Action research implemented to improve Zoology laboratory activities in a freshman biology majors course

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Introduction

Traditional zoology laboratory activities include observation of slides, observations of living and preserved organisms, and dissections of preserved animals. While these activities are valuable, they have not consistently included higher levels of intellectual challenge. For the zoology laboratory course studied, learning was typically evaluated by performance on written laboratory reports and on an end of the semester laboratory practical exam, where students essentially had to regurgitate rather than use and synthesize information. However, Bloom's taxonomy suggests that the development of cognitive ability is hierarchical, progressing from simple understanding to application and synthesis of that knowledge, and that performance tasks undertaken by students should reflect the range of cognitive skills (Reed & Bergemann, 2001). This led us to reconsider how the zoology laboratory section was taught, using an action research approach.

Effective teaching involves enabling students to develop a deep understanding of the materials they are studying. This can be achieved through a variety of thought-demanding tasks (Levin & Nolan, 2000), including having student explain concepts in their own words, making predictions, doing drawings, finding exemplars in new contexts and applying concepts to new situations (Brandt, 1992). Zuber-Skerritt (1992a) concurred, stating

> So far we have arrived at the position that the most appropriate mode of learning and teaching in higher education is that of the alternative paradigm which may be characterized by learner-centered, problem-oriented, interdisciplinary, process-centered, and using an open, critical approach. (p. 147)

One way to encourage students to achieve a deeper understanding of course materials is to facilitate higher levels of learning by increasing the intellectual challenge of the tasks requested in student assignments and activities. This can be achieved by the use of Bloom's taxonomy, where the use of activities that can be associated with specific verbs correlate with higher levels of intellectual challenge, such as the use of "find", a knowledge term, versus "classify," an analysis term with a higher expectation of intellectual challenge.

Studies of student learning in higher education in the United States have tended to focus on learning-oriented behaviors and their relationship to grade and performance-oriented behaviors (Cross & Steadman, 1996). In contrast, there is a rich body of research by scholars in the United Kingdom and Australia that have concentrated on studying deep and surface approaches to learning by students (Prosser & Trigwell, 1999). A surface approach is characterized by an attempt by learners to reproduce information, a concern for grades and course requirements, and is characterized by minimal mental effort. In contrast, a deep approach relies on relating new information to existing knowledge, the application of new information to new contexts and on the creation of meaning (Cross & Steadman, 1996). This deep approach correlates to Bloom's taxonomy, in that moving tasks beyond a knowledge level to application, comprehension, analysis and synthesis will encourage learners to move beyond that surface approach.

There is a clear relationship between teaching strategies and student learning, with students adopting deep approaches in classrooms that are more student-centered (Prosser & Trigwell, 1999). Students with a deep approach to learning and who were shown to have a solid initial grasp of subject matter tended to be more successful than students with poor initial conceptual development who used a deep approach, or groups that used a shallow approach to learning (Prosser, *et al*, 2000). Students' conceptual knowledge was determined using open ended questions and a concept mapping activity both done before and after instruction. These were scored quantitatively. Approaches to study were assessed using Biggs's Study Process Questionnaire (Biggs, 1987), which is a validated questionnaire developed to determine if a student uses a deep or surface approach to learning. Using these techniques, Kember, *et al* (1997) examined student approaches to learning in three courses redesigned to promote a deep approach to learning, at a University in Hong Kong. Their results showed that when students are engaged in integrating theory and practice and in reflecting on learning, they are more likely to develop a deep approach. To achieve these effects, instructors must move away from lecture-based teaching to more participative approaches that include real-life applications of learning, such as the increased involvement of students in experimental design and in the construction of dichotomous keys implemented in the redesigned activities in this study. In comparison, traditional courses using traditional approaches lead to a decline in deep approaches to learning (Kember, *et al*, 1997).

In addition to our concern about student engagement in learning, past poor student performance on the laboratory practical raised the question as to whether or not the laboratory activities performed were useful for the students' learning experience. While exploration of the connection between laboratory activities and student success in the course was the driving motivation for this study, the authors also began to wonder whether or not dissections added to student learning, given the current trend away from dissection activities. For instance, Akpan (2002) investigated whether traditional dissections were as effective as computer simulated dissections and found that students learned more when simulation preceded actual dissections.

The basic design of the project used action research to explore the effects of specific changes in the laboratory curriculum for four laboratory activities. Students participated in both the previously scheduled laboratory activities for most of the semester, and in the four redesigned activities for the Annelid, Mollusc, Arthropod, and Echinoderm laboratory sessions.

Carr & Kemmis (1986) made a significant contribution to understanding and implementing action research. They envisioned the following steps in the process, (a) analyzing the problem, (b) planning strategies and interventions to remedy the problem, (c) evaluation of the course of action, (d) reflection on the results, and (e) repetition(s) of the cycle. In summary, action research is an iterative process involving successive cycles of question generation, planning, action, observation, and reflection, with the latter being termed the four moments of action research (Zuber-Skerritt, 1992b; Hopkins, 1993). In this paper we present information from our first cycle of action research over a two-year period.

Action research is a qualitative research technique (Denzin & Lincoln, 2000), using methods including observation, field notes, interviews, questionnaires, sociometry, archival data (e.g. documents), artifacts, and self-reporting (e.g. journal entries) (Hopkins, 1993; Mills, 2000). The basic assumption is that people learn and create new knowledge out of personal experiences through reflection, then formulate abstract conceptions and generalizations. These are then applied to new contexts and situations (Zuber-Skerritt, 1992b). Action research then is about developing an understanding of praxis, the dialectical relationship between formal theory and the theories generated in a particular context (Hadfield & Bennett, 1995). “Action research projects are always case studies” (Hermes, 1999, p. 203) because they focus on local context and action, and thus any generalizations relate only to that situation.

Methods

Participants

The participants were 36 students (10 males, 24 females, 2 not reported), enrolled in two different semesters of a freshman undergraduate Zoology course in a small, private university of around 800 students. Data concerning prior experience in college laboratory courses or prior knowledge of zoology was not collected in this study. These students participated in the study as a part of the normally scheduled laboratory, of which there is only one section offered in the spring semester of each academic year.

Project Design

Due to past poor performance on the lab practical, Myka asked Raubenheimer to help improve the zoology laboratory course. One of us, Raubenheimer, was the participant observer in the study attending all sessions, making and recording observations and making suggestions. The other, Myka, was the lead instructor teaching the class. We met prior to each session to plan the revisions to the laboratory handouts.

In this action research, four laboratory activities were redesigned to include higher levels of intellectual challenge in two semesters of an undergraduate Zoology laboratory. Previous laboratories throughout the semester had included observations of slides and preserved specimens, as well as group dissections of preserved animals. Laboratory activities for study of the Annelids, Molluscs, Arthropods, and Echinoderms were altered to include animal behavior experiments, a dichotomous key activity, construction of tables of structures and function, classification exercises, and a model building activity, in addition to the traditional laboratory observations and dissections.

In year two, while Myka was on leave of absence, another veteran instructor taught the course, using the same laboratory activities in the same laboratory setting, and we also gathered data from this class for comparative purposes.

We analyzed the laboratory handouts with regard to two points: a) the level of intellectual challenge as indicated by the level of verbs as per Bloom's taxonomy and b) the relationship of each activity to the goals for the course. We chose to revise four specific laboratory handouts, leaving alone other activities in the course that were similar to the original non-revised laboratory activities.

A survey was constructed to analyze student perceptions of learning and enjoyment for laboratory activities performed throughout the entire semester, not just the redesigned activities. The intention of the survey was to compare student learning and enjoyment for all types of activities performed throughout the semester to determine if student enjoyment and student learning were correlated, with the intention of looking for discrepancies, i.e. activities which students enjoyed but did not feel that they learned from, or activities which students did not enjoy but did learn from, so that future activities could be modified to capitalize on student enjoyment to help increase learning. The results of the survey were compared with the results of a lab practical exam for one semester to determine if student impressions of learning were associated with performance. Additional information was collected to determine both student feelings and student learning from dissections, to begin to address whether the format of dissection activities was effective. A preliminary study of the lab practical was performed to determine whether student learning was improved on items related to the redesigned activities as compared to the original activities

Survey results were analyzed statistically using Kendall's coefficient of concordance and Spearman's rank order correlation and qualitatively by examination of student comments. Kendall's coefficient of concordance was used to assign an overall order to combined student rankings of learning and enjoyment, i.e. to determine which activity students learned the most from, even though not every student's ranking was identical. Spearman's rank order correlation was used to determine if there was a correlation between activities that students indicated they enjoyed and those they felt resulted in the most learning (see attached survey in appendix 1 for the variables used). Students were also asked to comment on the laboratory activities, and these responses were coded with regard to whether they gave no response, a neutral response, or a response indicating that they felt the activity either helped or didn't help learning.

A preliminary analysis of the 2002 lab practical was performed to determine if there was an increase in student performance on questions relating to the revised activities versus the original activities. Ten questions based on original lab activities and five questions based on revised activities were analyzed. Finally, the authors discussed their findings, and formulated a list of recommendations for future action research cycles and future improvements to the course.

Analysis of Laboratory Activity Handouts

Myka had taught the original lab activities for the four years preceding the start of this study. After the laboratory activities and handouts were redesigned to include more intellectually challenging activities, both the original and redesigned laboratory handouts for the four redesigned activities were content analyzed for the tasks that students were required to undertake by counting the number of times particular verbs were used. Content analysis is a method of determining the purpose and meaning of text (Bernard & Ryan, 1998). In this case, the content analysis focused on the level of Bloom's taxonomy (Reed & Bergmann, 2000) of the verbs used in the handouts for the lab activities. We wanted to determine the level of intellectual challenge according to Bloom's taxonomy in the original lab activities, so we could increase the challenge in the redesigned activities. We hoped that increased challenge would result in deeper learning, and would correlate to an increase in student learning and performance on the lab practical.

Verbs with the same intent were combined into one common group. For example, the group labeled 'observe' includes words such as see, look, note, observe, and notice, while the category 'manipulate' includes words like cut, pull, remove, raise and split – words used during dissections. Using Bloom's taxonomy, the total range of tasks (i.e. verbs used in the laboratory handouts) in the four redesigned activities were classified into the six levels in Bloom's taxonomy: (a) knowledge, (b) comprehension, (c) application, (d) analysis, (e) synthesis, and (f) evaluation. Based on these findings (which are presented in more detail in a later section), we found that laboratory materials typically focused on lower order tasks, and so, four laboratory sessions were redesigned to include more cognitively demanding tasks. The original and redesigned laboratories are described and content analyzed in the Results section.

Materials and Activity Summaries

Laboratory activities for each lab session were included in a laboratory handout. The handout included some background material on the animals to be studied, as well as protocols and directions for each laboratory observation or activity. Four laboratory activities (annelid, mollusc, arthropod, and echinoderm) were analyzed for this project. Myka taught the original activities once each spring semester beginning in 1998. These activities were originally put together by a veteran instructor and were used by Myka with a few variations that mainly included the introduction of diagrams from various texts for students to reference while in lab. In each case, activities were altered or added to improve the level of intellectual challenge, as determined by the increased level in Bloom's taxonomy. Note that in both semesters a group vertebrate dissection project, in which students selected a particular animal to dissect as a group, was also completed and presented by them by the end of the semester.

Survey

A survey was given to each group of students at the end of the semester in both 2002 and 2003 (see appendix 1). Students were asked to rank 15 laboratory activities, first by learning and then by enjoyment. They were asked two questions about dissections in general, to begin to gauge students' feelings about dissections, as Myka had been considering implementing non-dissection alternatives for both philosophical and economic reasons. Finally they were asked to rate each activity for learning by whether they agreed or disagreed with a statement such as "Looking at dissections helped my learning," and asked to provide comments to explain their choices. Results were collated and analyzed descriptively and statistically. Because students individually ranked both their preferred learning activities and their enjoyment of laboratory activities, Kendall's coefficient of concordance was used to determine the degree to which the rankings of preferred learning activities were similar for all students. This analysis was repeated for the rankings of student enjoyment. Next, Spearman's rank order correlation was applied to determine if there was a correlation between student learning preferences and student enjoyment of activities. Spearman's rank correlation was also applied to compare the 2002 and 2003 student rankings for both the preferred learning activity and preferred activities for enjoyment, particularly because the courses were taught by two different instructors. The survey results led to several recommendations for future cycles of action research in this course.

Qualitative Analysis of Student Work

As a part of the survey instrument, students were also required to provide a qualitative response as to how the various activities had helped or not helped their learning. These were coded as (a) helpful for learning, (b) not helpful, (c) neutral, or (d) no response. The response rate for the qualitative portion of the survey in 2003 was very low at only 50% and so only data for 2002 is reported. These data were also examined to determine if the activities that students felt did not help their learning were more or less cognitively challenging than activities they felt were helpful.

Finally, students were surveyed for their feelings and learning from dissection activities. Specifically, students were asked to explain what they learned from dissections and how they felt about doing them. These qualitative responses were analyzed by coding for emerging themes (Merriam, 1998) to determine what students felt that they gained from doing dissections. Data for both years are combined because the responses were similar in both years. Again results were examined for potential changes in the course for the next time it was offered.

Results

Comparison of laboratory activities and tasks

Content analysis, specifically text analysis, is a systematic method used in the social sciences for analyzing the purpose and meaning of text (Bernard & Ryan, 1998). Textual documents portray insights into the thinking and intentions of the authors and are therefore a valuable source of information about the author's intended purposes and philosophy. There are different approaches to content analysis, including word counts in which the incidence of particular words are counted in a text to indicate the emphasis adopted by the author, and this approach was used in this project in the following manner. Each of the four laboratory handouts were content analyzed for the tasks that students were required to undertake by counting the number of times particular verbs were used. Words with a similar intention were categorized together. For example, 'set it on a sheet of wet paper towel', 'run your finger along its sides', 'feel', 'put', 'touch', and 'turn it over' are all examples of "manipulate." Based on the results of the content analysis, the number of times a verb in a category was used in the laboratory handout was plotted for each original and redesigned laboratory activity. The original labs are labeled # 1 and the redesigned labs are labeled # 2. These lab activities, both original and redesigned, are described below and the results of the content analysis are presented in Figures 1 though 4.

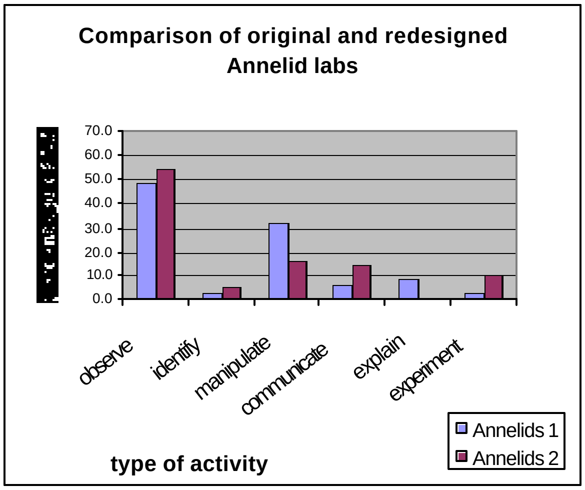

Figure 1. **Verb content analysis for Annelid activity.**

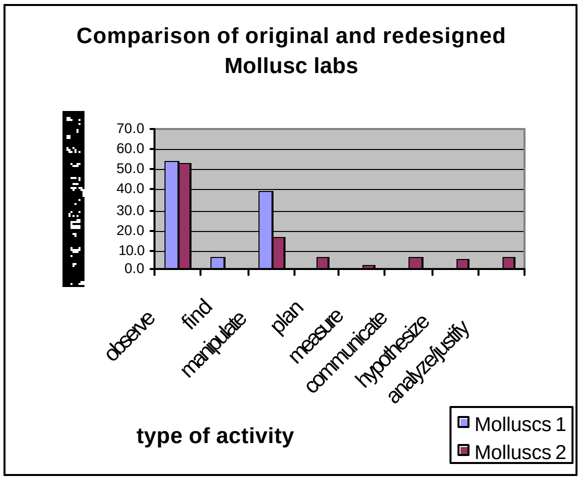

Figure 2. **Verb content analysis for Mollusc activity.**

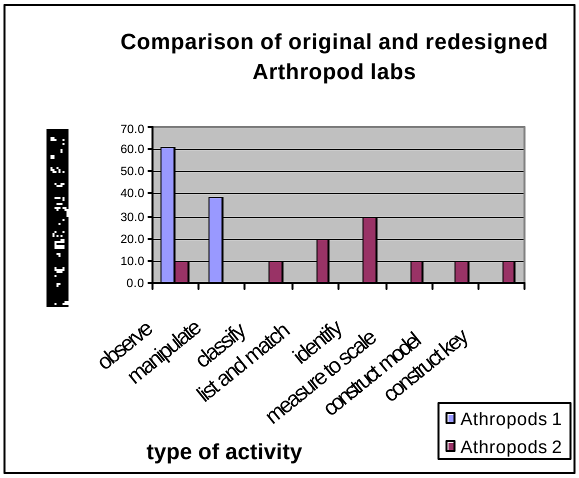

Figure 3. **Verb content analysis for Arthropod activity.**

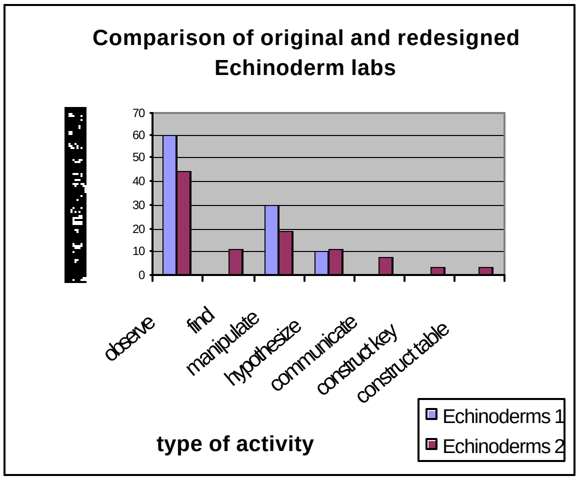

Figure 4. **Verb content analysis for Echinoderm activity.**

In all cases, the redesigned labs contained a greater range of tasks and categories, while the original labs focused on some form of observation or manipulation of the animals.

We then used the levels in Bloom's taxonomy and associated verbs (Reed & Bergmann, 2001) as the basis for further textual analysis, counting the number of times particular verbs were associated with a particular level in the taxonomy. Using Bloom's taxonomy the total range of tasks (i.e. all the verbs used in the laboratory manual in all four laboratory sessions) were classified into the six levels in Bloom's taxonomy, namely (a) knowledge, (b) comprehension, (c) application, (d) analysis, (e) synthesis, and (f) evaluation. For instance, the "manipulate" examples were then included in Bloom's "application" category. These data were transformed into percentages. These results are presented in Figure 5.

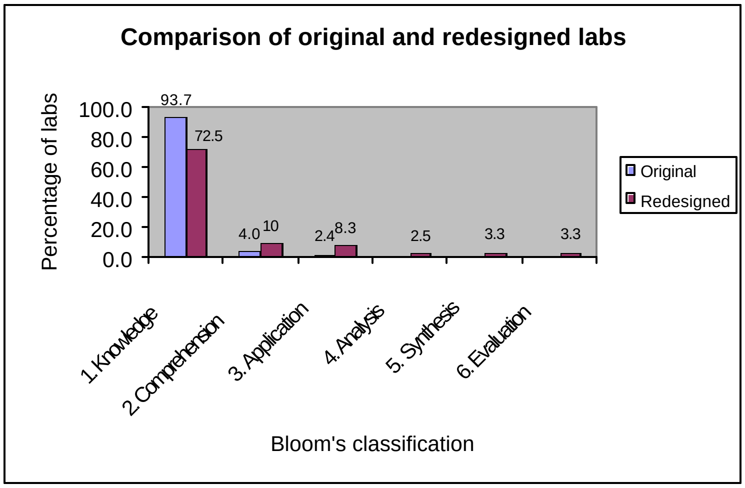

Figure 5. **Comparison of original and redesigned lab tasks based on Bloom's taxonomy.**

As illustrated in Figure 5, in general, in the four laboratory handouts, there is a change in frequency of direct observation (Bloom's level 1) with a concomitant increase in the range of tasks, including planning, experimenting, hypothesizing, analyzing data and constructing models and tables, from a total of 6.4% Bloom's levels 2 and 3 in the original activities, to a total of 18.3% for Bloom's levels 2 and 3 plus 9.1% in Bloom's levels 4, 5, and 6 in the redesigned activities. Also, there is a decrease in the manipulative skills required, because there was a reduction in the number of dissections, but a concurrent increase in other tasks.

For example, in the redesigned arthropod laboratory session, little attention was given to direct observation only (Bloom's level 1; 10% as compared to 61.1% in the original arthropod activity). Rather students were required to use their observations to identify (Bloom's level 1; 30%) and classify (Bloom's level 2; 10%) animals and use this knowledge to construct both arthropod models (Bloom's level 5; 10%) and a classification key for the models (Bloom's level 5; 10%). This represents a much broader application of knowledge to new contexts.

Therefore, the percentage of lower order, Bloom's level 1 tasks decreased by more than 20%, from 92.7% to 72.5%, with a concomitant increase in higher order tasks, up 21% overall, with a addition of activities in the top three levels of Bloom's taxonomy where none had been present in the original activities. While the percentage of level 4, 5, and 6 tasks is still relatively low, this is because these individual tasks were complex. For instance, constructing a key contains many sub-skills (e.g. compare and contrast), but the verb construct was only counted once for each time students were required to create a key.

Original Activities

1.) Original Annelid activity

The original annelid activity included observations of live earthworms (*Lumbricus lumbricoides*) organized by leading questions in the lab handout. Students were directed to design, but not carry out, a simple experiment to determine if the earthworms were attracted towards gravity or not, i.e., if the worms were positively or negatively geotactic. In a separate exercise, students anesthetized, examined, and then dissected earthworms. An earthworm cross-section slide was observed by light microscopy and demonstration materials and preserved specimens of other annelids were observed by students. The original activity consisted mainly of observation (48.6%) and manipulations (32.4%), both at Bloom's taxonomy level 1 (Figure 1).

2.) Original Mollusc activity

The original mollusc activity included observations of live aquarium snails, dissection of a preserved freshwater clam, and observations of demonstration materials and other preserved specimens. The original mollusc activity consisted mainly of observation (54.5%) and manipulation (39.4%), both at a Bloom's taxonomy level 1 (Figure 2).

3.) Original Arthropod activity

The original arthropod activity included observations of dried horseshoe crabs, slides of whole spiders, ticks, mites, and Daphnia. Students dissected a crayfish, and observed a preserved grasshopper, as well as other preserved specimens and demonstration materials. As shown in Figure 3, the activity consisted of exclusively observations (61.1%) and manipulations (38.9%), both at Bloom's level 1.

4.) Original Echinoderm activity

The original activity included a dissection of a common sea star (*Asterias forbesi*), observations of live brittle stars, and observations of preserved specimens and demonstration materials. This original lab consisted primarily of Bloom's level 1 with 60% observe and 30% manipulate, with 10% hypothesize (Bloom's level 3) (Figure 4).

Redesigned Activities

1.) Redesigned Annelid activity

The annelid activity tested in this action research project led the students through a series of observations of live earthworms, a cross-section slide, demonstration materials, and preserved specimens. However, the redesigned activity included a directed experiment on worm behavior, followed by a student-designed experiment that resulted in a written laboratory report due one week later. As shown in Figure 1, the redesigned activities led to a decrease of 8.1% in explanations, but an increase of 8.9% in communication, both with a Bloom's taxonomy of level 2. However, the addition of the directed experiment was particularly valuable in that the manipulations (Bloom's level 1) were reduced by 15.7%, while experimentation (Bloom's level 6) was 6.8%. A dissected earthworm was on demonstration, and was observed by students, and a plastic model was also available. These alternatives to student dissection were implemented for two reasons: a.) the earthworm dissection was never very successful in that the anaesthetized earthworms were difficult for students to accurately dissect and they usually were not able to visualize the features discussed in the lab handouts, and b.) we wanted to see if student performance would be affected if they did not perform the dissection themselves, but used alternatives to visualize specific features.

The original annelid activity directed students to observe living and preserved earthworms and other annelids, and to design a simple experiment,

> "DESIGN A SIMPLE EXPERIMENT that would show whether the worm is positively or negatively **geotactic** (gravity). You need not be able to do the experiment; just design it."

In addition, the original activity asked students to anesthetize and dissect a living earthworm. Myka had noted that the anesthetizing did not work consistently, and that students often seemed disturbed by trying to vivisect the earthworm in order to see the hearts beating. Indeed, Myka noted that only one student group had actually been able to make this observation during the previous five semesters in which it had been attempted; usually the worm died before the students could dissect enough to observe the heart. In addition, students often could not visualize the noted features in their own dissections, and most students actually identified all of the structures on an instructor-dissected earthworm or from a photographic atlas.

The revised annelid activity greatly expanded the experiment, by asking students to perform one experiment to observe earthworm locomotion, and a second experiment which they designed, to test a hypothesis of their own:

> "a.) DESIGN A SIMPLE EXPERIMENT that would test a hypothesis of your own construction concerning earthworm behavior. Be sure to include an appropriate control group of earthworms, and an appropriate control for the variable that you test. b.) Check with the instructor to ensure that your experiment can be done in our laboratory, and that your controls are sufficient so that you can collect meaningful data on earthworm behavior. c.) Set up and carry out your experiment in lab today. Take sufficient notes on your observations so that you can submit the results of this experiment in a written lab report due next week in lab."

To address the concerns that students were not able to observe the desired features in the anesthetized earthworm, and to address concerns about dissecting a still living animal, the revised activity asked students to make the same observations but provided a dissected preserved earthworm and a plastic earthworm model, both on demonstration. The text of the observations remained the same as before.

2. Redesigned Mollusc activity

The redesigned mollusc activity (Figure 2) included the same observations of live aquarium snails, as well as observations of a dissected freshwater clam, a plastic model, and other preserved specimens on demonstration leading to no significant change in observations (-0.5% in redesigned lab). However, the addition of a directed gastropod experiment led to decreases in Bloom's taxonomy level 1, with a decrease of 6.1% in finding and of 22.4% in manipulations. In addition, there was a strong increase in Bloom's levels of intellectual challenge in the following activities, up from 0% in the original: +7% communicate (Bloom's level 2); +5% and +7% in hypothesize and plan, respectively (Bloom's level 3); and +7% analyze/justify (Bloom's level 4). Students measured the distance traveled by a snail in five replicates of one-minute observations. They determined the question being addressed, the hypothesis tested, and how to process the data for clear communication. The students then designed an independent gastropod experiment based on their experiences in the directed experiment. They were directed to determine the question being addressed, the hypothesis tested, the variables involved in their experiment, and a conclusion based on the data they collected.

For example, the original mollusc activity asked students to observe live aquarium snails:

> "Place your snail on a BIOLOGICALLY CLEAN slide. Allow it to attach firmly, then examine it upside down under a dissecting microscope or hand lens. Note the mouth opening and the mode of locomotion. Its gliding movement is the result of waves of muscular contraction passing over the foot."

The revised activity included these identical observation activities, but added a directed gastropod experiment followed by an independent experiment, which enhanced the intellectual challenge of the investigations by students:

> "Using your experiences in the Directed Gastropod Experiment, design and execute a simple experiment regarding gastropod behavior. … Before you begin your experiment, answer the following questions: a. What is the general question being addressed by this experiment? b. Record the hypothesis you wish to test. c. Identify the variables, both experimental and controlled, in this experiment. d. Analyze the data to come to a conclusion as to whether or not the data supports your hypothesis."

3.) Redesigned Arthropod activity

The redesigned arthropod activity included the study of preserved arthropods to classify a set of arthropod photographs, diagrams, and specimens into arthropod classes. Students prepared a structure/function table of 5 external features for the grasshopper, spider, and crayfish, and 5 internal structures of a dissected crayfish on demonstration, with a list of the functions for each structure. Students formed small groups of 2-4 and chose the name of an arthropod from a hat, and constructed a model of that arthropod to illustrate the characteristic features of that arthropod. Finally, students constructed a dichotomous key that could be used to distinguish between the models made by each group. As shown in Figure 3, while observe and manipulate were reduced by 51.1% and 38.9%, respectively, identify and measure to scale, also Bloom's level 1 activities increased by 30% and 10%, respectively. However, considerable gains were made by the addition of 20% list and match (Bloom's level 3), 10% construct model (Bloom's level 5), and 10% construct key (Bloom's level 5).

The original arthropod activity included examination of preserved horseshoe crabs, spiders, ticks, mites, *Daphnia*, crayfish, other crustaceans, grasshoppers, and other insects, with some slides of the smaller arthropods. A dissection of the crayfish was also included. Typical observations were accompanied by instructions such as the following for the grasshopper observations:

> "3. Subphylum Uniramia a. Grasshopper (*Romalea*): Insects constitute the most diverse, largest, and most widespread class of arthropods, so spend some time looking at the external anatomy of the representative insect provided at your table. Insects are distinguished from other arthropods by a combination of the following characteristics in adults:
>
> – body divided into three segments (head, thorax, abdomen)
> – one pair of antennae
> – three pairs of legs
> – (usually) two pairs of wings"

In contrast, the revised activity did not lead students through these specific observations, but instead directed them to determine for themselves which were the characteristics of different arthropods. For example:

> "Your task for today is to first study the animals and specimens on demonstration and then use your knowledge and available resources to **a.) classify a set of arthropod photographs, diagrams, and specimens into their appropriate arthropod classes or groups.** …
>
> Using the information you obtain by your examination of these three arthropods, **b.) prepare a table which lists 5 external features for each animal and 5 internal features of the crayfish.** For each feature, list the function the structure provides for each animal.
>
> … You need to identify the main characteristics for the arthropod you are assigned and used this information to **c.) construct and arthropod model** using paper, scissors, tape, etc."

Therefore, with the revised activities, students were able to determine on their own that, for example, insects had 3 pairs of legs and a body made of three segments, rather than being told that these were distinguishing characteristics of insects, leading to a deeper understanding of the classification of arthropods. Interestingly, Myka noted that at the lab table whose members usually left lab early and did not generally seem particularly engaged during other lab activities, the students became very involved in the arthropod model construction, constructing a very detailed and accurate scorpion model, and actually left the lab last for the only time during the semester.

4.) Redesigned Echinoderm activity

The redesigned activity included a similar dissection and observations of live animals, preserved specimens and demonstration materials. In addition, students were directed to prepare a structure/function table including 10 echinoderm structures of their choice from one echinoderm example and a list of the function of each structure. Students also prepared a dichotomous key to distinguish between the five echinoderm classes studied. These changes resulted in a decrease of 15.6% in observe and an 11.5% decrease in manipulate, but the addition of 11.1% in find, all at Bloom's level 1, with a slight increase of 1.1% in hypothesize (Bloom's level 3) (refer to Figure 4). However, communicate was 7.4% (Bloom's level 2), and construct key and construct table were both 3.7% (Bloom's level 5).

The original activity contained instructions for studying echinoderms, such as the following for observations during the sea star dissection:

> "The mouth is on the aboral side and opens into a short **esophagus** which leads to a large two-chambered **stomach** that fills most of the central disk. ..."

The revised echinoderm activity included the entire lab, including the above instructions, with the following addition:

> "a.) Observe the living and preserved echinoderms in the lab. **Prepare a table** with 10 structures from one echinoderm example of your choice and list the function of the 10 structures that you choose. … b.) Prepare a **dichotomous key** to distinguish between organisms in five echinoderm classes we have studied

> today: Classes Asteroidea, Ophiuroidea, Crinoidea, Holothuroidea, and Echinodea."

Again, the revised activity directed students to determine for themselves which structures were characteristic of a class, and to learn to distinguish between organisms for themselves.

Student ratings of activities

Student average ranks for learning preference and enjoyment preference are listed in Table 1 for 2002 and Table 2 for 2003.

Kendall's coefficient of concordance showed that there is an overall similarity between student ranking of preferred learning activities (*W* = .491, *p* = 0.000), as well as for activities rated for enjoyment (*W* = .325, *p* = 0.000).

***Table 1*. Ranking of activities for 2002.**

Activity	Learning preference rank	mean	S.D.	Enjoyment preference rank	mean	S.D.	n
Looking at dissections	3	4.11	3.01	3	3.72	2.82	18
Observing live animal behavior	1	3.33	3.05	1	2.56	1.54	18
Looking at plastic models	11	9.17	3.87	9	8.78	3.02	18
Designing and conducting own investigation on live animals	4	5.11	2.85	4	4.89	3.36	18
Drawing observations	5	7.33	3.85	6	7.11	3.68	18
Observing specimens in bottles	15	10.2	3.97	7	7.39	3.63	18
Looking at professionally-prepared microscope slides	8	8.33	4.65	12	10.3	4.2	18
Constructing models	6	7.89	4.51	5	5.56	3.52	18
Looking at photographs and diagrams	7	8	3.18	8	7.67	3.4	18
Classifying animals into classes	12	9.5	3.6	14	11	3.45	18
Doing own dissections	2	3.78	3.54	2	2.94	3.15	18
Observing using the light microscope	14	9.89	3.31	10	9.44	3.82	18
Constructing dichotomous keys	10	8.83	4.3	15	11.6	3.91	18
Constructing tables of structure and function	9	8.72	3.16	13	10.7	4.13	18
Looking at self-prepared microscope slides	13	9.5	4.18	11	10.1	3.7	18

The first four rankings are the same for both the activities preferred for learning and those selected for maximal enjoyment. These are (a) observation of live animals, (b) doing own dissections, (c) looking at dissections, and (d) designing and conducting investigations on live animals. Spearman's rank order correlation showed that the overall ranking of the two categories is significantly correlated ($\rho = .729$, *p* = 0.01).

The data for 2003, presented in Table 2 also showed a there is an overall similarity between student ranking of preferred learning activities (*W* = .255, *p* = 0.000), as well as for activities rated for enjoyment (*W* = .339, *p* = 0.000).

***Table 2*. Ranking of activities for 2003.**

Activity	Learning preference rank	mean	S.D.	Enjoyment preference rank	mean	S.D.	n
Looking at dissections	2	4.2	4.0	2	4.6	4.1	18
Observing live animal behavior	3	5.2	4.0	3	4.9	4.1	18
Looking at plastic models	9	8.2	4.3	8	8.3	4.1	18
Designing and conducting own investigation on live animals	4	6.1	4.6	5	5.9	4.2	18
Drawing observations	8	8.0	3.2	13	10.2	3.6	18
Observing specimens in bottles	6	7.1	4.5	6	6.3	4.3	18
Looking at professionally-prepared microscope slides	11	8.8	3.8	11	9.4	3.6	18
Constructing models	7	7.8	3.4	7	7.4	4.4	18
Looking at photographs and diagrams	5	6.3	3.5	4	5.7	3.4	18
Classifying animals into classes	13	8.9	4.5	13	10.2	4.8	18
Doing own dissections	1	3.5	4.3	1	3.2	4.3	18
Observing using the light microscope	14	9.3	3.4	9	8.7	3.5	18
Constructing dichotomous keys	15	10.8	4.5	15	11.4	4.0	18
Constructing tables of structure and function	10	8.3	3.6	13	10.2	2.8	18
Looking at self-prepared microscope slides	13	8.9	4.5	10	9.1	3.9	18

The first three rankings are the same for both the activities preferred for learning and those selected for maximal enjoyment. These are (a) doing own dissections, (b) looking at dissections and (c) observation of live animals. The overall ranking of the two categories is also significantly correlated (Spearman's rank order correlation, $\rho = .877$, $p = 0.01$). The high correlations showed that overall students felt they learned more from activities they enjoyed, and conversely, that they learned less from activities they did not enjoy.

While the overall rank orders differed between 2002 and 2003, there is a strong correlation between the two years for both rank preferences of activities for learning (Spearman's rank order correlation, $\rho = .749$, $p = 0.01$) and activities enjoyed (Spearman's rank order correlation, $\rho = .877$, $p = 0.01$). Therefore the instructor change between 2002 and 2003 did not significantly alter student rankings.

In terms of items for course improvement, we looked explicitly at activities in which there was not an overall correspondence between enjoyment and learning because these highlighted areas for improvement. For instance, in 2002, 'observing specimens in bottles' ranked 15th for learning preference but 7th for enjoyment. This meant that in terms of learning potential we were not capitalizing on the inherent interest students had in observing preserved specimens. This indicated an area for future development. Other discrepancies were found in both years were ‘observing using the light microscope’ and ‘constructing tables of structure and function’.

Qualitative Student Responses

Student explanations of which activities helped their learning show that overall they found constructing dichotomous keys the **least** helpful for learning, followed by observing preserved specimens and observing self-prepared slides (see Figure 6). Several students also did not find the following activities useful for learning; (a) making structure and function tables, (b) classifying animals using a key, (c) observing professionally prepared slides, and (d) conducting their own investigations. It is interesting that most of these activities that students did not find helpful are the more cognitively demanding tasks. In the future action research cycle, comparisons will be made to student’s learning style and whether they students adopt a surface approach or a deep approach to learning.

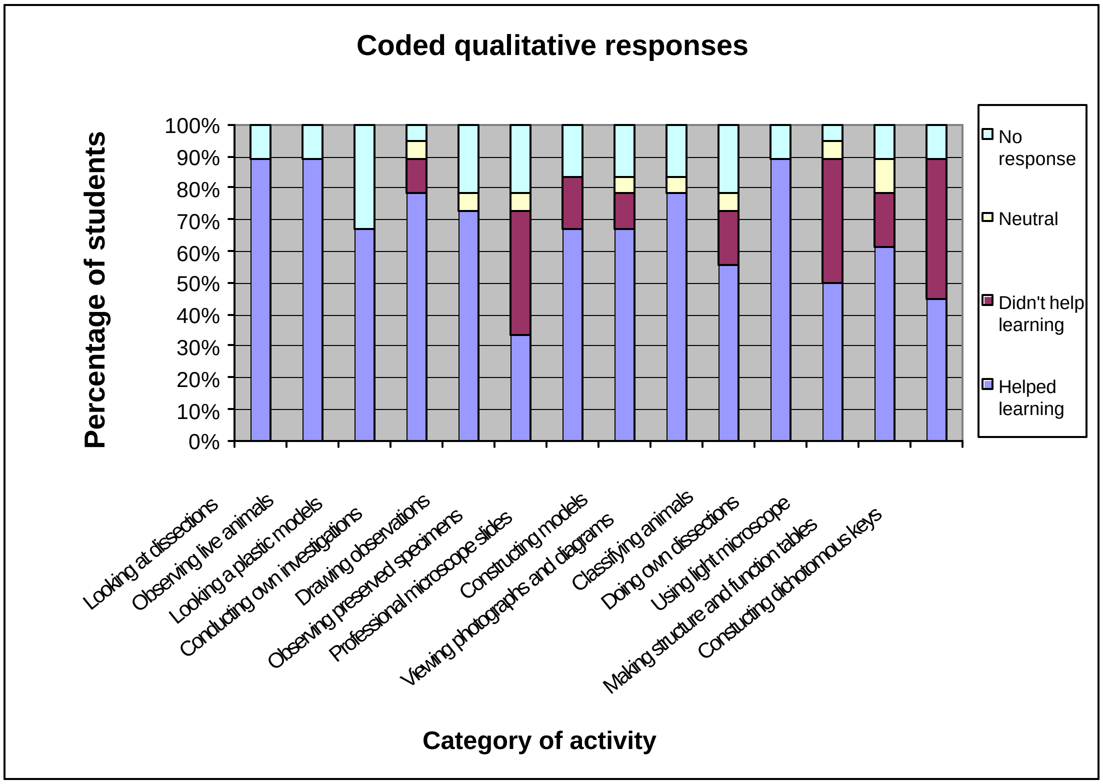

***Figure 6.* Qualitative results coded for emerging themes.**

The majority of students (85.7%) were very positive about doing dissections (Figure 7). Two (4.8%) were slightly positive, expressing concern for the dead animal, one (2.4%) was neutral stating that s/he had no problem with them, and two (11.1%) were slightly negative saying that they “stink” (smell) or that they hate the write-ups accompanying them. Only one student (2.4%) was more negative stating that s/he “did not enjoy the dissections.” Explanations given for their positive views towards dissections were (a) that they enhanced learning (33.3%), (b) that they like/love doing them (41.7%), and (c) that they enjoyed the hands-on dimension (25%) (Figure 8).

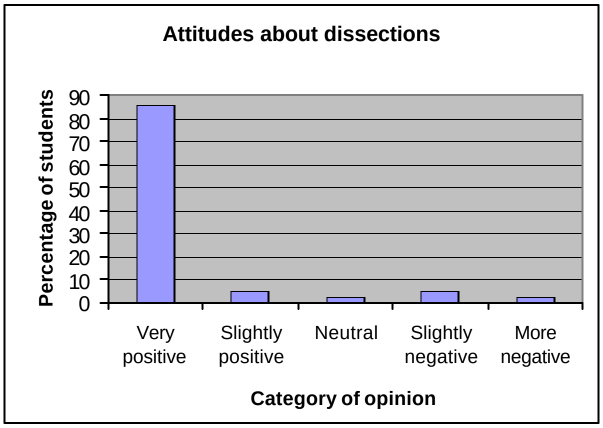

Figure 7. **Student attitudes towards dissections.**

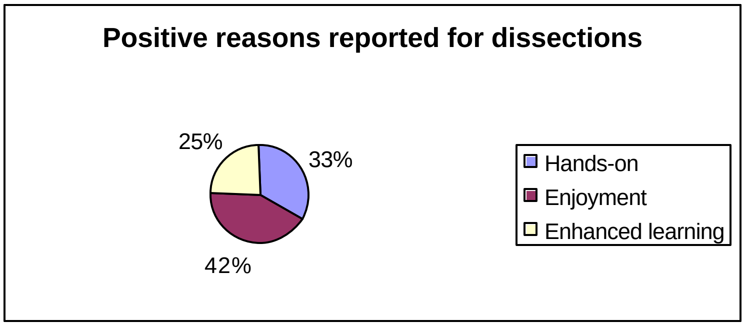

Figure 8. **Positive student responses regarding dissections.**

More students cited a lower order cognitive task, that of identifying structure and location, as the reason they learned from dissections (Figure 9). Fifty-six percent of the students cited that dissections were important to learn about the structure of organisms, 39% that they helped with locating structures, 25% that they were valuable for associating function with structure, and 14% that dissections helped to develop important skills, like accuracy, following directions and making incisions.

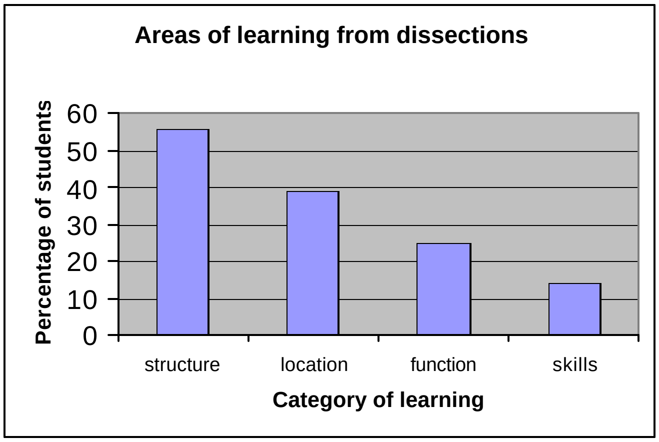

Figure 9. **Areas of student learning from dissections.**

Preliminary Analysis of the Practical Exam

The lab practical final exam was analyzed for 2002. For the analysis, ten questions were selected which were based on the original lab activities, and five questions were selected that were based on redesigned lab activities. Preliminary analysis of student answers on the 2002 lab practical indicated that students performed better on redesigned activities with 73% correct responses than on original activities with 62% correct responses. While this 11% increase appears equivalent to a grade increase from a D to a C, in the next cycle of action research, the lab practical exam will be redesigned to reflect the 15 types of activities more closely. This will be the focus for the second cycle of action research.

Discussion

As is the intention of an action research process, our findings have highlighted a number of changes that need to be made in instruction in order to enhance student learning. A discussion of the results and the changes suggested by the data follows.

Our results indicate that the revised activities asked students to perform tasks with a higher level of intellectual challenge, as indicated by the increase in higher Bloom's taxonomy verbs determined by content analysis of the original and revised activities (refer to Figures 1 through 5). Additionally, there was a decrease of 21.2% in the use of terms from Bloom's level 1, the knowledge terminology. It may be possible to further increase the use of higher levels of intellectual challenge, and further reduce the reliance on knowledge terms (93.7% of original activities) by revising other activities in the semester-long laboratory course. However, it should be noted that part of learning a subject like zoology is to learn the "language" of zoology, and the authors do not suggest that tasks at Bloom's level 1 should be abandoned. Students need to be led through the levels, so that they can learn and build upon what they learn, and they would not be well served by eliminating this first step.

In addition, the survey results from the ranking of activities by student enjoyment and student learning indicated a strong correlation between student enjoyment and student learning, suggesting that students felt that they learned the most from activities which they enjoyed the most. However, the rankings also indicated areas where activities could be improved to increase student learning. For example, in 2002, student learning for observing specimens in bottles was ranked last at 15th, while enjoyment was ranked 7th, suggesting an area for improvement. In support of this conclusion, in 2003, the year the course was taught by another instructor, both learning and enjoyment were ranked at 6th, and this instructor often gave quiz questions pertaining to the specimens in bottles, which the first instructor had not done. To benefit from these results, in the next cycle of this action research project, learning will be enhanced with directed activities involving specimens in bottles. For example, to study the Phylum Arthropoda, the students will view a collection of specimens in bottles, along with dried specimens and photographs. The students will be asked to construct a table that identifies each organism by taxonomic class and describes the distinguishing characteristics that the student used to make the classification. This activity is expected to increase interest in the specimens in bottles, as well as increase the learning potential based on student observation followed by classification of the organisms.

From the qualitative survey results, there were several areas where students indicated that specific activities did not help their learning. For example, 39% of students felt that using a light microscope did not help their learning, and 16.5% also felt that observing professional microscope slides did not help their learning. Considering that many biologists use a light microscope regularly in their research, and that students are expected to learn from microscope slides, this result indicates that activities involving light microscopy could be modified to increase student learning from this valuable activity. For example, to increase student learning from slides, in the next cycle digital images from each microscope slide will be made available to students, and these images will be reviewed prior to each laboratory activity to highlight key content and concepts, including microscopy, followed by assignments tailored to ensure student comprehension of slide images.

Another finding from these qualitative results is that some of the activities which were higher in Bloom's taxonomy and were more cognitively demanding were ranked by students as not being helpful to their learning. Overall, students did not enjoy classifying animals into classes or preparing dichotomous keys. For example, students ranked their learning from constructing dichotomous keys and classifying animals into classes at 10 and 12 out of 15 in 2002, and at 15 and 13 out of 15 in 2003, respectively. The qualitative responses indicated that, in 2002, while 44.5% and 55.5% of students felt that the keys and classification were helpful, respectively, 44.5% and 17% felt that they did not help learning, respectively. Paradoxically, in 2002 students ranked learning based on dichotomous keys at 10th out of 15, while ranking their enjoyment last at 15. Again, since these are both higher order tasks, and important in the study of biology, these data suggest that the activities and/or preparation of the students for these activities should be modified to increase the perception of learning by the students. To increase student learning from these activities, they will be introduced much earlier in the semester, with a dichotomous key activity in the protist lab. With more practice and guidance in these activities, it is hoped that their learning, and also their enjoyment, of these new activities will increase. However, it is possible that students simply did not appreciate the increased level of intellectual challenge involved in these activities, and this may be difficult to change. Again, monitoring their preferred approach to learning, whether deep or surface, will help establish the extent to which this was a factor.

Finally, the survey results concerning dissection showed that students appeared to have very positive attitudes concerning dissections (90.5% indicated very or slightly positive) (Figure 7). Of their reasons for this positive attitude, students indicated that they enjoyed dissection, that they liked the hands-on nature of the activity, and that they felt it enhanced their learning (Figure 8). However, more students cited the lower order cognitive task of identifying structures (56%) and their locations (39%) as the reason that they learned from dissections, while only 25% cited associating function with structure, and only 14% cited that dissections helped to develop important skills such as accuracy, following directions, and making incisions. These data indicate that while students enjoyed this activity, the dissection activities could be improved to enhance higher order tasks.

Cormas (2004) makes the case that the dissection of an organism is a qualitatively greater learning experience than are the many other dissection alternatives. This was not the initial sentiment of the instructor, who felt that dissections were often meaningless activities. However, the students surveyed overwhelming ranked “doing own dissections” and “observing dissections” very highly. While encouraging, these data must be interpreted in the context of the entire course, including the very popular independent group-project vertebrate dissection, where each group selected a vertebrate, did a thorough dissection, and presented their dissection, plus information concerning the natural history of their vertebrate in both oral and poster or slide format. The students have always seemed to really enjoy this activity, and their presentations typically showed a great deal of learning from the dissection and their research. This study intended to analyze student learning from dissections, and indeed students performed poorly on practical performance on questions where dissected animals were used. Since the survey did not distinguish between dissection activities as a part of each topic, such as the sea star dissection, and the final vertebrate dissection, it is possible that the students were not referring to the semester dissections in their responses. This flaw needs to be addressed in future surveys, before the authors can make a decision as to the role that dissections should play in this laboratory course. It may turn out that the smaller invertebrate dissections do not lead to greater student learning, but the vertebrate dissection project does, in which case the lab activities could be altered accordingly. However, to increase student learning from dissections in this course, a pre-dissection activity will be added to each dissection scheduled.

Akpan (2002) found that the addition of a computer-simulated dissection activity prior to actual dissections increased the quality of and student learning from the dissections. In addition, the authors noted that most student dissections were of poor quality such that they could not identify many structures that they were dissecting to observe. Therefore, a CD-ROM with a series of images showing students the specific stages for each of the dissections to be done will be prepared and distributed to students at the beginning of the semester. With this resource, the students will know what their specimen should look like after each incision, and they will be able to refer to these images in the laboratory during their actual dissection as well. This resource it is hoped will assist students in doing a more precise dissection, therefore allowing students to observe and identify all structures noted in the lab handout. In this manner, the quality of student dissections is expected to improve, with the result that more students can use their own specimens for their learning, and rely less on the instructor demonstrations. The instructor will briefly go over the images in the preceding lab, and a homework activity will be added to ensure that students have studied these images prior to starting the dissection activity in the following lab session.

In conclusion, because action research is an iterative process, and to further reap the benefits of this study, the next cycle of our action research will include the following objectives. First, because we are interested in encouraging deep learning, through the use of the validated Study Process Questionnaire (Biggs, Kember & Leung, 2001) we will establish students' approach to learning, whether deep or surface, and then look at the relationship between the approach adopted and the outcomes of student learning. Second, in order to better understand the role that dissections should play in this laboratory course, we will focus on identifying the skills and knowledge acquired through animal dissections. We will also alter our survey instrument to distinguish between dissection activities and the vertebrate group dissection project. Our goal is to monitor and improve student learning from dissections so that students relate structure to function and learn the location and structure of organs in the context of the entire animal. Third, to quantitatively assess student learning at the end of the semester, we will redesign the lab practical final examination to reflect the skills presented during laboratory activities. This is important in that our goal is to promote higher-order cognitive processes and skills, and therefore must specifically test the learning of students with regard to those processes and skills to ensure that the modified activities are achieving this goal. This data will also be correlated with results from the Study Process Questionnaire to achieve the first objective just listed. Finally, we believe that student enjoyment is correlated with student learning. To determine if there is indeed a link between enjoyment and learning, we will correlate student rankings with student achievement on the lab practical mentioned above, and also on other activities such as the dichotomous key and written lab reports. Our goal is to capitalize upon student motivation, and if student enjoyment and student learning can be enhanced simultaneously, the increased intellectual challenge that we desire will be better received by the students.

Acknowledgements: The authors would like to thank Dr. Michele Morek, OSU for her help and support of our work at Brescia University.

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Appendix 1
Zoology Laboratory Survey

Intended Major:___________________ **Level:** Fre Sop Jun Snr

Gender: Male Female

We are interested in finding out about your learning experiences during the General Zoology BIO102L laboratory sessions. Please complete the following questionnaire to help us enhance student learning in the future.

1. Rank preference: Learning

Please rank 1 – 15 which activities you **learned** the most from. 1 should be your first preference and 15 the activity you learned least from.

Rank	Activity
	Looking at dissections
	Observing live animal behavior
	Looking at plastic models
	Designing and conducting own investigation on live animals
	Drawing observations
	Observing specimens in bottles
	Looking at professionally-prepared microscope slides
	Constructing models
	Looking at photographs and diagrams
	Classifying animals into classes
	Doing own dissections
	Observing using the light microscope
	Constructing dichotomous keys
	Constructing tables of structure and function
	Looking at self-prepared microscope slides

2. Rank preference: Enjoyment

Please rank 1 – 15 which activities you **enjoyed** the most. 1 should be your first preference and 15 your least favorite activity.

Rank	Activity
	Looking at dissections
	Observing live animal behavior
	Looking at plastic models
	Designing and conducting own investigation on live animals
	Drawing observations
	Observing specimens in bottles
	Looking at professionally-prepared microscope slides
	Constructing models
	Looking at photographs and diagrams
	Classifying animals into classes
	Doing own dissections
	Observing using the light microscope
	Constructing dichotomous keys
	Constructing tables of structure and function
	Looking at self-prepared microscope slides

3. Dissections

Explain what you learn from doing dissections yourself.

Explain how you feel about doing dissections.

4. Rating activities for learning

For each of the activities listed, please circle the appropriate answer. Please provide a written response for your ratings.
SA = strongly agree; A = agree; DN = don't know; DA = disagree; SDA = strongly disagree.

a) Looking at dissections helped my learning.
SA A DN DA SDA

b) Observing live animal behavior helped my learning
SA A DN DA SDA

c) Looking at plastic models helped my learning
SA A DN DA SDA

d) Designing and conducting my own investigation on live animals helped my learning
SA A DN DA SDA

e) Drawing observations helped my learning
SA A DN DA SDA

f) Observing specimens in bottles helped my learning
SA A DN DA SDA

g) Looking at professionally-prepared microscope slides helped my learning
SA A DN DA SDA

h) Constructing models helped my learning
SA A DN DA SDA

i) Looking at photographs and diagrams helped my learning
SA A DN DA SDA

j) Classifying animals into classes helped my learning
SA A DN DA SDA

k) Doing my own dissections helped my learning
SA A DN DA SDA

l) Observing using the light microscope helped my learning
SA A DN DA SDA

m) Constructing tables of structure and function helped my learning
SA A DN DA SDA

n) Constructing dichotomous keys helped my learning
SA A DN DA SDA

o) Looking at microscope slides that I prepared myself helped my learning
SA A DN DA SDA

p) Please provide any additional comments in the space below.

About the authors…

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