursework through a guided approach to a specific biological topic. Students had a greater understanding of the scientific process of developing a hypothesis, designing experiments, and collecting and performing rigorous statistical analyses of data to become well-informed, rather than passive readers. Students were required to write a comprehensive laboratory report based on their data indicating a deeper knowledge of the endocrine physiology, the scientific methodology. This led to an improvement in scientific presentation skills. After completing the laboratory module, students reported feeling confident with histological and analytical techniques. Students stated "I was also able to not only learn histological techniques, but also learned how to identify different structures within the pancreas, as well as their respective functions" and "In being a part of the histology lab, I was able to directly learn about the effects of diabetes on the pancreas using several different techniques".

Overall, this project stimulated and enhanced the cognitive skills of students in understanding type 1 diabetes and its underlying physiological changes. It also provided a great platform to learn and hone histo-technological skills like tissue preparation, sectioning, staining and imaging. Additionally, students became proficient in performing an ELISA, hands-on hypothesis testing, statistical analyses, and the interpretation and presentation of scientific data associated with it. It should be noted that this laboratory module could be modified by excluding the ELISA in order to shorten the laboratory to two weeks. Further, the student experience may be enriched by including paraffin embedding which will extend the duration of this module. Overall, we have developed an inquiry-based laboratory module that directly involves students in their learning process as recommended by the NSF. We believe that inquiry-based scientific experimentation and analytical skills, like those obtained by completing this laboratory module, are crucial for advanced biology courses for STEM majors and strongly recommend incorporating it in the coursework to improve scientific literacy.

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A Game-based Approach to Teaching Concepts of Infectious Disease

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Abstract: With over 1,400 known disease-causing organisms in humans alone, and hundreds of named infections, the realm of Medical Microbiology is both fascinating and intimidating. The wealth of information covered in this subject area often demands much memorization that can be difficult to handle. By integrating key concepts and terminology of this subject into a disease-based game concept, student interest and engagement in class as well as retention of information and performance on exams can be greatly improved, however. Here, I will introduce the elements of this game-based activity and several suggestions of how it can be integrated into the classroom to foster active learning as well as greater interaction and communication among students.

Key words: active learning, game, Medical Microbiology, disease, pathogen

Introduction

In more than 20 years of teaching Microbiology and related subjects, one of the areas that always catches my students' attention and interest is the nature and cause of infectious diseases. Every student has, of course, experienced sickness and most have a natural curiosity about the causes of their illnesses. Moreover, frequent headline news reports of significant disease outbreaks such as the recent Ebola crisis in West Africa, cholera epidemics in natural disaster areas, or cruise ship norovirus outbreaks generate much interest in students, and enrolment in my Medical Microbiology course is always good. Students are very interested in what causes disease, how symptoms develop, how diseases can be identified and treated. By searching the scientific literature and cataloguing the different microbial species responsible for disease in humans, researchers in the UK listed >1,400 different species (Taylor et al., 2001) – a huge number were one to try to cover each one in the course of one semester! Yet even the more modest amount of material in an undergraduate course includes roughly 250 different pathogenic species and infections. Various approaches have been used, such as by organ systems affected, symptoms, or by pathogen group – often called the "bug parade" (Murray et al., 2016). The latter approach is very relevant in clinical diagnostics, as isolation and identification of particular pathogens often precedes diagnosis and treatment of an infection. Regardless of approach, students are left to memorize or integrate large amounts of material.

The authors of my favorite text for this course (Murray, Rosenthal and Pfaller) provide helpful suggestions for mastering such information, including the frequent cross-referencing of information and sub-categorizing into more easily remembered groups, such as arthropod-borne or sexually transmitted diseases, exotoxin-mediated infections, hemorrhagic diseases, and zoonotic (animal-harbored) diseases. Understanding such groupings and remembering associated diseases does indeed increase retention of this information and improves understanding of mechanisms, and I have used various strategies to incorporate this into my teaching (review sheets, summary charts, diagrams, cross-linked web pages). But the most notable improvement in student performance and learning occurred with the (gradual) implementation of the "Survivor"-styled game activity in the course over the past 8 years. The goal of this game activity was to increase student interest and participation in class as well as to provide a novel way to integrate key course concepts in one activity. At the core of this activity is a set of disease cards (Fig. 1) which integrate key information about each infectious disease in easily identifiable pictograms and key words.

Procedure

Here, I will describe the methods through which I integrated the Survivor game activity in my course, with suggestions on variations to this activity. I will also introduce the key game elements. A more comprehensive discussion of each game element and its relevance, as well as explanations of core concepts, follows. While I was not successful in garnering interest among Microbiology publishers, I hope you will find these materials to be fun, engaging, and ultimately a valuable teaching tool and I will be happy to share these with you.

At the start of the semester, I divide students up into 3 teams. Team names are usually derived from diseases (Ebola, Lassa, Nipah), and I purchased a set of colorful bandannas for each team. Students begin to interact with teammates early on, and weekly on-line quizzes are announced. Quizzes serve three purposes: to review the week's lessons, to earn team points, and to earn treatment cards (see below). A weekly contest is announced during which 2 players are eliminated from competition. This exercise encourages teams to cooperate, review material together, and work together to answer questions. The quiz is administered via the college's Moodle

platform (it could certainly be given in class in printed form as well). Following each quiz, I calculate team averages. The team with the highest average gains immunity (exempt from the elimination competition), while the other 2 teams each eliminate one member. This process is repeated for the first 8 – 10 weeks of the semester, when all remaining competitors are joined into one new team. At this stage, weekly quizzes award immunity to a single competitor, with the remaining students competing to eliminate 2 more competitors. This continues until the last week of the semester, when all remaining survivors compete in a final game to crown the winner. Adjustments to how many teams are formed, how many students eliminated each week, and how many compete in the semester's finale are made based on class size. You can even tailor the activity in a way that nobody is eliminated along the way. Keep in mind that the goal is to encourage participation and stimulate interest.

I realized very quickly that players who were eliminated did not have much incentive to participate in the weekly quizzes, and therefore include a way for some students to return to the game, based in part on their quiz scores and participation. The weekly quizzes thus were well used by students. Quizzes generally are 10 multiple-choice questions with answer choices randomized and questions randomly drawn from a larger pool of 20+ questions. This broadened the amount of material reviewed, especially if team members worked together. Quiz scores are not part of the students' grade for the course, except to award a small number of bonus points proportional to each student's participation.

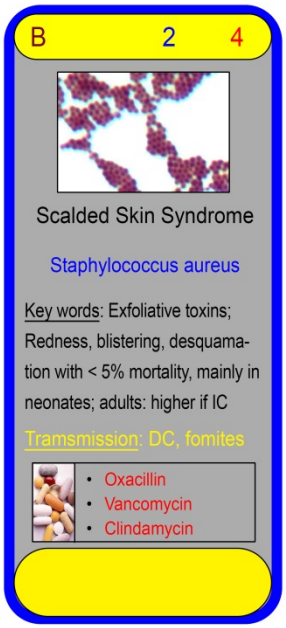

Fig. 1. Sample disease card for Scalded Skin Syndrome

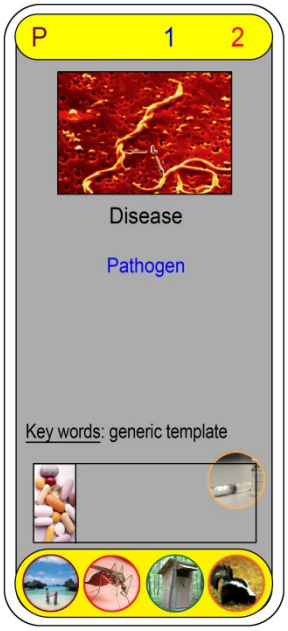

Fig. 2. Disease card symbols and elements

Each elimination contest centers on the two key elements of the game design: disease cards and treatment cards. This is the second area in which students integrate and review information. Each disease card includes key information as shown in Fig. 2: Disease name, cause (pathogen name), mode of transmission, key symptoms, key terms, main treatments available, and special symbols to identify vector-borne diseases, zoonotic diseases, sexually transmitted diseases, food/water-borne diseases and vaccine availability. Each card also identifies the type of pathogen (bacterial, viral, fungal, protozoan or parasitic) and its virulence, represented by a number between 0 and 5 (5 being the most harmful). Each treatment card, in turn, provides students with a means of treating (or preventing) an infection, and thus a way to survive longer in the game. Finally, a third element that can be introduced at any point are so-called event cards, which present variations to the process of infection and recovery, such as exposure to animals, antibiotic resistance or health status of a patient.

Students who participate in the weekly quiz earn treatment cards based on their quiz score. I usually award 1 card for every point above 5 (on a quiz worth 10 points), and players get between 0 – 5 cards. These are shuffled and randomly distributed. As there are 108 cards, students usually get very different ones. Although having more cards increases one's chances of doing well, it does not at all guarantee having useful ones!

Elimination contests are based on a simple premise: play continues until a player reaches a set number of points (the sum of all the virulence scores of any diseases the player has received, minus any that he/she has successfully treated), usually 10. Disease cards are shuffled and randomly distributed among players; the number of cards handed out to each player can be varied based on how quickly the contest must be conducted. The game features 180 distinct disease cards, thus assuring an almost completely random chance of ending up with each disease. If time allows, I start with only 1 card per student, meaning that nobody is eliminated right away. Students who have a treatment card that exactly matches a listed treatment on their disease card can get rid of that disease. Once every student has treated (or prevented) what they can, a second round of cards is distributed. Students now add the virulence points on their remaining cards and attempt to treat/prevent what they have. If a student has reached 10 points, he/she is eliminated (a rare but not unheard-of event after 2 rounds in my experience with this game!). The manner in which new cards are distributed can vary from simply handing out a card to each player to using the game board. I use the former method if only a few minutes are available (i.e. students cannot stay after class), and the latter at later stages of the game when I can schedule a special time and student interest is heightened. An additional variation that is added to the game is the use of event cards, which can be given out randomly (1/student) or uncovered via the game board. These cards present unusual situations or events by which a player may immediately receive or get rid of a disease, gain or lose treatments, gain or lose points, or alter their health status. For example, uncovering a card that states the player is bitten by an arthropod immediately allows another player to hand them a disease card with the vector symbol (mosquito) on it. In this way, disease points can change very quickly.

In contests where only 1 or 2 players are eliminated, contests usually end quickly (within 3 or 4 rounds). The biggest drawback to this method is that contestants have very little control over the outcome of the game: they try to match treatments to diseases, keep track of their points, and hope the next randomly drawn card does not put them over the top (10 points). I have tried to relieve this issue to some extent by introducing event cards between each round, in which case contestants interact with each other by handing off disease cards based on the event described. The use of the game board (Fig. 3) adds significantly more variation and random elements such as when new disease cards are picked up, when event cards are drawn, and when players interact directly. However, this demands more time (15+ minutes). Other variations which have not been tried include allowing students to choose one or more treatment cards before the game, or answer a question during the game to avoid drawing another disease card.

Fig. 3. Laminated game board with decks of disease cards, treatment cards and event cards

Assessment

Student engagement in the course, performance on graded assignments and tests, and voluntary feedback have served as a partial measure of the impact of this activity. In turn, exam performance and "survivor" quiz performance also help to assess student comprehension of the material being taught.

Exam performance: I have typically given 4 exams, 2 of which cover general material and concepts, and 2 which cover the detailed information targeted by this game activity, such as case studies, disease summaries, unique modes of transmission etc. Exam performance for the first 2 tests was slightly improved (80.6 to 81.5) since implementation of the game, but performance on the last 2 exams significantly improved (73.6 to 81.9) in that time (Student's t-test, $P < 0.01$). Although the sample size is small, I find the marked improvement on the later exams to be significant, in part because students previously struggled more with this part of the course. **Feedback**: Student comments about this course have generally been highly favorable, as students clearly were interested in the subject. But the specific comments about the Survivor activity indicated that many students really enjoyed the game,

which was mentioned specifically at least 5 times. One student commented: “The game he made (the details of immunity, bandannas, membership cards, etc.) was great!”. Another student’s comment points to the challenge of learning this material: “To really understand some parts required a lot of learning of new names and details to general concepts. It was more finding a way to piece intimidating loads of data together in useful ways to identify causes in case studies and other ways to categorize diseases”.

Participation/engagement: Student participation in the optional “survivor” quizzes was around 90% for each of the past 3 times the course was taught. By comparison, optional bonus point assignments in my General Microbiology course have a participation rate of only ~50%. Students seemed to really want to participate, especially during the team competition phase. It is not unusual for students who are not competing to watch a competition among others, or for one student to feel bad for another if they are eliminated – and usually, competitions are accompanied by good-natured ribbing and laughter.

1. Participants get treatment cards as before, based on Survivor quiz scores
2. Contest is conducted on the Survivor game board
3. Each contestant starts with 2 disease cards. Contestants start on fields numbered 1 – 8
4. Contestants take turns rolling dice and move clockwise. Actions depend on the field a contestant lands on:
    - Numbered field: pick up one disease card
        - You may treat any disease you pick up with the specific treatment if you have it
    - Field designated B, V, F or P: get a disease card specific to the pathogen class (bacteria, virus, fungi, protozoa – see pictures below)
        - If you have a treatment card for this category, you may play it to prevent infection; no disease card is picked
        - If you pick a card first, only the treatments indicated on the disease card may be used
    - Syringe: pick up an event card and read it out loud. Follow the action
        - If you contract a zoonosis, vector-borne disease, STD, HAI, Bioterror agent or food/water borne disease, the first opponent to place a matching disease card on the table passes it on to you
    - Outhouse: you contract a food/water borne disease from the first opponent to place it on the table
    - Mosquito: you contract a vector-borne disease from the first opponent to place it on the table
    - Beach couple: you contract an STD from the first opponent to place it on the table
    - Skunk: you contract a zoonosis from the first opponent to place it on the table
    - Pills: you get a free treatment card
    - Hospital: you get rid of one disease card of your choice
    - Picnic pond: skip a turn
    - H: go directly to the hospital
    - Blank field: nothing happens
    - IC/HIV: you become immunocompromised, and immediately use the red numbers in place of blue numbers (If only blue numbers are present, you still use these)
    - Shortcut: you must follow the shortcut path on your next turn. You may choose which way you go at forks in the path, but you may not backtrack. Once you reach the edge of the board, proceed clockwise again. If you land on the shortcut symbol on your way out, stay on the edge.
5. If you land on a space already occupied by another player, you may give one of your diseases to your opponent. Then follow instructions on the field you landed on.
6. Special rule: You may play a numbered treatment card instead of rolling the die when you are on the outer track. You now move ahead by the number of spaces matching the # on your card. Your treatment card is turned in. All other rules apply.
7. If a player reaches 10 points at the end of a turn, he/she is eliminated

Table 1. Survivor board game rules

Discussion

The Survivor – Pathogen Island game incorporates many key concepts into its design. The following terms, concepts and principles of medical microbiology are all incorporated into each disease card and can be further elucidated and illustrated through the additional use of the game board, treatment cards, and event cards. Table 1 explains the rules of the game. No matter how you choose to use the game, you will find many opportunities to launch a discussion or emphasize a key point in the midst of every game activity!

Pathogen types: Infectious diseases in humans are caused by > 1,400 known pathogens, which includes bacteria, viruses, fungi, protozoa, and parasites. Each disease card is color-coded by these main categories and includes an identifying letter for each. Every card also includes a specialized symbol for each specific class within these categories. For example, bacteria are divided into Gram-positive rods, Gram-positive cocci, gram-negative rods, Gram-negative cocci, Gram-negative curved/spiral bacteria, and unusual/intracellular Gram-negative bacteria

Virulence: The seriousness of any infection is the product of several factors, including the virulence (nastiness) of the pathogen, the ease of infection, the number of infecting microbes, and the host's immune system. I have taken these factors into account to generate a relative virulence number, which is printed in blue on the top of each disease card. Numbers range from 0 (harmless) to 5 (extremely harmful).

Immunocompromising conditions: Many infections are made more serious if a host has a compromised (deficient) immune system. This may be due to genetic defects, HIV infection, immunosuppressant drugs, or even age and malnutrition. This concept is integrated into an upgraded virulence number, printed in red next to the relative virulence number for infections where it applies, and indicates to students the significant impact of such immunocompromising conditions.

Biohazard: Certain infectious agents are classified as potential bioterror agents by the CDC (CDC, 2018). Such agents include anthrax (Category A), Typhus fever (category B), and hantavirus (category C). Pathogens in these categories are identified with a special biohazard symbol.

Disease name: Many infectious diseases have one specific cause and unique symptoms; the association between disease and pathogen is obvious (e.g. anthrax – *Bacillus anthracis*). However, the majority of infections that occur in humans have a less precise correspondence to one particular pathogen. Many infectious agents have multiple anatomical manifestations (e.g. Staphylococcus aureus – impetigo; toxic shock syndrome; scalded skin syndrome; carbuncle), while some infections are named by the anatomical location where they occur and have multiple causes (e.g. pneumonia – Klebsiella pneumonia, Mycoplasma pneumonia, Streptococcus pneumonia). This concept is reinforced as students encounter multiple cards with the same pathogen or the same disease name but different corresponding disease/pathogen.

Pathogen name: In addition to the above-mentioned concept of pathogens having more than one potential effect (disease), the nomenclature of microorganisms is reinforced. Bacteria, fungi, and protozoa/parasites follow the binomial system on nomenclature while viruses are more generically named and categorized by structure, size, host range and replication pattern. Relationships between certain pathogen groups emerge as well as students recognize certain Genera as causing multiple diseases, and when appropriate, a pathogen's Family or larger taxonomic level may also be indicated in the key words.

Pathogen image: Recognition of a pathogen and laboratory diagnosis of an infection often involves microscopic observation, and in some cases this alone may be sufficient for an accurate diagnosis (e.g. Giardiasis – *Giardia lamblia* has a very unique shape). In other cases, the shape and/or color may narrow down the possibilities. In combination with the pathogen type information (symbol/letter in the top section), a clinical diagnosis is much more likely with this information. Likewise, it becomes much easier for students to remember and identify certain diseases if they are narrowed down to one specific category (e.g. spiral-shaped bacteria). Lastly, visual association of a pathogen's image with its name and disease reinforces learning and aids in case study identification where images may be given.

Key words: Each disease card features important terms that should be associated with the infection. This includes key symptoms (e.g. flaccid paralysis – Botulism), unique reservoirs/animal associations (camels – MERS virus), key complications (Weil's disease – rat bite fever), diagnostic clues (owl's eye inclusions for Cytomegalovirus), alternate names (Athlete's foot – ringworm), geographic areas of prevalence (Ohio/Mississippi river basins – Histoplasmosis), and more. Remembering even one key word may be enough to trigger recollection of disease or pathogen names and other associated data.

Transmission mode: The most common mode of transmission is identified for each pathogen. In some cases, multiple modes exist. Common modes of transmission include direct contact (DC), inhalation/respiratory, ingestion or fecal/oral route, vector (e.g. insects, ticks), and trauma. Grouping diseases by unique modes of transmission facilitates retention of information, helps understand geographical incidence of certain infections (e.g. mosquito-borne), and highlights prevention efforts.

Special categories in terms of transmission mode include sexually-transmitted infections, arthropod-borne diseases, food/water-associated pathogens, and zoonotic (animal-associated) microbes.

Vaccination: Availability of a vaccine for a particular disease is indicated on these cards with a vaccine symbol in the corner of the treatment box. The concept of vaccination is not new, but needs to be emphasized particularly now, when many preventable infections (influenza, mumps, whooping cough, polio) have re-emerged due in part to public misconceptions about vaccines. The effectiveness of vaccination is built into this game by using vaccine cards (one of the treatment card options) to completely prevent a disease.

4) antimicrobial resistance is a real and present danger to our efforts to combat and treat disease. This idea is reinforced through a) the lack of available treatments for some diseases and b) special "event cards" which introduce resistance and antibiotic expiration.

Sexually transmitted diseases/infections: A special symbol (beach couple) is present on cards for STDs, allowing students to quickly identify (and hopefully remember) these diseases as well as recognizing ways to prevent these infections. Prevention of STDs is also incorporated into the game via "Abstinence" treatment cards. Students learn to recognize STDs by name; understand that STDs can include viruses, bacteria and protozoa; realize that new information has come out which adds some diseases to the list of known STDs (e.g. Zika); and recognize the collective burden of STDs. While STDs are often relatively "mild" compared to terrible diseases such as tetanus, they are much more common and therefore present a greater impact on society as a whole.

Vector-borne diseases: Each vector-borne disease features a special symbol (mosquito) on the bottom of the card, helping students quickly identify this category of diseases. The specific vector is often identified in the key terms or transmission section. Students learn to associate diseases with their vectors, and follow-up questions can easily reinforce this concept (e.g. "How many other pathogens do you remember that are transmitted by ticks?"). This concept is further incorporated into game play using the game board and event cards, both of which feature the mosquito symbol. Prevention of transmission is also addressed with the use of "Bug spray" (insecticide) treatment cards. Yes, I know not all bugs can be repelled this way, but the concept works in the game setting!

Food/water-borne diseases: A special symbol (outhouse) represents this category of diseases. Such infections may be transmitted by contaminated food (can be specific or general), water, or fecal-orally.

Treatment: Each card features a black-bordered box with some of the major treatments (primarily antimicrobial drugs) listed which are effective against the particular infection. This aspect of microbiology is built into the game through the use of treatment cards (a separate set of cards with a playing card theme). Several key concepts are emphasized: 1) antibiotics are effective only against bacterial infections (with rare exceptions); 2) antiviral, antifungal and anti-parasitic drugs are needed to treat these respective infections, and the number of such drugs is fairly small; 3) many different infections respond to antibiotics differently; one pathogen must sometimes be treated with different drugs depending on body location, resistance, or duration of infection.

This often represents an additional important epidemiological consideration to diseases normally not associated with food (e.g. Toxoplasmosis – usually transmitted by cats). Students will learn to recognize that this mode of transmission is wide-spread, common, and a significant challenge for prevention. Event cards and matching game board symbols further integrate the concept into the activity.

Zoonotic diseases: The special (skunk) symbol represents diseases which maintain an animal reservoir. This helps to reinforce the concept of disease reservoirs and distinguishes these diseases from those with strictly human reservoirs (e.g. gonorrhea) or environmental reservoirs (e.g. tetanus). Although transmission mode varies widely among these diseases (bites, ingestion, touching, inhalation), animal contact in some form is often an identifying clue for these diseases and should always be inquired about in trying to diagnose an unknown infection. Furthermore, unique animal reservoirs may be associated with some diseases (e.g. leprosy – armadillos) and make for interesting case study material. Again, this concept is also built into the event cards and the game board.

Event cards and the game board (Fig. 3) furthermore add the following elements to the game which reinforce additional key terms and concepts in microbiology:

Healthcare-associated infections (HAI): Also known as nosocomial infections, people become susceptible to them in hospital/health care settings. This concept is integrated into the event cards as an optional element.

Antibiotic resistance: Many microbes evolve to become resistant to treatments, including superbugs such as MRSA, CRE and VRE, all of which have made the news lately. Resistance is included as an event card.

Health of a host: Immune defenses and ability to fight off infections are improved in a healthy person and lessened in a weakened host. Event cards

can add points due to weakening of the body (fever, inflammation) or subtract points (healthy diet). Furthermore, event cards and game board spaces designated as immunocompromised ("IC") force a player to use the red numbers on their disease cards, reinforcing the concept that the immune system plays a critical role in the defense against infection.

Potential game variations: I hope you'll find new, innovative ways to combine the elements of this game activity with new ideas, and that you will feel free to share with me your successes and failures. One could print out (or computer-generate) a random question a student would have to answer if they land on certain fields, for instance, instead of separating the questions from the game as I have done.

Medical Microbiology is a daunting subject when one begins to consider the vast number of pathogens and infections to be learned – but it does not need to be. Games are often fun, entertaining and engaging – and have limited educational value – but they don't need to be this way! By combining key terms and concepts from my course and competitive class activities within the context of a comprehensive game, I have seen increased student engagement, improved exam performance and more excitement among students.

Acknowledgements

A short article published in Microbe in 2006 served as a seed to plant the idea of a game involving microbes in my head (Casadevall, 2006). I am also grateful for the many encouraging comments from students regarding the game design and implementation.

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The Value of Experiential Learning: a Case Study with an Interdisciplinary Study Abroad Course

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Abstract

Experiential learning provides students the time and space to participate in the process of learning by engaging in real, modern situations. Via hands on activities and reflection, students are able to assimilate new experiences with previous ones, and it has been repeatedly shown to improve student learning. We assessed how ten days of experiential learning in Tanzania, Africa affected student understanding and retainment of fundamental concepts in evolution, ecology, and ethology. We assessed 25 college students (n = 12 biology majors, n = 13 non-biology majors) with a pre- and post-test. The pre-test was announced to the students and given before travel, and a nearly identical post-test was unannounced and given four weeks after travel. Non-biology majors performed at least ~15-30% higher on their post-exam compared to their pre-exam, and biology majors performed 5-10% higher on their post-exam compared to their pre-exam. The success of our interdisciplinary course can partially be attributed to experiential learning, and our results suggest that experiential learning has a particular value to non-majors.

Keywords: experiential learning, assessment, non-majors, interdisciplinary, study abroad

Introduction

Experiential learning is the type of education that occurs when students actively participate and interact with their surroundings. Originally proposed in the 1930's, the application of experiential learning as part of the higher education process has been growing exponentially since Kolb introduced his Experiential Learning Model in the 1970's (Dewey, 1938; Kolb, 1984; Manolis et al., 2013). Although the details of the experiential learning model (as well as other closely related learning models) continue to be refined in the literature, the fundamentals of all experiential learning theories are the same: in experiential learning students are given the time and space to participate in the process of learning by engaging their senses real, modern situations (Cantor, 1997; Kolb, 1984; Kolb et al., 2001; Kolb & Kolb, 2005; Lewis & Williams, 1994; Manolis et al., 2013; Schwartz, 2013; Wenger, 2009). Student learning takes place via hands on activities, via contextualization of information in real world examples or scenarios, and with reflection, they assimilate new experiences with previous ones. Studies documenting the value of experiential learning are plentiful (especially compared to a "knowledge transfer" based education), and it is a powerful teaching tool across many disciplines (for reviews see Kolb & Kolb, 2006 and Springer et al., 1999).

Like experiential learning, interdisciplinary course offerings are also growing in popularity. Cross-curricular programs allow faculty to weave together timely fields of study and allow students to learn about topics through multiple, and different, faculty lenses (Coops et al., 2015; Jacobs, 1989; Klein, 1997; Kurland et al., 2010; Matthews et al., 2010; Sherchan et al., 2016; Smit & Tremthick, 2013; Weinberg & Harding, 2004). Interdisciplinary courses provide the opportunity to make explicit connections with topics that might otherwise be treated as insular, and this can be especially true in undergraduate programs where departments, divisions, or schools separate academic topics (i.e., a Department of History and a School of Engineering). The value of interdisciplinary coursework can be directly seen in the trend for many colleges and universities having adopted "globalization" or "internationalization" as part of their mission statement or long term plans (Maringe & Foskett, 2012). While overhauling entire programs to be more interdisciplinary is a daunting task, there are smaller, more manageable approaches to helping students become global citizens who interpret the world through multiple lenses. 'Studies Abroad' programs for example, are by definition already global and have an experiential learning component, as students travel to a potentially new and foreign setting. Moreover, they can be relatively easy to make interdisciplinary, as they are often comprised of a small group of students that are taking the same few courses. We began thinking about the value of interdisciplinary coursework in the light of experiential learning in a new study abroad course we developed at The University of Portland, "Ecology, Evolution, and Culture in East Africa". It is a 300-level course with sixteen weeks of classroom time during fall semester, ten days of experiential learning in Tanzania over winter break, and two weekend

retreats during spring semester. During the fall semester students are exposed to a unit on environmental communication as well as a unit on the fundamental concepts of ecology, evolution, and ethology. The field component in Tanzania is the hopeful climax of the course as it provides the students with the opportunity to apply and expand their views and understanding of the world around them; ideally they internalize the academic topics covered in the classroom, challenge their previous beliefs, and recognize how their experiences are shaping the way they have come to understand information.

The current learning outcomes of our international and interdisciplinary course are lofty. First, students should be able to demonstrate critical thinking in the social and biological sciences. This includes using concepts and ideas from scholarly sources to enrich personal views about global awareness and cultural consciousness as well as reflecting on what it means to develop international goodwill and appreciating difference. Second, students should be able to demonstrate knowledge of theories and research related to ecology, evolution, and culture of East Africa. This includes analyzing the role of culture in nature and the role of nature in culture as well as explaining how human relationships impact the social and biological environment, locally and globally. Additionally, our course aims to contribute to deeper questions that are part of our University's Core Curriculum: How does the world work and how could the world work better? How do relationships and communities function? What is the value of difference? What is the role of beauty, imagination, and feeling in life? Given such comprehensive learning outcomes, our assessments are a work in progress. Students who take this study abroad course come from diverse backgrounds, and since experiential learning is in part based on previous experiences, we would like to develop ways to tease out the variables that contribute to their ability to achieve our learning outcomes. Eventually we aim to demonstrate if and how their understanding of biology and environmental communication grows over time and some of these assessments are inherently or logistically difficult. However, one piece of assessment that was realistic to capture on our first few iterations of the course was how the experiential learning portion of the course influences student understanding and retainment of biological content. Tanzania is one of the richest sites of human and biological histories in the world, and the examples of flora and fauna there can be used to explain any basic principle in evolution, ecology, and ethology. Thus, we explored if and how the *in situ* travel in Tanzania affected student understanding of core concepts in evolution, ecology, and ethology. We hypothesized that all students would demonstrate an improvement in their ability to explain fundamental theories in biology, and that non-majors would show more of an improvement than biology majors.

Methods

We assessed two cohorts of students who participated in the course, one in 2015 and one in 2017. In total there were 25 students: 12 biology majors and 13 non-biology majors. All students were juniors or seniors, and other majors represented were business, education, communications, German, Spanish, history, and sociology. The first round of assessment was given as an in-class exam prior to travel. It was announced in the syllabus (as an exam) and students expected and prepared for it. Students did not get their exam grades or the paper copy of the graded exam before taking the post-test. A nearly identical assessment (see below) was given four weeks after students returned from Tanzania during our first weekend retreat. The students were given no warning or chance to prepare or study for this second assessment; it functioned like a pop-quiz. Both the pre- and the post-test were proctored by the authors.

The assessment tool (or exam) consisted of four parts: animal identification (30%), evolution (30%), ecology (20%) and ethology (20%). For the animal identification portion, students were given a list of 50 East African animals to be able to identify. These animals were covered in lecture pre-departure, usually as examples of biological concepts. They learned about the animal's life and natural history with a particular focus on its ecological niche and/or its unique adaptations and behaviors. For the exams, thirty pictures (via a PowerPoint presentation) were shown to the students and they had to identify it. There were different pictures and animals on the pre- vs. post-assessment, but all animals presented to the students were included on the original list of the 50 animals. These identification questions were worth one point each and were graded as correct (1 point) or incorrect (0 points). Incomplete or vague answers such as "monkey" or "bird" were counted as incorrect. The second portion of the exam focused on terms, short answers, and examples of evolutionary concepts. Examples of test questions included *Explain natural selection and provide an example* and *What is Olduvai Gorge and why is it important to studies of human evolution?* The third section were questions about ecology such as *What is a keystone species? Describe with two examples*. The fourth section focused on ethology and included questions such as *What are the fitness costs and benefits of living in a group? Describe with an example* and

Name and describe (using examples) two types of mating systems common in intraspecific competition. Throughout the exam the terms were worth two points each (2 points for a complete definition, 1 point for an incomplete definition, and 0 points for an incorrect definition) and the open-ended short answer questions were graded on a "points earned" basis. For example, providing two examples of keystone species was worth six points, and students could earn up to three points for each example. An answer of "dung beetle" earned one point, while an answer that elaborated on the specifics of why dung beetles are a keystone species was worth three points. In other words, answers with more details and synthesis earned more points. Ultimately the test was ~45% "right or wrong" and ~55% "points earned". Students were instructed to write something for every answer (even if they didn't know the correct answer), and with only one exception (see Results), all students answered all questions. Paired t-tests were used to compare pre- and post-exam scores. We did not test for differences between cohort 1 and cohort 2 due to sample size (i.e., each cohort individually was not large enough for statistical analyses). Instead, the two cohorts were pooled for all statistical analyses.

Students spent a total of ten days in Tanzania. The company that handles logistics while in East Africa is Thomson Safaris and they have a unique vehicle that seats 16 people; it accommodated all the students, two faculty, and one Tanzanian guide. Thus, unlike many travel safaris, we did not have to separate into small groups of Land Rovers that hold 2-6 people. This helped ensure similar visual experiences for all students (i.e., there were not situations where one group of students go to see something that another group of students did not). We traveled to four different conservation areas, each chosen because of their biological setting. Days 1-3 were spent in Tarangiere National Park. It is a microcosm of rainforest in an otherwise dry landscape, and reinforced topics included biomes, mating, and adaptations in plants. Days 3-5 were spent in Ngorongoro Crater National Park. This 2 million year old caldera is the largest in the world, and reinforced concepts included biogeography, natural selection, male-male competition and female choice, keystone species, and ecological niches. A travel day either to or from Ngoro Ngoro was punctuated with a visit to Oldupai (or Olduvai) Gorge; after a lecture on the history and major discoveries of the area, students explored the museum and interacted with volunteers and docents. The primary reinforced topics were hominid evolution and geologic time. Days 5-8 were spent in Serengeti National Park. As the most famous park in Tanzania, it houses the most species of ungulates anywhere in the world. Reinforced concepts at this park include group living, game theory, migrations, and the arms race between the hunters and the hunted. The final few days were spent in the Eastern Serengeti. This area, outside any national park, is a 12,600-acre conservation area that used to be owned and farmed by Tanzanian Breweries. It was purchased by Thomson Safaris and named "Focus on Tanzanian Communities" (FoTZC) and the focus of the organization's efforts include education, women's empowerment, community development, and clean water. Large carnivores no longer roam the Eastern Serengeti so students were able to explore the area on foot and experience the macro and micro ecological differences between wild and agricultural lands. Students also visited with farmers and a local veterinarian. Finally, because reflection is such a key component of experiential learning (Kolb, 1984; Kolb & Kolb, 2005), we also had nightly discussions around the campfire. While the topics always involved some aspect of Tanzanian flora or fauna, discussions often dovetailed into issues in conservation; this often provided a social context for students to understand fundamental biological concepts.

Results

Non-biology majors performed at least ~15% higher on their post-exam compared to their pre-exam, with their greatest improvements in concepts related to evolution and ethology (~30% improvement for both topics in post-exam scores compared to pre-exam scores, see Table 1). The average pre-test grades for non-biology majors were C, C-, and D and the average post-test grades were B, B+, and A+. For all four learning areas (identification, evolution, ecology, and ethology), as well as the exam overall, there were statistically significant differences between their pre- and post-exams (all $p < 0.01$, see Table 1).

Biology majors also showed some improvements in the test overall as well as some of the knowledge areas (identification, evolution, and ecology), but none of these differences were statistically significant. On average, biology majors performed 5-10% higher on their post-exam compared to their pre-exam (see Table 1). The average pre-test grade was a B while the average post-test grade was an A. For the ethology questions, student performance decreased by 2%; students averaged 99% on the pre-test and 97% on the post-test (see Table 1). One biology major did not answer an ethology question worth eight points on the post-test, and analysis of the data without this question in the pre- and post- exam revealed a 3% improvement in majors understanding

of ethology (96% average pre-test score, 99% average post-test score, data not shown on Table 1).

Biology majors performed better than non-majors on all aspects of the pre-test; biology majors averaged an 88% on the pre-test and non-biology majors averaged a 71%. The greatest differences in performance between majors and non-majors on the pre-test were in the evolution and ethology questions; for the evolution questions, biology majors averaged an 88% on the pre-test and non-biology majors averaged a 71%; for the ethology questions, biology majors averaged a 99% on the pre-test and non-biology majors averaged a 69%. However, there was little difference in the performance between the majors and non-majors in the post-test, and in some cases the non-majors out performed the biology majors (see Table 1). For animal identification, majors and non-majors differed by 6%, for evolution questions they differed by 1.4%, for ecology questions they differed by 6.6%, and for ethology questions they differed by 2.9%.

	Non-Biology majors (n = 13)				Biology majors (n = 12)			
	average pre-test	average post-test	average % difference	paired t-test results (pre and post test)	average pre-test	average post-test	average % difference	paired t-test results (pre and post test)
Exam Total	71.1%	88.0%	+ **16.9**	**<.001**	88.0%	91.7%	+ 4.9	.190
Animal I.D.	70.2%	85.2%	+ **15.0**	**.003**	85.8%	91.3%	+ 5.5	.376
Evolution Questions	60.1%	88.2%	+ **28.1**	**.003**	79.6%	86.8%	+ 7.2	.126
Ecology Questions	72.9%	86.9%	+ **14.0**	**.005**	83.3%	93.5%	+ 10.1	.257
Ethology Questions	68.8%	100%	+ **31.2**	**<.001**	99.2%	97.1%	- 2.1	.408

Table 1. Comparisons of pre- and post-tests for non-biology majors and biology majors. For non-biology majors, students demonstrated a 14-31% improvement in their understanding of fundamental biological concepts, and comparisons between pre- and post-tests revealed statistically significant differences for the exam total as well as each of the four test subject areas (all $p < 0.005$). For biology majors, students demonstrated a -2-10% difference in performance, and none of the differences were statistically significant (all $p > 0.1$).

	average pre-test	average post-test	average % difference	paired t-test results (pre and post test)
Exam Total	78.6%	89.8%	+ **11.1**	**<.001**
Animal I.D.	77.7%	88.1%	+ **10.4**	**.008**
Evolution Questions	69.5%	87.5%	+**18.1**	**<.001**
Ecology Questions	77.9%	90.1%	+ **12.2**	**.012**
Ethology Questions	83.4%	98.6%	+ **15.2**	**.003**

Table 2. Comparisons of pre- and post-tests for all 25 students revealed significant differences between student pre- and post-test (all $p < 0.05$).

Discussion

Non-biology majors showed a dramatic improvement in their ability to explain fundamental evolutionary, ecological, and ethological concepts. Across the range of topics, non-biology majors showed a ~15-30% improvement in their post-exam scores compared to their pre-exam scores. Since the students were given no warning or chance to prepare or study for the post-test, we believe most or all of the improved performance can be attributed to experiencing the biology themselves in Tanzania. Once they had seen, smelt, and heard the topics and animals firsthand, students were able to transform their previously sophomoric and vague answers into detailed explanations of how the world works on a biological level. Our results are consistent with other research that has demonstrated improved scientific learning from an outdoor experience (Bogner, 1998; Ernst et al., 2014; Falk & Balling, 1982; Jose et al., 2017, Lisowski & Disinger, 1991, Randall 2012; Scarce, 1997).

Interestingly, when we combined all 25 students for data analyses, there were statistically significant differences between student pre- and post-test. However, given the results when we analyzed the data by students' major, it is clear that non-biology majors are driving the differences of the group as a whole. That is, any conclusion about an improved performance of the entire group of 25 students would be misleading, as majors and non-majors did not benefit equally from the experiential learning portion of the course. If we had not specifically compared majors to non-majors, we would not have found this exciting difference in the value of experiential learning to non-majors compared to majors. East Africa is an exciting place for anyone to visit, and our data suggest that it has a disproportionate, and hopefully life long effect, on teaching science to non-scientists. This result is consistent with other studies that have demonstrated the value of experiential learning specifically to non-majors (Arwood, 2004; Packer, 2009; Wolfe et al., 2005).

There are three other noteworthy comments about our results. First, we were struck by the lack of detail in non-major pre-tests compared to the level of detail provided in their post-tests. The best examples were in the questions about Oldupai Gorge (i.e., What is Oldupai Gorge and why is it important to studies of human evolution?). No (non-major) student used a scientific name in the pre-test, yet in the post-test almost all the students provided the Latin name of at least one (if not all three) species discovered at Oldupai Gorge (*Homo habilis, H. erectus,* or *Paranthropus boisei*). Similarly, many students applied dates, years, or researcher names in their post-test answers. Second, we did not expect the biology majors to show a statistically insignificant improvement in their biological knowledge. While the students did perform 3-10% better on the post-test compared to the pre-test, we expected both biology majors and non-biology majors to significantly benefit from the field experience. We plan on developing future assessments that might elucidate if and how biology majors academically grow after their experiences in Tanzania. And third, it is interesting that students showed the biggest improvement in topics of ethology. The sights and sounds of birds singing or big horn sheep butting heads are nothing new to our students, as pictorials of these behaviors are often in commercials or billboards. We believe the changes in their understanding of ethology are from the thrill and excitement of being so close to the large, colorful, and active animals of East Africa. Students got woken up by the sound of male impalas fighting and the sounds of the rainbow colored lilac breasted roller singing just a few feet from their tent; these experiences allowed them to internalize how animal phenotypes represent their intense struggle for a chance at offspring. Their original understanding of the ornaments and armaments of the Serengeti transformed from something "cool" to concrete examples of the products of sexual selection.

One of the most unexpected dimensions of our experience in the field was the peer-to-peer learning that took place among the students. As previously mentioned, all students were in the same vehicle, meaning we were physically together during most of the day. At night, we camped in isolated campgrounds where, for safety reasons, our tents had to be within a few feet of each other. So while the group was physically together for all day and night activities, there were inevitably moments where a few students in the back of the truck would be having a different conversation than those students in the front. For example, upon seeing an elephant poached for its ivory tusks, a German major wanted to know why park rangers don't remove the body. As we all watched the venue of Lappet faced vultures feeding on the carcass, a biology major explained the basics and significance of nutrient cycling and food webs (something we had not extensively covered in the classroom pre-departure). As another example, the night after an impromptu visit to a local market, students engaged in a healthy debate over the cultural significance of our presence there, and how our behaviors were and weren't appropriate. It was incredibly exciting for us faculty to see our students share their knowledge and positionality with each other; our students were smart enough to provide facts within their disciplines as well as confident and open enough to discuss them. While we have no

formal assessment data on this, we believe the extraordinary level and intensity of interactions that took place among the students broadened their perspective. The organic nature of how students interacted with each other also highlights the value of having the field component of the course be 100% outdoors with no technology or cell phones as distractions. In the future we plan on being much more intentional and deliberate in facilitating peer-to-peer learning (as shown in Boud et al., 2014; Goldschmid & Goldschmid, 1976; Secomb, 2008; Whitman, 1988), and we suggest that any interdisciplinary approach develop assignments and assessments that specifically address interactions among students.

In conclusion, our assessments suggest that experiential learning in the realm of biology has particular value to non-biology majors. With the incredibly bio-diverse birthplace of much human and ecological history as their field site, our students culminated with a deeply important and powerful first-hand understanding of the interdependent and dynamic connections between animals and their environment. We think the success of the course can be attributed to the heavy participation of both the faculty and the students while in Tanzania, as well as peer-to-peer learning and the pre-trip classroom preparations. We believe there was a depth to the course experience made possible only by physically being in the location they are learning about, where any disconnect between fact and feeling was completely abolished; there was no barrier between student learning and engagement, just as there was no fence between ourselves and the wildlife

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Using Primary and Secondary Literature to Introduce Interdisciplinary Science to Undergraduate Students

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Abstract: Undergraduate students often lack opportunities to comprehend, present, and produce scientific literature as part of their regular curriculum. In courses that have already been already developed, students either analyzed a few journal articles and/or studied disciplinary content typically with the assistance of a textbook. In this study, I have developed a course that primarily relies on scientific literature to introduce interdisciplinary science in the intersection of biology and physics. Here, not only students learn content knowledge through literature, but also how to thoroughly analyze about 20 journal articles published in top-tier journals in the field. Students demonstrate their understanding of the content matter through weekly assignments, oral presentations, and a written review article.

Keywords: scientific literature analysis, interdisciplinary science, biophysics, DNA, scientific literacy

Introduction

Using primary literature to increase science literacy is used in different levels of classrooms from college-level introductory biology to graduate-level courses and has been the focus of many previous studies. In one study, students analyzed literature generating from the same laboratory over a period of time (Hoskins et al., 2007) and in another, students have studied a few articles in depth by learning how to dissect each section of the article (Janick-Buckner, 1997). In a third study, students in humanities were taught science literacy by analyzing one journal article of their choosing (Eslinger & Kent, 2018). Not only does scientific literature offer students a way to understand how a study is being performed, its hypothesis, methodology, and conclusions, but also teach them analytical skills to "follow a story," and to comprehend data through illustrations, graphs, and tables. Furthermore, students gain content knowledge supplementary to their coursework and textbooks. To that extent, many disciplinary courses have used selective primary literature as an introduction to scientific thinking *(*Kitchen et al., 2003; *M*uench*, 2000). However, there is a lack of use of scientific literature in interdisciplinary courses taught at the undergraduate level.* To address this void, I have developed a 3-credit course in biophysics that stresses interdisciplinary research in the intersection of biology and physics through intensive use of primary and secondary literature. Importantly, I used these articles to teach content knowledge in lieu of a textbook. In addition, students read an autobiography and a biography and watch documentaries to gain insight on ethics and politics behind major discoveries in the field. Furthermore, students write a comprehensive review article based on the literature they have read during the semester to gain further understanding and experience of producing scientific literature.

Methods

The target student population were upperclassmen who completed two semesters of biology and/or two semesters of physics. Out of the 66 students who completed the course during its three iterations, about 15% were non-biology majors (physics, engineering, education, psychology). Students could enroll in the course either as a biology or physics course.

The theme of the course was biophysics of DNA nanotechnology. Although the majority of students who completed this course learned basic biology and physics principles through the pre-requisites, I held short review sessions of major topics needed for the course such as DNA replication and optics. The physics reviews often included hands-on activities such as finding the index of refraction of water. While these concepts were familiar to students, interdisciplinary biophysics topics such as DNA origami, Atomic Force Microscopy, nano-robots, and magnetic tweezers were learned through primary and secondary literature. I introduced interdisciplinary topics such as the use of optical tweezers on DNA through short videos before students read any literature about the subject familiarizing them to nomenclature and the techniques.

In addition, some class periods were used to discuss the two books and the documentary. Students read the first book towards the beginning of the course, *The Double Helix: A personal account of the discovery of the structure of DNA* by James Watson. It is a candid autobiography on the discovery of the structure of DNA from Watson's impressions on Francis Crick to his opinions on Rosalind Franklin. Towards the middle of the semester, I assigned students to watch the documentary *Cracking the Code of Life* (2001) on PBS Nova about the Human Genome Project. In the last half of the semester, students read *Rosalind*

Franklin and DNA by Anne Sayre which is a biography of Franklin authored by her friend. I assigned readings on several chapters of the books per week and as a class, discussed ethics, humor, interdisciplinary nature of science, and politics behind each book and similarly on the documentary. Students were eager to share their thoughts which made it possible for lively discussions. Anecdotally, these discussions and the reflection papers students wrote enhanced their understanding on various aspects of producing scientific literature from how authorship is decided, how funding is secured, the ownership of science, the human aspect of scientists, and rivalries between scientific entities.

Scientific literature

As stated previously, the main aspect of this course was learning interdisciplinary science through scientific literature. Students were evaluated through two group presentations on research articles, take-home assignments based on these articles, a written literature review article, and three reflection essays based on the two books and the documentary. Since the theme of the course was biophysics of DNA nanotechnology, the first primary research article of the semester was the article that predicted the structure of DNA (Watson & Crick, 1953). I assigned students to read the article outside of class and to annotate; and used one class period to discuss the article from how it is structured to its content. The first secondary research article of the semester discussed three techniques used in biophysics to investigate biological molecules: Atomic Force Microscopy, Optical Tweezers, and Magnetic Tweezers (Neuman & Nagy, 2008).

The group presentations were broken into two categories: a PowerPoint presentation and a poster presentation. During the first half of the semester, I selected primary and secondary research articles based on biophysical studies of DNA nanotechnology that have used one of the three above mentioned techniques. Students presented in groups of two as 30-minute PowerPoint presentations. Each week, they completed a take-home assignment based on the articles/presentations of the week.

A sample of questions were:
1. Fig 4b shows displacement vs. time of the nano-robot movement. What information can we gather from the slope(s) of this graph?
2. What characteristic of an object (cantilever or DNA) is given by its spring constant?
3. In class, we talked about the Hooke's Law. Explain in 70-90 words how Optical Tweezers are used to obtain force-extension measurements of DNA.
4. What's "Brownian motion" and how is it different from the nano-robot movement in DNA origami?

The second half of the semester, I let student groups choose their own articles to present as posters, given that it fits within the theme and the techniques of the course. Students presented in groups of two, and each student was expected to invite at least one outside faculty member to attend the poster session, where only one poster was presented during a 50-minute class period. Therefore, for the 18-student class, there were nine poster sessions. The rest of the class attended the session along with invited faculty. Moreover some students invited their friends to attend the session, and on some occasions, additional faculty members saw the poster being presented and stopped by. The poster sessions were held in a room other than the usual classroom and I had instructed students not to gather around the poster as large groups, which let the presenters explain the poster multiple times during the time period. Usually, if there were five or six visitors to the poster, students waited their turn. After a few poster presentations, I noticed that each student would attend the session at a chosen time, some would attend at the beginning, and some would attend 30-minutes into the class period. Each presentation accompanied an assignment, and students who were not presenting spent the class time working on the assignment when they were not attending the poster. Prior to this course, some students did not know the purpose of a poster or how it is a medium for dissemination. Only one or two students in the class had attended a conference beforehand, therefore many students did not have an understanding of what a poster session entails.

As mentioned above, students completed a take-home assignment based on each poster. As opposed to detailed questions about the articles presented in PowerPoint, these were "big picture" questions about the study.

A sample of questions were:
1. What is the purpose of this study?
2. What were (if any) the previous studies that led to these experiments?
3. Pick two figures from Figs 2, 5, and 6 and explain each in 100-150 words.
4. If you were to follow-up on this work, what would you research on?

Before the start of poster presentations, I held a "poster workshop" where I shared sample posters from my own research and critiqued them. I let

students work on their posters for the rest of the class time while I assisted with their designs and layouts. Furthermore, student groups met with me prior to their presentations so that I could give feedback on their PowerPoint slides and posters and clarify any content questions they may have. Some groups met me with complete presentations while others had only a layout. After each PowerPoint and poster presentation, the rest of the class did anonymous peer-evaluations and grading based on a rubric. These were later shared with the presenters along with my feedback. Grades for the presentations were based on the following factors:

1. Comprehension and explanation of the article
2. Organization of the presentation
3. Aesthetics of the PowerPoint slides or the poster
4. Confidence, enthusiasm, and handling of questions
5. Audience interaction

Towards the end of the semester, I guided students to write a literature review article based on the course theme. At this point in the semester, students had read a few review articles, therefore they knew the difference between primary and secondary articles. I selected two peer-reviewed journals (one biology and one physics) and guided students on how to find journal guidelines. They had the choice of writing their review article to be hypothetically submitted to one of the two journals. To assist with their review article, at first, I asked students to select a topic based on the course theme and to write a skeleton of the article. After obtaining my approval for the skeleton, students searched for suitable journal articles through the university library in addition to the ones we have already read. I assisted with at least two edits per student before their final submission.

Results

Students read 20 assigned articles during the semester, not including the additional literature they researched to write the review article. I conducted pre- and post-tests based on a primary research article describing a synthetic DNA walker (Shin & Pierce, 2004). Students completed the pre-test during the first week of classes, and an identical post-test during the last week of classes. We did not discuss this particular article during the semester. The mean score for the pre-test was 51.8% while the mean score for the post-test was 81.8%. Statistical analysis were done using a paired t-test which showed significant gains with $p = 2.32 \times 10^{-8}$ and $t = 1.77$.

A sample of questions were:

1. What is the 'point' of this article?
2. What is a bipedal DNA walker?
3. What techniques did the authors use to monitor the walking movement?
4. What is the difference between Fig 1a and Fig 1b?
5. In Fig 3, the purple line shows that the fluorescence decreased between time 1000 and 5000 seconds. Why did the fluorescence decrease?

At the end of the semester, students were given an anonymous survey about their experience in the course, which they answered in a Likert Scale. For questions, "Prior to taking this course, I was familiar with the basic biology related topics discussed in this course," and "Prior to taking this course, I was familiar with the basic physics related topics discussed in this course," students responded with ratings 4.17 ± 1.25 and 3.78 ± 1.17 out of a 1 – 5 scale, where 5 is "strongly agree." On the question "Prior to taking this course, I was familiar with the biophysics topics and methods discussed in the class," students responded with a much lower 1.67 ± 0.91 rating [Table 1]. It is clear that they were familiar with the basic disciplinary content knowledge prior to taking this course, but were not familiar with the interdisciplinary content introduced through scientific literature

As discussed previously, comprehending, presenting, and writing interdisciplinary literature is emphasized in this course. For questions, "I feel more confident about comprehending an interdisciplinary scientific article after having taken this course," "I feel more confident about presenting an interdisciplinary scientific article after having taken this course," and "I feel more confident about writing a scientific review article after having taken this course," student ratings were 4.50 ± 0.71, 4.56 ± 0.51, and 4.00 ± 0.77 respectively [Table 1]. These results show that students felt more confident on understanding, presenting, and producing interdisciplinary science than prior to taking this course.

The following rankings and comments show that overall, students were positive about the nature of the course. Students rated questions "The nature of this course comes very close to what I think of as interdisciplinary science," and "This course made me aware, understand, and/or think about ethics and politics in science" with 4.33 ± 0.59 and 4.17 ± 0.71 ratings, respectively. In addition, students rated the questions "This course piqued my interest in biophysics," and "I would recommend taking a course of this nature for all science students" at 4.17 ± 0.86 and 4.33 ± 0.97 respectively [Table 1].

Prompt	Mean Score
Prior to taking this course, I was familiar with the basic biology related topics discussed in this course.	4.17 ± 1.25
Prior to taking this course, I was familiar with the basic physics related topics discussed in this course.	3.78 ± 1.17
Prior to taking this course, I was familiar with the biophysics topics and methods discussed in the class.	1.67 ± 0.91
I feel more confident about comprehending an interdisciplinary scientific article after having taken this course.	4.50 ± 0.71
I feel more confident about presenting an interdisciplinary scientific article after having taken this course.	4.56 ± 0.51
I feel more confident about writing a scientific review article after having taken this course.	4.00 ± 0.77
The nature of this course comes very close to what I think of as "interdisciplinary science."	4.33 ± 0.59
This course made me aware, understand, and/or think about ethics and politics in science.	4.17 ± 0.71
This course piqued my interest in biophysics.	4.17 ± 0.86
I would recommend taking a course of this nature for all science students.	4.33 ± 0.97

Table 1: Results of the anonymous survey conducted during the last week of the semester (n = 18)

The comments were:

"I learned a lot more of the history and politics behind scientific endeavors than I thought I would, which I am grateful for as it shows the scientific process under a different light."

"I now understand how to analyze and interpret dense papers and use the information in a valuable and beneficial way."

"I have really enjoyed this course because of its practicality. It has helped me refine skills that I know will benefit me throughout my academic and professional career."

"I now am better at reading, dissecting, and understanding difficult primary articles and their information and figures."

"I was able to learn how to create a poster which I think will be a valuable skill in the future."

"I learned how to research different topics [online] and how to optimize my searches."

"I knew about DNA structure and interactions, but I didn't know how we knew this info, so this class was really eye-opening for me in that sense."

Discussion

Anecdotally, during the first half of the semester, some students were nervous about presenting an interdisciplinary article to the class. However, during the second half of the semester, students were confident and looked forward to the poster presentations and took ownership of the article they had selected. There were 18 class periods dedicated to PowerPoint and poster presentations, and compared to the first few weeks of the semester, students asked better questions from the presenters as the semester progressed. This elevated students' critical thinking and analytical skills whether they were the presenters or audience members. Assignments based on each article as described earlier solidified the students' knowledge on each presentation. Many students were initially not confident on writing a review article, and I spent a significant amount of time towards the end of the semester helping them with the edits. But over time, they became more confident and produced better drafts. After the semester was over, I selected one of the better submissions to be further edited and submitted to a peer-reviewed journal, which is now published (Arora & de Silva, 2018).

From the pre- and post-test results it is clear that students learned to comprehend interdisciplinary science through primary and secondary articles.

Furthermore, from student perceptions, this course is a fun way to learn interdisciplinary content while acquiring oral and written communications skills. Anecdotally, many other students have asked me about this course and when I would be teaching it next. They had heard about it from their peers who had recommended the course.

A course of this nature could be developed for any interdisciplinary science from biophysics to biopsychology depending on the expertise of the instructor. Here, instead of traditional lectures, upperclassmen self-learn material by reading, presenting, and producing science literature in addition to being exposed to ethics and politics of science. The instructor's role is to introduce basic material and then to guide students to comprehend relevant research articles in order for them to gain further knowledge on the subject. By presenting self-taught material in PowerPoint and poster forms to their peers, students learn to present in the two most common mediums of dissemination at conferences. Additionally, instead of passive learning that is emphasized in traditional science classrooms, this course encouraged students to be active learners while take ownership of elevating their skill sets. The course was offered three times as a special topics course both in biology and physics and is now a regular course in the course catalog. The first two times the course was offered, the enrollment was 24 students each time, but for the third iteration, the number of students was reduced to 18 to allow more in-class discussions, presentations, and better student-instructor interactions.

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Measuring Student Learning Gains in Independent Research Experiences in the Sciences through Reflective Practice and ePortfolios

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Abstract: Undergraduate scientific research experiences provide students unscripted, active learning opportunities where the students take the lead in inquiry, problem solving, and analysis. Biology and chemistry majors at St. John Fisher College participate in a competitive 10-week summer research experience mentored by a faculty member. Evaluation of the program began in 2016 with a final reflection at the end of the experience being required of students in this cohort. In 2017, students were guided through three prompted reflection exercises and then utilized an ePortfolio to house their reflections and key components of their research experience. Students in both cohorts were required to complete both the Preflection and SURE III nationally-vetted surveys designed to measure self-reported learning gains in independent research by Professor Lopatto at Grinnell College. In 2016, students rated their learning gains on the SURE III survey lower than those students who participated in the survey at other colleges and universities across the country. In 2017, the cohort that completed the reflections and ePortfolios, reported their learning gains on par with students nationally. The coding of student reflections and SURE III survey data taken together show synergy and agreement pointing to areas of focus for program improvement moving forward.

Key Words: undergraduate research, reflection, metacognition, ePortfolio

Introduction

Undergraduate research as a high impact practice allows students to foster broad knowledge of human cultures and the natural world, strengthen intellectual and practical skills, and practice integrative and applied learning (AAC&U, 2007; Kuh, 2008). Graham et al. (2013) have identified early research experiences and active learning as key components for increasing confidence and motivation for STEM majors and for strengthening their persistence (Toven-Lindsey et al., 2015; Bandura, 1997; Estrada, 2011).

As a result, many colleges and universities offer intensive, faculty-mentored summer research experiences in the sciences. National Science Foundation supported programs are common, but one is not available on our campus at St. John Fisher College at this time. Our Summer Fellows Research Program aims to support students as they engage in an intensive summer research experience, practice goal-setting and critical self-reflection, and learn to communicate research findings to peers and a broader community of scholars. The program also aims to support mentors as they intellectually engage the next generation of scholars in their discipline as they also extend their scholarship. In efforts to provide improved holistic student support, we have critically examined our program and implemented guided, metacognitive reflective practice for students in this program.

While the literature is slim regarding support for reflection and ePortfolios with science students, there is growing support for these impactful pedagogies (Harring & Luo, 2016; Onorato, 2014). Other noted benefits of ePortfolios supported in the literature are described by Haave (2016) who noted students did not realize skills like critical thinking, communication and research skills were part of their degree, instead focusing on the science specific skills, while ePortfolios allowed for the conversation on the development of those types of skills through metacognition and reflection. Also, Haave (2016) remarks on the ability to make connections across multiple courses, the requirement for students to read and reflect on instructor provided feedback, and finally, students' ability to use the ePortfolio for potential employment opportunities in the future all result in positive student outcomes.

Few of those who adopted ePortfolios began with reflection as a primary goal, however most came to recognize the role of reflection very quickly in the use of ePortfolios. Instructors were surprised at

students' lack of ability to reflect and therefore needed to spend time teaching students this skill. Reflection was used in a wide variety of courses and programs using ePortfolios, but the specific types of reflection fell into two categories; helping students make connections between their learning and other experiences and to help students reflect on themselves (metacognition) (Landis et al., 2015).

"Folio thinking is a reflective practice that situates and guides the effective use of learning portfolios. Drawing upon the literature in experiential learning, metacognition, reflective and critical thinking, mastery orientations to learning, and, of course, learning portfolios, folio thinking aims to encourage students to integrate discrete learning experiences, enhance their self-understanding, promote taking responsibility for their own learning, and support them in developing an intellectual identity" (Light, Chen, & Ittelson, 2012).

Reflection does not come naturally to students, however, and instead must be taught and encouraged to see its benefits. Providing students with coaching support through the creation of an ePortfolio leads to students becoming "reflective practitioners" (Hadley, 2007; Parkes et al., 2013).

Importantly, students in the sciences often feel a high level of pressure related to future career aspirations, based on the number of available jobs and being able to adequately differentiate themselves from other job or graduate and professional school candidates. Wilson et al. (2018) reinforces the scholarly data on the positive impact undergraduate research has on STEM majors' career success, and the use of ePortfolios, along with career development learning tasks, can increase students' confidence in their own ability to apply and acquire graduate positions and jobs in their desired field (Yang et al., 2014). Oehlman et al. (2016) describes how creating an ePortfolio as a living document over a four-course and two-summer research experience allowed students to focus on their reflection skills, communication and writing skills, develop a professional identity and demonstrate their learning for external audiences. Complementing scholars' high-quality liberal arts curriculum, like that offered at St. John Fisher College, research experiences are one way to ensure scholars have the in-demand communication, collaboration, and problem-solving skills employers seek, further setting our students up for future success (Supiano, 2013).

Along with the use of a widely-used, nationally vetted survey tool (SURE III; Lopatto, 2004), we have implemented the use of student reflections and ePortfolios to guide students as they develop and recognize their own learning through the independent research experience. The reflections and ePortfolios provide a mechanism for students to study and then communicate their own progression and development as scientists in a way that research alone does not provide. The metacognitive practice of prompted reflection and composition of the ePortfolio itself improves students' recognition of their learning gains. Reflection prompts were designed to encourage and foster a growth mindset, which is especially critical to success in the reiterative process of scientific research (Howitt & Wilson, 2016).

Methods

The student surveys utilized in this study were supported by Grinnell College's Professor Lopatto, designed with support through HHMI funding (Lopatto, 2004). The Preflection survey helps to gauge a student's perception on their experience before they begin their research. The SURE III (Survey of Undergraduate Research Experiences) survey collects quantitative data on student research experiences and provides benchmarking data comparing our students to all those that participate nationally in the same time frame. Evaluation of student reflections took a qualitative approach similar to that utilized by Hunter et al. (2007), where ethnographic coding and analysis was utilized.

Results and Discussion

In 2016, 12 of our biology and chemistry summer research students completed the Preflection and SURE III surveys, 75% of whom were new to research. Nationally, 2,777 students took the Preflection survey and 3,478 completed the SURE III survey.

Our students identified the following as their *strongest* learning gains:

- Tolerance for obstacles in the research process
- Readiness for more demanding research
- Understanding how scientists work on real problems
- Learning laboratory techniques
- Learning to work independently

Our students identified the following as their *weakest* learning gains:

- Learn ethical conduct
- Skill in science writing

Figure 1 depicts how our students noticeably rated their learning gains lower than the national peer pool on the SURE III survey. With the exception of *learn*

lab techniques and *learn to work independently*, obvious components of a summer research program in the sciences, all other learning gains appear to be a concerning, stark difference compared to other students.

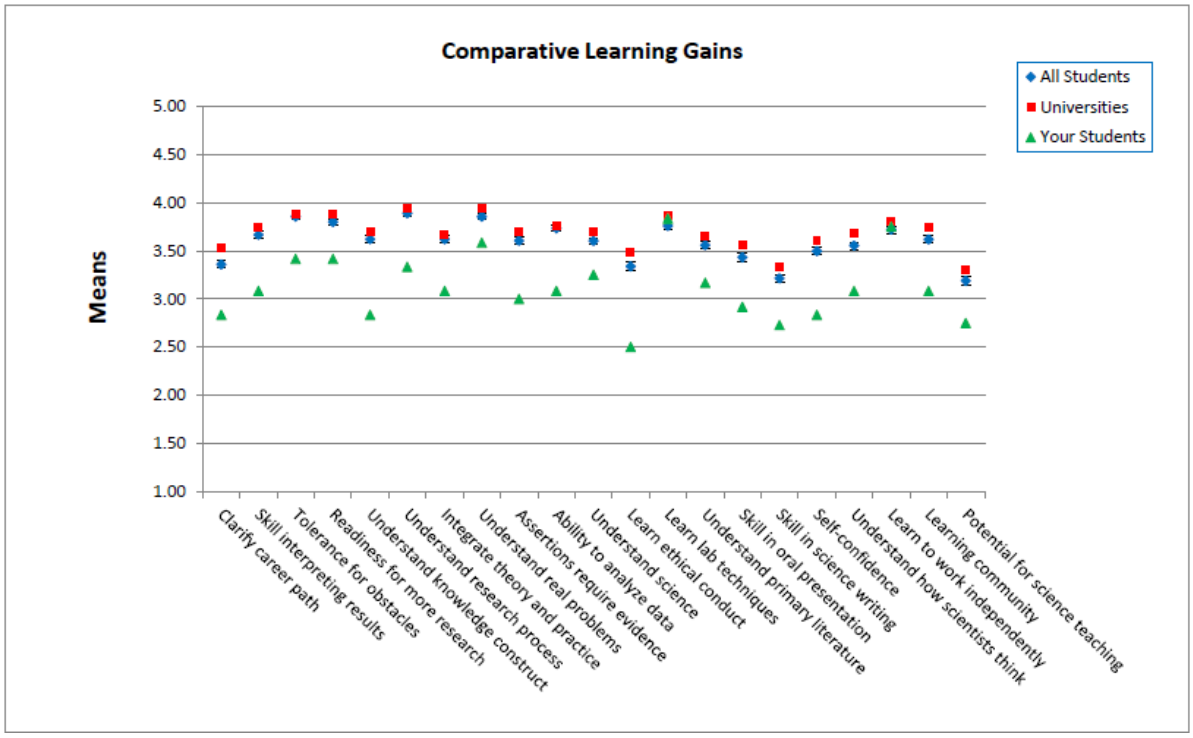

Figure 1: SURE III survey results, 2016. St. John Fisher College students in the summer research program are represented by green triangles, n=12. The blue diamonds represent n≤3478 responses from students nationwide who also took the SURE III survey between January 1 and September 8, 2016. The vertical lines depict plus or minus two standard errors.

This evidence that the students self-identify as less competent compared to the national peer pool was surprising and although students otherwise indicated a positive research experience (e.g. positive mentor ratings and finding research interesting), we felt action and further investigation was critical to providing a rich experience for our summer research students.

In our effort to utilize assessment data collected in 2016 to close the loop, we implemented a small, but significant change to the student experience and assessment plan through requiring students to reflect, with guidance, on their experience. These reflections were not used to formally evaluate or rate students in any way and did not influence their ability to earn a stipend or count toward a grade if the student was earning course credit.

Student reflections not only provide an assessment tool, but encouraging directed metacognition serves to support a growth mindset and the practice of recognizing self-growth in students (Howitt et al., 2016; Hunter at al., 2007). Also, we implemented an ePortfolio requirement as ePortfolios are considered a meta high-impact practice (Eynon & Gambino,2017). Student responses to the prompts below were uploaded to the students' required ePortfolios throughout the experience.

Reflection 1 – Week 2: What are your goals for this summer research experience? Describe at least one that relates to your academic growth and at least one that relates to your personal growth. Then, tell which goal you think will be easiest to reach, which will be the hardest to reach, and why for both.

Common themes identified through coding student reflection #1:

- To become independent in the lab
- Increase confidence
- Learn new techniques, how to use new equipment, and new methodology
- Gain experience for work or graduate school

- Improve information literacy skills
- Help clarify career path
- Improve note taking skills
- Improve problem solving skills
- Move out of comfort zones (physically and mentally, be open to new ways of learning)
- To contribute scientifically

<u>Skills Matrix Activity – Week 5:</u> Prior to completing the second reflection (prompts below), think about your goals for after Fisher. You could think about your immediate next step (e.g. graduate school, professional school, employment) or further out (e.g. your career in 5-10 years) and then complete the matrix below for yourself:

<u>Reflection 2 – Week 5 (after skills matrix activity):</u> How do you feel about this research project? What parts of it do you particularly like? Dislike? Why? Is there a particular aspect of the experience that is satisfying or frustrating? Describe.

	WHAT I *HAVE*	**WHAT I *NEED***	**IDENTIFY 1 OR 2 AREAS OF <u>NEED</u> AND DESCRIBE HOW YOU WILL TAKE A STEP TOWARD MOVING *FORWARD* IN THIS AREA.**
ACADEMICS ***(E.G. COURSES TO TAKE, MAJORS/MINORS)***			
EXPERIENCE & SKILLS ***(E.G. LAB SKILLS/TECHNIQUES, DATA ANALYSIS, TROUBLESHOOTING, DESIGNING DATA SLIDES, WRITING, ORAL PRESENTATION)***			

Table 1: Skills matrix activity students completed prior to writing their reflection at the mid-way point of the 10-week research experience.

Likes	***Dislikes***
Research topic	Data analysis
Accomplishing a set task	When experiments don't "work"
Being independent and trusted	Data interpretation
Contributing own ideas	When equipment failure impedes progress
When an experiment "works"	Reading so many articles
Applying class knowledge to the lab	Volume of data
Being responsible for something important	Worry about doing something "wrong"
Learning what they like and dislike	Making mistakes
Having time to focus on research	Writing & preparing presentations

Table 2: Common student responses to reflection #2 prompt. Students reported on what they liked and disliked about their projects at the mid-way point in the 10-week summer research experience.

<u>Reflection 3 – Final Reflection – Week 10:</u> You must complete a final, written reflection. As a guide, plan to write 2-3 pages (although, more is great if you have more to say).

- *What did you learn about yourself as you worked on this project?*
- *If you were to continue on in research, what would you want your next mentor to know about you? (What things are you good at? What would you like help with?)*
- *What work would you show your mentor to help them understand those things (question above)?*
- *How has using the ePortfolio and reflection activities for this experience impacted your responses to the above questions/prompts?*

Common themes identified through coding student responses to the first bullet point prompt, reflection #3, related to students' areas of personal growth and self-recognition:

- Increased confidence to apply to external research programs
-
- Capable of working independently
- Able to do more than they thought they could
- Proud of their work and how they learned from their mistakes
- Research requires an entirely different way of thinking
- Clarity in future career path and what they are passionate about
- Think this experience will help them tackle unexpected experiences in work and life
- Growth as a scientist (Students began calling themselves *scientists*!)

Areas of self-reported improvement	***Students want help with***
Techniques & following protocols	Data analysis & calculations
Problem solving	Data interpretation
Information literacy skills	Writing & preparing presentations
Patience	Organizing data & determining relative importance
Overcoming obstacles	
Seeing the importance of small goals that lead to large goals	Access to mentors for asking their questions (want this to remain)

Table 3: Common student responses to reflection #3, second prompt statement. Students reported areas they felt they had improved and specific areas they feel they still would like support.

Common themes identified through coding student responses to the final bullet point prompt, reflection #3, related to writing reflections and using ePortfolios:

- Can now see how far they've come compared to their original goals
- Helped keep track of their progress as a person and as a scientist
- Never would have spent time thinking about self-development
- Made them think about the experience in a different way
- Would use their ePortfolio to show their progress
- Gave them a chance to "say what they feel"

- The reflections are not just for "me" – they are for future employers/grad applications
- This will improve medical school application because they've already thought about what the experience has done for them
- Saw how much was accomplished
- Made this a personal experience
- Allowed them to be constructively self-critical and to achieve goals

In 2017, 17 of our biology and chemistry summer research students completed the Preflection and SURE III surveys, 59% of whom were new to research. Nationally, 1,817 students took the Preflection survey and 2,252 completed the SURE III survey. Our students identified the following as their *strongest* learning gains:

- Tolerance for obstacles in the research process
- Understanding how scientists work on real problems
- Learning laboratory techniques
- Learning to work independently
- Understanding the research process

Our students identified the following as their *weakest* learning gains:

- Learn ethical conduct
- Skill in science writing
- Skill in how to give an effective oral presentation
- Becoming part of a learning community
- Clarification of a career path

In 2017, our students, again, indicated a positive experience as they did in 2016 through strong mentor ratings and finding research interesting. Yet, interestingly, this cohort, who completed the reflections and utilized ePortfolios, self-identified as equally or more competent compared to the national peer pool on most learning gain areas measured by the SURE III survey. Again, the survey reveals areas for program improvement that we are using to continually improve our summer research experience at St. John Fisher College.

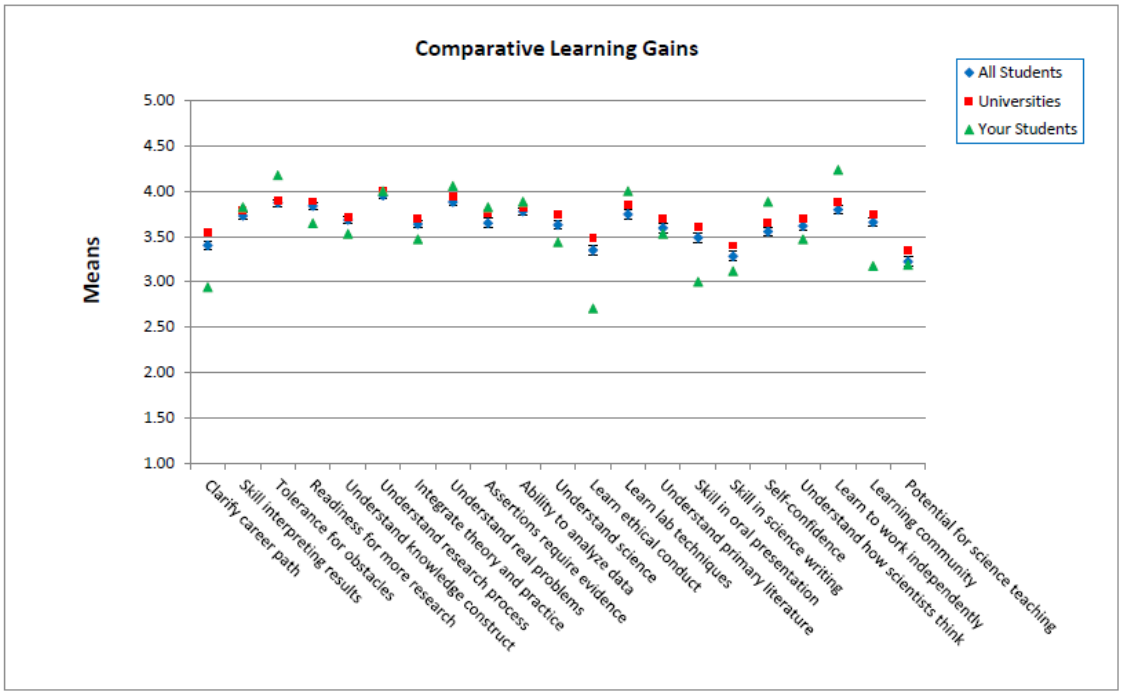

Figure 2: SURE III survey results, 2017. St. John Fisher College students in the summer research program are represented by green triangles, n=17. The blue diamonds represent n≤2252 responses from students nationwide who also took the SURE III survey between January 1 and September 4, 2017. The vertical lines depict plus or minus two standard errors.

Conclusion

This article describes a case example of how a sound assessment plan can measure student learning, improve the student experience, and lead to overall program improvement of the high-impact practice of undergraduate research in the sciences. Often times students engage in a mentored research experience, complete a final poster or paper, and even perhaps present their work to others without reflecting upon their own development through the process. In order to have the promised impact, students must be able to recognize the skills and habits of mind they are developing in order to continue to improve. Our program offers students structured reflection activities, along with professional presentation of their ideas through the use of an ePortfolio, to document their growth. Also, we employ the use of nationally vetted survey tools and a homegrown rubric for mentors to measure student laboratory skill development (not described here). This rubric is meant to stimulate discussion between mentors and student researchers along the experience, provide measurable outcomes, and to facilitate mentor writing of letters of recommendation for students in the future. Overall, our plan is effective in measuring multiple aspects of student learning through science research, providing actionable data for mentoring improvement, and overall data for program-wide improvement.

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Innovations

Using Cancer Staging to Teach about Tissue Layers

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Abstract: Histological assessment of tissues is a critical component of diagnosing diseases and determining disease severity or stage. In order to fully appreciate tissue pathology, an understanding of healthy tissue layers is required. Students traditionally learn this information by memorizing different layers within healthy tissue. This is often a daunting task if not placed into a meaningful real-world context. Described here is a hands-on inquiry-based laboratory where students make a diagnosis based on their knowledge of tissue layers. Students are provided readily available preserved tissue from two patients. Students are unaware that one patient is normal while the other has bladder cancer. Students stain the tissues using a common histological technique and are responsible for providing a bladder cancer diagnosis with corresponding cancer stage. This activity not only provides real-world technical experience, but since cancer staging is determined by the tissue layers the tumor has infiltrated, it also reinforces the importance of knowing different tissue layers. Following their diagnosis, pathology reports are assembled using images from either a microscope or cell phone. Students then compare these results with professional pathology reports accompanying the tissue. This activity is well suited for health sciences, cancer biology, histology, or pathology classes.

Key words: Histology, cancer, pathology

Introduction

Teaching students about basic histological features of tissues can be a challenging task. This is often accomplished by asking students to observe and memorize various layers using prepared slides of healthy tissue. However, many students have trouble retaining this information or appreciating its value when not connected to a medical application. Conversely, students are much more engaged in learning about tissue layers after their importance in disease diagnosis becomes clear. Described is an inquiry-based learning activity where students identify different tissue layers and compare normal vs. pathological cancer tissues. While cancer could be explored in various organs, bladder cancer is an ideal tissue type for this activity. A bladder cancer diagnosis requires the ability to recognize abnormal tissue and the severity/stage of the cancer is determined by identifying which tissue layers the tumor has infiltrated, as described by commonly used cancer staging guidelines (the Tumor-Node-Metastasis (TNM) Staging System). Bladder cancer is also the 9th most commonly diagnosed cancer worldwide and the 13th most common cause of death (Antoni et al., 2016), thus highlighting the importance of its diagnosis. Importantly, stained and unstained bladder cancer tissue is readily available for purchase at various tissue repositories.

The goal of this inquiry-based activity is for students to assess and diagnose bladder tissue samples. To do this, students are provided tissue from two separate patients experiencing various symptoms. While the symptoms for both patients are provided to students, diagnoses are not provided. Students then stain these tissues using hematoxylin and eosin (H&E) to visualize tissue composition. Using their knowledge of normal bladder tissue, students determine which tissue is diseased and what disease that patient has. This activity typically requires two lab periods. The first lab period is devoted to completing the H&E stain. In the second lab period, students visualize and assess their stained tissues. Students also acquire images of their tissues by placing a cell phone to the oculars of the microscope or by using a dedicated microscopy camera. These images are then used to assemble a pathology report (see report outline below).

Methods and Materials

Lab Period 1

Activity Introduction: To prepare students for this activity, students were provided background information on the two patients. This included their age, gender, and symptoms. Symptoms were generated by the instructor based on known bladder cancer symptoms and were identical for both patients (see pathology report section below for a detailed list of symptoms). Students were then briefly introduced to de-identified patient IDs, tissue procurement, paraffin embedding, and H&E staining.

Bladder Tissues: Paraffin-embedded human bladder tissue sections were obtained from The UConn Health Research Biorepository. H&E stained and unstained tissue sections from non-cancerous normal individuals and individuals at various cancer stages can be purchased from the Biorepository for approximately $7 per slide. Tissue sections are sent pre-mounted to individual glass slides, which can be stored long-term and subsequently stained when needed. To observe a range of disease stages and patient diversity, each student group can be provided tissue from different bladder cancer patients. By doing this, early (T1), intermediate (T2a, T2b), and late-stage (T3b) cancer can be observed. Moreover, each patient shows unique pathological characteristics, including variability in tumor size, tissue layer infiltration (i.e., stage), fibrosis, and inflammation. As described below, student groups can briefly share images of their tissue with the entire class so all students gain an appreciation for disease stages and diversity.

Description of Patient Samples: In compliance with HIPAA regulations, patient samples provided by the Biorepository have been de-identified. Instead of investigating a patient sample based on their name (e.g., John Smith), students investigated patient samples using unique patient ID numbers (e.g., patient 08-29). Information regarding the gender and ages of the patients is provided.

Hematoxylin and Eosin Staining: Mounted tissue slides from one cancer patient and one normal control patient (labeled with their patient ID numbers) were provided to each group of 3 students and placed in glass coplin jars in preparation for staining. Tissue sections were deparaffinized with two washes of xylene (2 mins each). The tissue was then rehydrated using sequential ethanol washes. To do this, tissue was first subjected to 100% ethanol, followed by 95%, 70%, and 40% ethanol. Each ethanol wash was done twice for 2 mins before proceeding to the next concentration. Tissue sections were then fully rehydrated using two washes of distilled water (2 mins each). Slides were placed in Hematoxylin 2 stain (Fisher Scientific) for 5 mins. Excess hematoxylin was rinsed from the slide using a gentle stream of running tap water. Slides were then differentiated using 4 quick dips in 0.3% acid alcohol (prepared using 1M HCl and 95% ethanol) for 30 secs. Slides were rinsed well in gently running tap water for 3 mins and then counterstained using an eosin solution for 45 secs. The eosin solution was prepared by dissolving 1% eosin Y (Sigma Aldrich) in distilled water containing 0.5% glacial acetic acid. Slides were then dehydrated by a sequential wash series consisting of 40%, 70%, 95%, and finally 100% ethanol. Ethanol washes were done twice for 2 mins each before proceeding to the next concentration. Slides were then washed twice with xylene (2 mins each) and coverslipped using Permount mounting medium (Fisher Scientific). Slides were dried for 1 week and observed the next possible lab period.

Lab Period 2

Activity Introduction: In the second lab period, students were introduced to commercially prepared normal bladder tissue slides. Students were asked to study and understand the various tissue layers as a solid understanding is required for accurate disease diagnosis. After students had a strong grasp of healthy tissue, they used their own stained tissues to compare staining proficiency and determine a disease diagnosis/stage.

Evaluation of Normal Bladder Tissue: Students were introduced to bladder tissue layers using H&E stained normal bladder tissue slides (Ward's Scientific). Students were again informed that a solid grasp of the bladder tissue layers is important for disease diagnosis and must be understood before observing their patient samples. To confirm and reinforce their understanding of theses layers, students can list 1-2 defining features for each histological layer and draw a representative image of each layer based on their observations of the normal bladder tissue slide and a provided histology textbook. Once students complete their drawings and describe the features of each layer to the instructor, they can be provided their H&E stained patient samples from the previous week. Students were asked to identify bladder tissue layers within their own samples and identify any abnormalities that might be present by comparing their samples with the normal bladder slide from the commercial vendor.

Diagnosis and Imaging: Students were encouraged to acquire images of tissue regions that appeared pathological. Images can be obtained by placing a cell phone to the oculars of the microscope or by using a dedicated microscopy camera. Representative images of normal and pathological tissues are shown in Figure 1. Students were typically able to diagnose the diseased patient sample as having cancer after observing dense tumors (Figure 1B-C). Normal patient samples show no obvious pathology and should be diagnosed as normal

Disease Staging. Once a cancer diagnosis was obtained, students then determined which stage of bladder cancer was present in their patient sample (Ta, T1, T2b, etc.; See Figure 2 and Table 1). How these stages are determined was not described, which required students to research bladder cancer staging. Students quickly found references to the TNM Staging System (Tumor-Node-Metastasis) developed by the American Joint Committee on Cancer (AJCC) TNM staging is the most commonly used staging system by medical professionals around the world and its guidelines can be easily found on the American Cancer Society website (American Cancer Society, 2016). Although the lymph node

involvement (N) and presence of distant metastases (M) categories cannot be assessed via histological investigation, the invasion of the primary tumor can be determined (T). As illustrated below, the bladder is comprised of various layers (Figure 2A-B) and cancer staging is dependent on which layers the tumor has infiltrated (Figure 2C, Table 1). For example, T2b bladder cancer is diagnosed based on infiltration into the outer muscular layer (Figure 2D), while T3 bladder cancer infiltrates the perivesicual fat layer (Figure 2E).

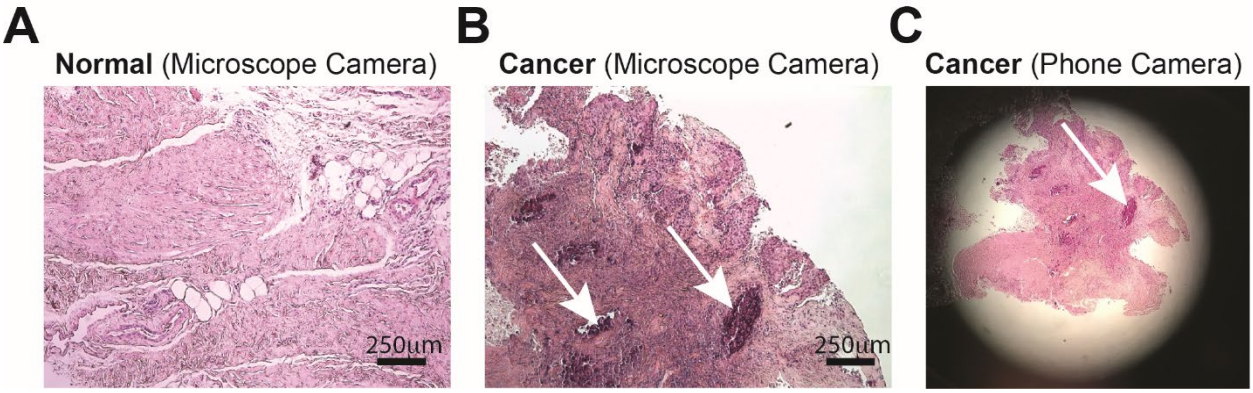

Figure 1. Representative images from normal and cancerous bladder tissue sections. Normal healthy bladder tissue (**A**) has fewer nuclei than cancerous tissue (**B**). The elevated numbers of nuclei in cancerous tissue is indicative of elevated immune cell numbers (i.e., inflammation of the bladder, also known as cystitis). Dense tumors are also apparent in the cancerous tissue, denoted with arrows. Similar images were also obtained using a student's cell phone camera held to the microscope oculars (**C**)

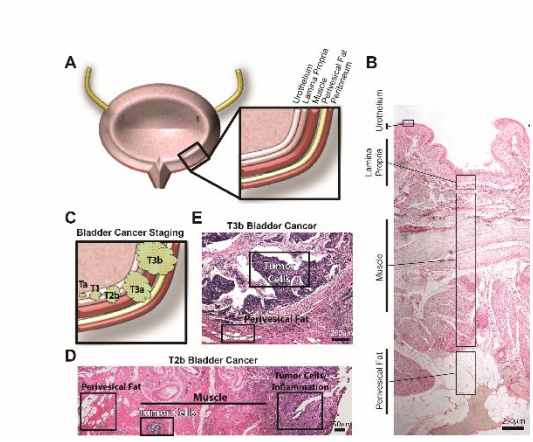

Figure 2. Guidelines for bladder cancer staging. The bladder is comprised of various tissue layers (**A**) that can be identified microscopically following H&E staining (**B**). (**C**) Bladder cancer staging is based on which tissue layers have been infiltrated by the tumor. Shown are examples of H&E stained T2b bladder cancer that is denoted by infiltration into the outer muscular layers (**D**), while T3b bladder cancer is denoted by tumor infiltration into the perivesical fat layer (**E**).

After disease stages were determined, students acquired additional images if needed and emailed their instructor images of the disease features that led to their diagnoses. All student groups can then briefly present their images to the entire class so that everyone can gain an appreciation for the differences in cancer stages and histological features between patients. Students can also compare their H&E staining technique with professionally stained sections. To do this, one professionally stained adjacent section from the same normal and cancer patien tissues were purchased from the UConn Health Research Biorepository. This activity allowed students to verify that their tissue samples were stained properly.

Stage	Characteristics
Ta	Non-invasive papillary carcinoma
Tis	Non-invasive carcinoma of urothelium
T1	Tumor has invaded connective tissue below urothelium
T2a	Tumor has invaded inner half of muscle
T2b	Tumor has invaded outer half of muscle
T3a	Tumor has spread to outer fat layer; only detected by microscope
T3b	Tumor has spread to outer fat layer; can be seen or felt
T4	Tumor has spread into nearby organs

Table 1. Overview of American Joint Committee on Cancer bladder cancer stages.

Pathology Report: To reinforce the histological findings from this laboratory and have students connect their findings back to their patients, students completed a pathology report. Students were provided guidelines as to what their report should contain, including

Patient ID number.

Symptoms experienced by the diseased patient.

Basic symptoms, which can be found on line, were provided during the first lab period. Symptoms may include severe pelvic pain and/or back pain, problems with frequent urination, painful urination, and bloody urine

Disease diagnosis with corresponding stage.

Histological observations of pathology that support the diagnosis, including how disease staging was determined

Students can discuss observations of inflammation and tumor pathology. Also, students should discuss which layers the tumor infiltrated

A stained and labeled image supporting histological observations and diagnosis.

Students can import their cell phone or microscopy images into PowerPoint so that labels can be added. Visible tissue layers and tissue pathology (e.g., tumor cells) should be labeled. Students should also list which stain they used to visualize the pathology in their tissue samples.

*Depending on the course or content covered, additional pathology report components may include:

Describing nuclear morphology of the tumor cells.

Discussions about possible origins of the tumor (>90% of bladder cancers arise from the urothelium; known as urothelial/transitional cell carcinomas)(Heney, 1992)

After submitting their reports, students compared their conclusions/diagnoses with those prepared by a professional pathologist. Basic pathology reports accompanied all bladder cancer tissues purchased from the UConn Health Research Biorepository.

Safety Considerations: This laboratory involves preserved human tissues. Human tissue should be considered biohazardous and all necessary safety precautions should be used when handling these tissues. All students should wear gloves, lab coats, and protective eyewear. Students should also wash their hands thoroughly upon completion of the lab.

Results

Upon completion of this laboratory, 14 students were polled using anonymous surveys regarding their thoughts about the laboratory. 93% of students considered this activity challenging but appropriate. 86% felt that the activity provided them a greater understanding of pathological tissue. 57% of students reported that they felt they learned tissue layers better with this activity than with traditional textbook and pre-prepared slides used in other laboratories, 35% reported learning the same, while 7% reported that this activity was less effective than traditional approaches. These results suggest that students experienced improved satisfaction and engagement with this activity.

Discussion

Inquiry-based activities are a useful means for stimulating interest, engagement, and problem solving skills (Lord, 2006). The activity described here offers students the opportunity to stain and diagnose diseased human tissue. Students gain real-world experience in common histological techniques (i.e., handling human tissue and H&E staining procedures), a strong knowledge of bladder tissue layers, and insight into cancer pathology and staging. Moreover, pathology labs routinely perform this type of investigation and a complete pathology report is provided with all tissues from the UConn Health Research Biorepository. Thus, students are able to compare their H&E stains and diagnoses with those prepared professionally by a pathologist. By asking students to determine a disease stage, this activity emphasizes the importance of learning different tissue layers for disease diagnosis. In addition to learning tissue layers, students also become aquatinted with common pathological hallmarks like inflammation and fibrosis, which are observed while intensely exploring their tissue samples. Students also have the opportunity to observe histological variability between different patients and different cancer stages. Although images may not be necessary for a pathology report, by requiring students to take representative images, students learn about selecting the appropriate parameters to capture features needed for a disease diagnosis (e.g., choosing an appropriate magnification, highlighting diseased tissue, and including tissue boundaries in the image whenever possible). Lastly, while the laboratory described here focuses on a bladder cancer diagnosis, this activity can be applied to a variety of different tissues where cancer staging is dependent on infiltration into defined layers (e.g., colon, esophagus, skin, or stomach cancer).

Acknowledgements

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Bioscene: Journal of College Biology Teaching
Submission Guidelines

I. Submissions to *Bioscene*

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

- Articles: Course and curriculum development, innovative and workable teaching strategies that include **some type of assessment** of the impact of those strategies on student learning.
- Innovations: Laboratory and field studies that work, innovative and money-saving techniques for the lab or classroom. These do not ordinarily include assessment of the techniques' effectiveness on student learning.
- Perspectives: Reflections on general topics that include philosophical discussion of biology teaching and other topical aspects of pedagogy as it relates to biology.
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- Letters to the Editor: Letters should deal with pedagogical issues facing college and university biology educators

II. Preparation of Articles, Innovations and Perspectives

Submissions can vary in length, but articles should be between 1500 and 5000 words in length. This includes references and tables, but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract, but not figure or table legends. Concision, clarity, and originality are desirable. Topics designated as acceptable as articles are described above. The formats for all submissions are as follows:

A. Abstract: The first page of the manuscript should contain the title of the manuscript, the names of the authors and institutional addresses, a brief abstract (200 words or less) or important points in the manuscript, and keywords in that order.
B. Manuscript Text: The introduction to the manuscript begins on the second page. No subheading is needed for this section. This supply sufficient background for readers to appreciate the work without referring to previously published references dealing with the subject. Citations should be reports of credible scientific or pedagogical research.

The body follows the introduction. Articles describing some type of research should be broken into sections with appropriate subheadings including Materials and Methods, Results, and Discussion. Some flexibility is permitted here depending upon the type of article being submitted. Articles describing a laboratory or class exercise that works should be broken into sections following the introduction as procedure, assessment, and discussion.

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

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

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

Single Author:

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

Two Authors:

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

Multiple Authors:

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

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

(1) Articles-

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

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

(2) Books-
BOSSEL, H. 1994. *Modeling and Simulation*. A.K. Peters, London. 504p.

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

(4) Web sites-
MCKELVEY, S. 1995. Malthusian Growth Model. Accessed from http://www.stolaf.edu/people/mckelvey/envision.dir/malthus.html on 25 Nov 2005.

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

D. Tables
Tables should be submitted as individual electronic files in Word (2003+) or RTF format. Placement of tables should be indicated within the body of the manuscript. All tables should be accompanied by a descriptive legend using the following format:

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

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

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

III. Letters to the Editor

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

IV. Other Submissions

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

V. Manuscript Submissions

All manuscripts are to be sent to the editor electronically. *Authors must clearly designate which type of article they are submitting (see Section I) or their manuscript will not be considered for publication.* Emails should include information such as the title of the article, the number of words in the manuscript, the corresponding author's name, and all co-authors. Each author's name should be accompanied by complete postal and email

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

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewers. Acknowledgement of the reviewers' comments and suggestions must be made for resubmission and acceptance. Further revisions should be made within six months if called for. Manuscripts requiring revision that are submitted after six months will be treated as a new submission. Should manuscripts requiring revision be resubmitted without corrections, the associate editors will return the article until the requested revisions have been made. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. Time from acceptance to publication may take between twelve and eighteen months.

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B. Make sure that references are formatted appropriately.
C. Make sure that recommended changes have been made.
D. Figures and legends sent separately, but placement in manuscript should be clearly delimited.

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