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Part I: Evaluation of Student Assessment of Learning Gains (SALG)

in Two Different Biology 100 Classes

Part 2: What Biology Concepts are Important in General Education?:

Analysis of Seventeen Core Concepts

Jessica Marie Rosenvall Howell

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

Part I: Evaluation of Student Assessment of Learning Gains (SALG)

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Part 2: What Biology Concepts are Important in General Education?:

Analysis of Seventeen Core Concepts

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The purpose of this two-part study is to examine how to improve introductory level non-majors biology courses to improve student attitude and learning gains in the sciences. The first part of this study examines the collective effect of three different pedagogies (service learning, concept mapping and guest lectures) on student attitude and learning gains in a freshman, non-majors biology course. Two classes, one with the three pedagogies, and one without, were compared. Data were collected from two classes in Fall 2008 (one treatment and one control) and two similar classes replicated in Fall 2009. Learning and attitude gains were measured by a pre and post biology assessment and the Student Assessment of Learning Gains (SALG) survey. Our findings indicate that the treatment methods did not improve student learning or attitudes compared to the control group. However, there was a significant increase in variability in the treatment group, indicating that the students exposed to the three pedagogies either had a very positive experience or a negative one, whereas the control group did not have this variability. Thus, the treatment did have a positive effect on some students. Both treatments experienced significant gains from pre to post on the biology assessment and SALG survey. The second part of the study investigated what concepts are considered by students and faculty to be most important to teach in introductory non-majors biology courses. A survey with 17 biology concepts was given to life science professors at BYU and UVU and biology students at BYU. Participants were asked to rank the concepts from most to least important. There were significant differences between professor and student mean rankings for 11 of the 17 biology concepts. This study showed a large discrepancy between what professors want students to learn and what students feel is important. It was particularly noteworthy that students ranked ecology and evolution as least important. This was especially alarming since evolution is considered to be the capstone of all biology and ecology is vital for capturing the “big picture” in biology.

Keywords: [service learning, concept mapping, guest lectures, attitude, biology, learning gains, introductory biology course, pedagogy]

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Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
Introduction.....	1
Literature Review.....	2
Research Hypothesis.....	7
Sample.....	8
Methods.....	10
Measures.....	21
Results and Discussion.....	27
Conclusions.....	48
References.....	51
Appendix.....	55

Introduction

In the past, the goal of science education was to produce more scientists. While it is still a goal to generate bright, innovative scientists, society recognizes the importance for all citizens to be scientifically literate as more national and international political and societal concerns involve scientific issues (Maehr & Widen, 2002, McDonald & Dominquez, 2005). The National Science Education Standards (NSES) defines science literacy as understanding key concepts of natural sciences, understanding the nature of science, and developing inquiry skills such as designing experiments, collecting and analyzing data, and drawing valid conclusions for evidence (McDonald & Dominquez, 2005). As society is confronted with scientific-related societal issues and concerns, citizens need a basic scientific knowledge as well as inquiry skills in order to develop informed and educated opinions and to be actively engaged in the decision making process (McDonald & Dominquez, 2005). Because of the increased need for citizens to be scientifically literate, educators are continually searching for new ways to engage students in the sciences and help bring forth a generation of citizens that know the fundamentals of science and use this knowledge to become civically engaged (Saltmarsh, 2005).

Despite the need for scientifically literate citizens, there has been a decline in interest in the sciences since the 1970's (Markow & Lonning 1998). Science education is often viewed by students as teacher-centered, based on rote memorization, and focused on test scores (Heinze-Fry & Novak, 1990; Mason, 1992; Huai, 1997; Kinchin, 2001). Because of this, students view science as a boring list of disconnected concepts, which consequently decreases their desire to learn science (Mason, 1992). Teachers can teach information and communicate ideas and concepts, but in reality, understanding takes place when learners are actively involved in the

learning process and make connections between the information learned and their daily lives (Kronick, 2007).

This research study is two-fold, with both parts designed to investigate ways to help students succeed and enjoy introductory level biology courses. The first part of the study is designed to test the effects of three different teaching pedagogies on students learning and attitude gains in an introductory level college biology course. These methods are: Service learning, guest lectures and concept mapping. The second part of the study is designed to determine what concepts should be taught in introductory level college biology courses. In order to educate scientifically literate citizens and help them become more engaged, we must first determine what is the most important information for students to learn. For many students, an introductory level biology course will be their last exposure to science in their formal education and, thus, will be their last impressions of why biology is important.

Literature Review

Many approaches have been and continue to be used to help students connect their learning and become actively involved in the learning process. One such approach is service learning. Multiple studies have analyzed the effects of service learning on student learning and engagement among all levels of education (Strange, 2004, Astin & Sax, 1998, Brindle & Hatcher, 1996, McDonald & Dominquez, 2005, Kronick, 2007). Research demonstrates that simply having knowledge of an issue does not result in behavioral change. Students must feel a responsibility for their environment and take ownership over issues (McDonald & Dominquez, 2005). Service learning may be one vehicle to provide an opportunity for students to take responsibility.

Although service learning can be implemented in a variety of ways, the Commission of National and Community Service (CNCS) has defined what service learning should entail in order to be used as a vehicle to help students in the learning process. The CNCS states that service learning is active participation in organized service experiences that meet community needs. These service experiences should integrate the students' academic curriculum. They should include time to think, write and reflect on their service experiences and allow students to use newly acquired skills and knowledge in real-life situations (McDonald & Dominquez, 2005). Eyler & Giles (2002) defined service learning as being "about doing, about action, about learning from experience, and using the knowledge and skills in learning...about knowledge in use, not just about acquiring and being tested on facts" (p.9). Service learning allows students to connect academic knowledge learned in the classroom to issues in their real lives and community, which help them to develop a sense of civic responsibility (McDonald & Dominquez, 2005). In other words, they begin to see that what they learn in the classroom actually applies to real-life situations.

The three major reasons that have been reported as to why faculty at the college level are hesitant to integrate service learning into their curriculum are: 1) the time and effort required to establish service learning and necessary community partnerships 2) concern that time spent addressing the service-learning requirements detract from covering all the "core" material and 3) the uncertainty about the breadth and depth of academic advantages of service learning beyond the course where it is required (Strange, 2004).

Although faculty express the above concerns, studies involved with college-level service learning show that college students manifest long-lasting academic benefits from participating in service-learning (Strange, 2004, Astin & Sax, 1998, Brindle & Hatcher, 1996). Some of the

benefits of service learning include enhanced student engagement, more commitment to school, enhanced achievement of curricular goals, and an enhanced civic responsibility (Strange, 2004). Other benefits include an increased feeling of connection to the community, greater self-knowledge and increased leadership skills (Blyth *et. al.*, 1997). All these benefits lead to students becoming more scientifically literate and civically engaged. Service learning is often termed as “experimental learning” because it allows students to actively experiment with the concepts learned in the classroom (Scales *et. al.*, 2006). In an era when education is criticized for not being relevant to students’ lives and the community, service learning helps students connect classroom learning to their actions in the world beyond the school building (McDonald & Dominquez, 2005). Students’ attitudes toward science improve because they have feelings of satisfaction for making a positive impact in the world (McDonald & Dominquez, 2005).

There is a lack of research investigating the effects of short-term service learning projects. In 1996, Myers-Lipton pointed out that most research conducted on service learning showed effects over long periods of participation in service-learning projects and proposed the need to study the attitude effects for those involved in short-term service learning. Reed *et al.* (2005) led a research study to investigate the effects of a small-scale, short-time service learning experience for undergraduate college students in a psychology class. The service project was only 8-10 hours long over a weeklong period. Students visited with dying patients in the hospital. Results indicated that students felt an increased desire to choose a service-related occupation, they felt more comfortable talking with people at the end of their life, and they felt an increase sense of the meaningfulness of college (Reed *et al.* 2005). This study showed that small-scale service learning projects may also have positive and measurable impacts on student attitudes.

Guest lectures may also be an effective way to help students connect the material they learn in the classroom, although few studies have analyzed its effects. In one study conducted by Maehr & Widen (2007), the benefits of international guest lectures were explored. The study focused on an international conservation biology course using international guest lectures to expand viewpoints and develop a better understanding for international conservation issues. The study demonstrated an improved cultural and political understanding in issues related to the countries involved in the guest lectures (Maehr & Widen, 2002). Although this study focused on international guest lectures, results signified that students engage in deeper learning and develop learning connections when given the opportunity to listen to other speakers in conjunction with their class instructor.

Another study conducted by Hemphill & Hemphill (2007) explored online guest lectures, which was found to enhance critical thinking skills and interest levels in the students. The study found that online guest lectures might increase student involvement as they add interest and bring in new perspectives and experiences by using a different teaching style and providing expertise in specific content areas (Hemphill & Hemphill, 2007). The benefits from online guest lectures in this study may be applied to other forms of guest lectures although it has not yet been studied.

Concept mapping is another method used to help students make connections with their learning and to help students see the “big picture”. It is designed to aid students in connecting the concepts to each other and also to the students’ own experiences. Concept mapping can be used in a variety of venues such as: a tool for communication between students and teachers (Roth, 1994), to document conceptual change (Mintzes & Wallace, 1990), and to increase achievement while decreasing anxiety (Mintzes & Wallace, 1990). Concept mapping is used as

a classroom instruction tool in the form of visual aids (Horton *et. al.*, 1993), as well as tools for more student involvement where students actually are involved in concept mapping activities (Regis *et al.*, 1996). Student responses to concept mapping are varied; some believe that it helps them to identify, organize and retain information while others feel that is not helpful (Heinze-Fry & Novak, 1990). Comparisons between pre and post multiple choice tests are most frequently used to evaluate the learning gains from using concept maps; however other methods to assess effectiveness are used, such as reflection papers, essays and interviews (Markow & Lonning, 1998). Although there are mixed opinions as to whether or not it is worth it to use concept mapping given the preparation and training time, concept mapping can help move both teachers and students to instruct, to assess, and to learn deeply (Briscoe & LaMaster, 1991).

Studies have also been conducted to measure the effects of different teaching methods on learning and attitude gains. A team of researchers at Brigham Young University studied the impact of different teaching methods on student learning and attitudes, specifically the use of multimedia lectures for a non-majors statistics course. Data was collected for over four semesters on 5,603 students. Teachers were assigned to teach both a control (use of overheads) and treatment class (use of multimedia). The Survey of Attitudes toward Statistics (STATS) was used to measure attitude gains, and statistics exams were used to measure learning gains. Results from the analysis revealed no significant treatment effect for any of the exam scores or the attitude survey (Hilton & Christensen, 2002).

Despite the push for changes in science education, little research has been done regarding college biology teaching and what should be taught (Gottfried *et. al.*, 1993). Many researchers and educators argue the need for more question-driven classrooms with an emphasis on scientific reasoning and thinking (Shodell, 1995, Tyser & Cerbin, 1991, Carter, 1990, Wartell, 1984).

Although research is sparse as to what concepts should be taught in college biology courses, there are concerns that students are not leaving college with an understanding of the most important biology concepts. For example, Alters and Nelson (2002) reported that it is not just the students that have had no science experience in college that fail to understand effects of evolution, but it is also those students who have taken science courses that have similar deficits in their understanding. This is particularly alarming because evolution is the capstone of all biology. More research should be conducted as to the concepts that are most important for students to understand in order to improve teaching and learning.

Research Hypotheses

Freshman Biology students who experience an “enriched” environment consisting of service learning, concept mapping, and guest lectures, will have a greater understanding of biological concepts, as well as an increase in their perception of understanding, skills, and attitudes toward biology over the course of the semester. More specifically, the mean increase from pre- to post-course for the enriched-environment freshman biology class (treatment) will be significantly greater than the mean increase from pre- to post-course for the non-enriched class (control) on both the biology examination and the Student Assessment of Learning Gains (SALG) survey. This hypothesis includes the students in the lower quartile. That is, in statistical terms,

$$H_0: \mu_T = \mu_C$$

$$H_a: \mu_T > \mu_C$$

where μ_T is the mean score for the treatment group and μ_C is the mean score for the control group.

Secondly, professors will rank seventeen biological concepts differently than students. We also hypothesize that professors from the different universities (BYU and UVU) will not differ in their average rankings of the seventeen concepts, but that there will be differences in average rankings between non-major and major students.

The Sample

Freshman Academy

The students in this study came from an organization called Freshman Academy. Freshman Academy is designed to help incoming freshman adjust and connect to the university learning environment. The incoming freshmen that choose to participate in Freshman Academy choose an envelope of three classes they take together. The students in an envelope divide into smaller groups for two of the courses in the envelope, but all students in the envelope combine for one of the three courses. Biology 100 is the course that encompasses all of the students in one envelope. Freshman Academy students live in close proximity of each other and they have peer mentors to help them learn about the resources available on campus and to aid them in their college adjustment. Professors that teach the Freshman Academy courses are to help freshman with this adjustment as well, and should help to make the first year for these students a positive experience.

The biology classes formed from the entering freshman class of Fall 2008 were examined for equality in gender ratios, entering high school GPA, and entering ACT scores (Table 1). The 2009 biology classes were also examined (Table 2).

Table 1: Fall 2008 Freshman Academy Biology 100 student statistics

	Treatment Class		Control Class	
	Female	Male	Female	Male
Gender	65 55.08%	53 44.92%	72 62.07%	44 37.93%
HS GPA	3.7268		3.7457	
ACT	26.92		26.01	
Housing	Helaman Halls		Heritage and Wyview Park	

Table 2: Fall 2009 Freshman Academy Biology 100 student statistics

	Treatment Class		Control Class	
	Female	Male	Female	Male
Gender	27 57.45%	20 42.55%	10 34.48%	19 65.52%
HS GPA	3.7368		3.7711	
ACT	27.5745		26.9286	
Housing	Heritage and Wyview Park		Helaman Halls	

In Fall 2008, the class that met at 12pm was the treatment class, which participated in the enriched activities. These students lived in on-campus housing. The students in the 1pm class were the control class and lived together in a BYU off-campus housing building. In Fall 2009, the class that met at 2pm was the treatment class and the class that met at 1pm was the control class. The housing situation was opposite from the previous year. There were fewer students in the second year of the study because fewer students registered for Freshman Academy envelopes in 2009, due to a registration problem. The differences in ACT and GPA scores between the

students in both Fall 2008 and Fall 2009 were adjusted for in the regression analysis. Although there were some differences, similarities between 2008 and 2009 were greater than what is usually expected in such studies, partly due to the fact that all students were a part of Freshman Academy. All students who participated in this study agreed to participate and signed a letter of consent.

Methods

A comparison study between two biology classes was used to evaluate the effects of an enriched learning environment on student achievement, content knowledge and attitudes.

The Control

Both classes of Biology 100 were within Freshman Academy, and shared the elements unique to the Freshman Academy program. Measures were taken to ensure that other elements of these classes were consistent. There were several components to Biology 100 that were incorporated in both the control and treatment classes in this study:

Instruction. The same instructor, Dr. Gary M. Booth, taught both Biology 100 classes. In Fall 2008, the treatment class was held at 12pm MWF and the control class was at 1pm MWF. In Fall 2009, we switched it so that the control class was taught first at 1pm MWF and the treatment class was taught at 2pm MWF; each class period was 50 minutes long. Dr. Booth has been teaching for 36 years and has developed his own unique style of teaching, which he tried to keep identical for both the treatment and control classes.

Dr. booth also incorporated pair-share learning in both classes. At the beginning of many lecture periods, the students completed a quiz on the previous class period content. At the

conclusion of the quiz, Dr. Booth allowed students to share their answers, encouraging peer instruction. He would then bring the microphone to individual students and allow them to report their quiz answers to the class.

Although it can be argued that no teacher teaches the same way twice, Dr. Booth's methods after years of teaching are consistent enough that they did not appear to vary consistently between the two treatments. To help ensure this consistency, we switched the order of treatments during the second year.

Teaching assistants and labs. Each class was divided into four lab sections (30 students in each for Fall 2008 and approximately 15 students in each lab for Fall 2009); these labs met for 50 minutes once a week. Trained teaching assistants taught the labs; two TA's were assigned to each lab section. One TA was responsible for teaching and the other TA was responsible for grading. This was intended to ensure consistency of teaching and grading within labs, helping to maintain a greater consistency overall. All teaching assistants (graders and teachers) held a minimum of two office hours a week and a review session before each exam. The teaching assistants also held open reviews and office hours for both classes, thus reducing any potential bias to one class.

Instrumentation. Both biology classes were given a biology-content exam at the beginning of the semester and again at the end. The exam was created by Dr. Gary M. Booth and covers the main content taught in his Biology 100 course. The pre-examination was given on the second day of class in both classes, and was graded by the TAs using the same key. The test questions were open-ended questions. The same TA graded pre- and post-exams for his/her

lab students to help maintain consistency. This biology examination was used to compare learning gains between the two classes.

Students also took four exams throughout the semester in both classes. The objective portion of the test was identical for both classes. Each test consisted of approximately 90 to 100 multiple choice questions and were completed by the students in the BYU Testing Center, with only a few exceptions made for students with learning disabilities, or with legitimate scheduling conflicts, in which case, the tests were taken out of the testing center.

The written portion of the exam, worth approximately 20 points (equal points were given for both classes) was different. The control class completed one to two essay questions and the treatment class completed one to two concept maps. The content for the essays and concept maps was the same.

A pre and post Student Assessment of Learning Gains (SALG) survey was administered online. Students were given the password and completed the pre-SALG survey online during the first week of the semester, and the post-SALG survey during the last week of the semester. Weekly online surveys regarding study habits and attitudes were administered to both classes online via BYU blackboard.

Peer Mentors. As both classes were within Freshmen Academy, both had peer mentors to aid the students in time management and in organizing study groups. Both classes were set up in an envelope format; the students in each section did not only have biology together, but also two additional classes: American Heritage and Book of Mormon. Thus the students interacted with their peers from their own Biology 100 class on a regular basis.

Research paper. Each student in both classes was required to write a six to eight-page research paper on a topic related to any biological concept discussed in this course. Students from both classes had access to TA assistance, the BYU writing lab, and to Dr. Booth. These research papers were graded by their individual lab TA's (because of the length of the papers, some labs split the papers between the teaching TA and grading TA). There was a grading rubric [Appendix E] to decrease grading biases.

Homework. The homework assignments for the two classes were different, but the time required for the assignments was approximately equal and the points allotted were the same. The treatment class' assignments consisted of concept mapping and service learning. The students participated in eight hours of biology-related service learning throughout the semester and wrote a one to two page reflection paper on their experience. They also completed one to two concept maps a week that correlated with the concepts discussed in class that week. The assignments ranged from the completion of skeletal maps (partially completed maps) to building their own maps from a list of given terms. There were several weeks for which only one concept map was due because the treatment class also participated in service learning.

The control class completed a current events assignment that was also designed to aid the students in connecting classroom learning to their everyday lives. The students were required to submit two write-ups each week on current events that related to science. They could find these events on the news, in magazines, on the Internet or anywhere they could find current reports. These weekly write-ups were designed to be equivalent to the concept mapping, guest lectures and service learning assignments required by the treatment class by providing the same amount of points and approximately equal work-load and time required.

The Treatment

The 12pm MWF Biology 100 class was the treatment section for this project for the first year (Fall 2008), and the 2pm MWF Biology 100 class was the treatment section for the second year (Fall 2009). In these classes, service learning, concept mapping and guest lectures were implemented to create an “enriched” learning environment in an attempt to help students see connections between concepts learned in class and also between class content and the outside world. Comparisons of the pre and post biology assessment and SALG survey scores, class exams, and weekly surveys were used to determine the effect of this enriched learning environment on student achievement.

Concept Mapping. Concept mapping was implemented in the treatment class through weekly labs and concept mapping assignments. Laura Jimenez, a doctoral student in Instructional Psychology at BYU studying concept mapping, monitored this part of the study. Training for the students took place the first week in lab. Laura Jimenez and Jessica Howell (author of this thesis) trained the four labs (treatment class) who participated in concept mapping. Each lab had one TA (the grader) who was trained by Laura on how to help students with concept maps and how to grade the maps. Training for both students and TAs included a presentation of the rationale (purpose) of concept mapping as well as verbal instruction on how to effectively create a concept map.

Laura created concept-mapping packets (Appendix B) that were distributed to each student during the first lab period. A brief overview of concept mapping was given and the students were trained as to how to complete the skeletal concept maps. Attention was given to emphasize the purpose of concept mapping rather than a lengthy instruction of concept mapping

rules. Previous years of concept mapping in Dr. Booth's Biology 100 classes taught us that students respond better to concept mapping when they understand the purpose and are not inundated with too many details the first week of school.

Students were given two concept maps to complete the second week of the semester, after training took place. These were practice maps and were awarded points based only on completion. TAs helped students make corrections so that the students were prepared to complete the concept maps for the rest of the semester. After the second week, all concept maps were graded based on correctness. A total of ten points was possible for each concept map.

Six concept maps were required of the students each month. We began with concept maps that only required the students to fill in missing links (skeletal maps). In the lab period following Exam 1, we trained the students on how to create their own concept maps when given a list of concepts (self-construction).

Each exam included one concept map. The first exam included a concept map with blanks for the students to fill in the missing links (skeletal map). The other exams included a list of concepts and required the students to create their own concept map. The control class had an essay question on each exam, which included the same concepts that were on the concept map question for the treatment class to ensure that both classes were assessed on the same concepts.

The students had five days after the homework concept maps were returned to make any needed corrections or get help from their TA. They could then resubmit their maps for partial or full points back, depending on the accuracy of their corrections. The purpose of concept mapping was not to penalize the students but rather help them learn from concept mapping and make accurate connections.

Service Learning. The treatment class participated in service learning. Each of the four labs was assigned to a particular project of service learning that related to concepts discussed in Biology 100. Some labs were split between two projects.

The different projects for Fall 2008 were: Senior World Games, Adaptive Aquatics, Bean Museum Tours, Science Education in Elementary Schools, a June suckers project at Utah Lake and a potato project in Idaho:

Senior World Games. Dr. Gary M. Booth took a group of 15 students to St. George, Utah to volunteer at the Senior World Games. The students helped with registration and measured the heart rate, blood pressure, blood-glucose levels, bone density and other health related tests for the participants. They volunteered for two days under the supervision of Dr. Booth and learned much about gerontology, disease, and the human body.

Bean Museum Tours. This lab group volunteered at the BYU Bean museum, which has live reptile shows and a huge exhibit of stuffed animals. The volunteers led tours through the museum and were responsible for sharing interesting facts about the various animals and their habitats. The students also aided in the reptile shows. These students were able to gain greater knowledge of animals and their ecosystems.

Science Education in Elementary Schools. Biology students worked with an elementary classroom teaching the children four lessons on basic biology principles. TAs coordinated teaching times with the classroom teachers and the biology students came in groups of four to teach. Students learned the biology principles by teaching and designing projects that helped students learn the concepts.

June sucker project at Utah Lake. One lab group (approximately 30 students) went to Utah Lake with Dr. Mark Belk (BYU professor) to aid in a project to learn more about the June suckers in Utah Lake. The students went out on boats and collected crates of fish. They then counted the suckers and measured the sizes so that the population of June suckers could be marked. Dr. Belk spoke with these students prior to their trip to Utah Lake so the students could understand the impact of the project and the importance of this specific ecosystem.

Potato project in Idaho. Approximately 15 students went to Idaho with Dr. Brian Hopkins (BYU professor) to work on a project to help improve potato production. The students picked and measured potatoes on the farm lot used for this study. Other volunteers from BYU also attended. The students learned about world hunger issues and how genetically engineered products can help feed a growing world population.

The following were the service learning projects for Fall 2009: Senior World Games and Adaptive Aquatics.

The Senior World Games requested more volunteers this year, and our lab sizes were reduced the second year because of fewer freshmen that enrolled in Freshman Academy. Because of this, we sent three of the four labs in the treatment class to the Senior World Games. About 15 students went one week and another 15 went a second week; both groups went with Dr. Booth and two teaching assistants and performed the same volunteer services as the previous year.

Adaptive Aquatics is a BYU-student operated organization set up for children with disabilities to come swim and play sports with BYU student volunteers. The volunteers meet two hours a week with these children. Students were able to see the effects of genetic disorders and experience first-hand how genetics can influence lives.

All service learning activities related to concepts discussed and studied in the Biology 100 lectures. Each service-learning project required a minimum of 8 hours for each student over the course of the semester. Teaching assistants were responsible for supervising the service learning activities. Students trained in their labs for their assigned service learning activity and the teaching assistants set up days and times for students to do their service learning activity. After completion of the service learning project, each student wrote a one to two page reflection paper describing their project, its relevance to the course, and their thoughts and feelings about the experience.

Guest Lectures. The treatment class also participated in guest lectures. Professors and specialists from BYU and the community spoke to the students about concepts learned in class that related to their specific fields of study. Dr. Booth and Jessica Howell discussed with each speaker what concepts we wanted emphasized. Focus was placed on allowing students to see how the concepts they learned in class were applied to biological professions and research around the world.

In Fall 2008, four guest lectures were available for the students over the course of the semester, averaging one lecture per month. Guest lectures were held outside of class, usually at 7pm in the evening on BYU campus. One of the four guest lectures was held during class because of scheduling conflicts; in this case the control class had a supplemental lecture by Dr. Gary Booth. Students were required to attend at least two of the lectures and write a summary of the lecture and how it related to the biology concepts taught in class. Students received extra credit for attending the other two lectures. For the first year's study the following guest lecturers spoke:

Sean Esplin, M.D. Dr. Esplin is a neonatologist who works in Utah County. He spoke the students about human development and genetic disorders.

Byron Adams, PhD. Dr. Adams works at BYU in the Department of Biology. He discussed his field research in Antarctica relating to global warming and evolutionary change and discussed how the Central Dogma (DNA replication, transcription and translation) is important in his research.

Clayton White, PhD. Dr. White also works at BYU in the Department of Plant and Wildlife Sciences. He discussed his research with a variety of birds of prey, particularly the Peregrine Falcon and the impact of DDT.

Ron Hager, PhD. Dr. Hager is a professor in the Department of Exercise Science at BYU. He spoke about the effects of healthy lifestyle and diet on the human body.

We provided two mandatory guest lectures for the second year (Fall 2009): *Dr. Sean Esplin* and *Dr. Byron Adams*. Both lecturers gave the same seminars as described above. Because of the low number of students in our classes the second year, we did not provide the two optional guest lectures. Instead, students could attend any two science/biology related lectures offered by the College of Life Sciences or the individual departments within the College of Life Sciences for extra credit.

Grading. TA graders graded all papers and homework assignments, with the exception of the objective portion of the exam, which was graded by the testing center. After each test, each TA grader graded all of the concept maps for the treatment class. Two weeks later, the same graders would grade all of the maps again. This special care to insure inter-rater reliability and accuracy for grading of the concept maps was due to dissertation work performed by Laura Jimenez.

Laura worked to develop an accurate and user-friendly concept mapping grading rubric. Laura and Jessica simultaneously worked on their graduate work and aided one another because the projects overlapped.

Following Fall 2008 and Fall 2009, analysis of data was done to detect differences in content knowledge and learning gains (understanding, skills, attitudes, and integration of learning) between the two classes. Inferences were made about the effectiveness of the enriched environment, with concept mapping, service learning and guest lectures, as a method to increase meaningful learning.

Biological Concepts Survey

A survey was sent out to all BYU life science professors and UVU life science professors, which directed the professors to rank a list of seventeen biological concepts from most to least important concepts to teach in a non-majors introductory biology course. Professors also included their demographic information on this survey (education received, current job, what they teach, etc.). Students included their demographic information as well (year in school, science class they were currently enrolled in, etc.). This survey was used to help determine which biological concepts should be taught in an introductory biology course and can serve as a guide for future introductory biology courses at BYU.

After sending these surveys to the professors, the survey was sent to Biology 100 students who were in Dr. Gary M. Booth's class the previous semester. Students who were currently taking Biology 120 at BYU, which is an introductory biology course for biology majors, also were given the survey. A comparison among non-majors biology students, biology

major students and professors was conducted to determine what each group considered as most important.

Measures

Student Assessment of Learning Gains (SALG). This survey was constructed by the NSF-funded program, *Science Education for New Civic Engagements and Responsibilities (SENCER)*.

SENCER aims to help teachers direct undergraduate students in applying math and sciences to help them become engaged and responsible citizens. SENCER developed the SALG survey to help teachers measure learning gains in their classrooms. The SALG survey is divided into four main sections: Understanding Gains, Skill Gains, Attitude Gains, and Integration of Learning Gains. Although we observed the scores in all four sections, we were most interested in the attitudes section. For this study, we used the survey created by SENCER, but altered some wording to fit the needs of this specific biology course. A copy of the SALG survey can be found in Appendix A.

The SALG pre-survey was available to the students online during the first week of school. The students were emailed the website and password so they could access the survey. The survey also included some personal information such as name, gender, GPA and major. The purpose of restricting the survey to the first week of the semester was to ensure that the students would complete the survey before being influenced by the lectures or coursework for Biology 100. The SALG post-survey was identical to the pre-survey except for a few small changes to indicate that the course had been completed (example: pre “What *do* you hope to learn?” post “What *did* you learn”). The students took the post survey the last week of class. We closed the survey before the students took the final exam so as to avoid any skewed survey results due to any anxiety or other feelings associated with taking the final exam.

We analyzed the pre and post SALG survey by comparing the mean scores in the two classes. A mixed model multiple regression analysis was used to account for other differences in the two classes such as GPA, ACT, major, and gender.

Biology Exam. Dr. Gary M. Booth and graduate students constructed a biology examination to test students on the main concepts taught in this Biology 100 students. Dr. Booth has used this instrument for over ten years and only small alterations were made to ensure that the exam was an accurate representation of the intended learning outcomes of the class. The students took the biology (pre) exam the first Friday in class before any instruction was given. The same biology (post) exam was given the last week of class instruction in the labs. TAs were responsible to ensure that each student took a pre and post survey. The pre biology exams were given full points for completion, although they were graded so the mean scores from the pre to the post could be compared. The post scores were graded and given points based on accuracy, with seventy points possible. The Biology Exam can be found in Appendix D.

Weekly surveys. Students in both classes took a weekly survey online created by Freshman Academy. The survey had questions about the students' study habits, sleep patterns, preparedness for class, etc. for that specific week. These weekly surveys were also compiled. We looked specifically at how many of the weekly surveys were completed by the students in the control versus treatment class. The students received one point for each survey completed.

Statistical Analysis

The data were analyzed using a mixed model multiple regression analysis to compare the effects of the treatments on pre and post scores on both the biology exam and the SALG survey

(understanding, attitudes, skills, integration of learning). The effects of ACT scores, gender, GPA, and declared science majors were included in the model. Significance was $\alpha \leq 0.05$.

From First to Second Year: Changes in Methods

SALG SURVEY. We gave the SALG survey the first week of the semester so as to avoid any biases from material learned or experiences gained in this course. We posted the survey online and although most of the students completed the survey before the closing deadline, there were students who did not. Some students complained that they could not get into the survey and others confused this survey with the weekly Freshman Academy surveys. We allowed these students to take the survey, but bias may have entered because of class exposure. The second year, we made the directions more clearly in class as to what the SALG survey is and how it was to be completed. We also set up times during the first week when students could come in if they could not get into the survey. We sent reminders before the closing day for the survey. Because of this, we did not have any students who took the survey late.

The post-SALG survey was given before the students took the final exam so as to avoid biases. However, the students only had a few days to take the survey the first year because we posted it late. This caused some problems and some students had to take the survey after taking the final exam. The next year, we posted the survey a full week before the final exam, announced it in class and sent reminders. We also set up times for students to come in if they had trouble getting into the survey. All students took the survey before taking the final exam.

We identified one key reason that students had difficulty entering the SALG survey. The survey has three options for student identify and we had chosen the ‘authenticated’ option, which requests that we enter the list of student email addresses that should have access to the survey.

This caused problems because if students tried to enter with a different email address than what we had listed, or if we failed to add their email address, they could not enter. The second year we chose the option “non-anonymous” which meant that access to the SALG survey was not controlled by an email list; however, we could still see which email addresses responded, just like with the authenticated case. This caused less frustration among students and quicker responses.

BIOLOGY EXAM. The pre-biology exam went well the first year. The students took the exam the first week in class. However, there were a few problems with the post exam. The post exam had been posted the previous year on BYU blackboard and we were unaware that students had access to the link. Most students never realized it was there, but there was a small group that found the old exam. Although we had altered questions for this year, there were still questions that were the same. We removed all access to previous exams on blackboard the second year. The first year of the study, we told the students only two days before the final biology exam that they would be taking this exam in lab that week. This caused some anxiety among students and little time to review the course material. The second year, we told them a week in advance so they had adequate time to study and prepare for the exam.

FRESHMAN ACADEMY WEEKLY SURVEYS. There were some complications with the first year weekly surveys. Some students said they could not find the survey link on blackboard, others confused these surveys with the SALG and others did not remember to take the survey weekly. Although some of these problems were due to student irresponsibility, we instructed TAs to remind students weekly in lab to take the online survey, we sent reminder emails, and we told students exactly where to access the weekly survey. There were no problems with students finding the surveys the second year.

SERVICE LEARNING. Most service learning projects went well the first year. However, there were a few problems. One group of students went to Idaho to help with a potato/agriculture project. When we talked with students about the experience, we heard some comments such as, “It was really fun. We just picked a lot of potatoes, although I’m not sure what it was for.” We realized that all the service projects need to be better explained in lab so that students understand what type of service they are rendering and how it relates to biological concepts they learn in Biology 100. Another group that collected June suckers from Utah Lake left their cell phones in the boat, which were damaged due to water leakage. Although this was an accident, some students expressed frustration and it was obvious it put a damper to the whole service project. In the second year, we better instructed the students as to what they needed to bring and what type of work they would be doing, as well as possible risks. Most of the students during the second year went to volunteer at the Senior World Games. We made sure each student attended a training session to learn how to perform the tests and procedures they would be expected to do, and also to answer any questions and give any clarifications of expectations. One group participated in Adaptive Aquatics, which we organized and explained to the students at the beginning of the semester. The second year service learning projects went very smoothly.

CONCEPT MAPPING. The first year of concept mapping went well. When concept mapping was done in previous years, students were frustrated with learning the details of concept mapping and did not understand the rationale behind using them. We spent the first few weeks allowing students to complete skeletal maps and get the feel for concept mapping. During our first training, we focused on the purpose of using the maps. Most students seemed to enjoy using the maps and felt they were beneficial. A few complications came when the students began creating their own maps. We did a quick training in lab and handed out packets, but it was apparent from

their first attempt at creating a map that they did not understand many components of concept mapping. The second year, we spent more time in lab giving examples of well-constructed maps and poor maps and set up specific times for students to get help with their maps.

GUEST LECTURES. The first year's guest lectures went well. All four speakers were well prepared and students gave positive feedback. One of the speakers could not speak in the evening and instead spoke during a class period. This caused a small complication because the control class reviewed for an extra class period previously learned material. Because of the smaller class sizes the second year (due to less students signing up for Freshman Academy) we only provided the two required guest lectures, both held in the evening. These were well attended and did not conflict with the control class. The students had the choice of attending two other science/biology related lectures for extra credit. This was more challenging for students, but was a necessity because of the low student numbers.

Biology Concept Survey. This survey was given to professors, Biology 100 students and Biology 120 students. It contained seventeen concepts to be ranked from one (most important) to seventeen (least important). The seventeen concepts were chosen because they were the most common concepts found in introductory biology textbooks. A copy of the survey can be found in Appendix C. We used an ANOVA test to compare the mean rankings for each of the seventeen concepts among the professors, major and non-major biology students.

Statistical Analysis

A one-way ANOVA was used to analyze the mean rankings of each of the 17 concepts for professors, non-major and major students to find differences. When there were significant differences (significant F test), an LSD post hoc test was conducted to find where the differences

were. An LSD test can be used when significance is found in the ANOVA, and LSD provides the most power. Significance was $\alpha \leq 0.05$. There were 66 non-major students, 352 major students and 64 faculty participants.

Results and Discussion

Both studies had unique components that differed from previous studies. Little research has assessed what should be taught in college biology courses (Gottfried *et. al.*, 1993) and no study has analyzed what professors and students view as the most important biology concepts to teach. Studies have analyzed the effects of service learning, concept mapping and guest lectures independently (Blyth *et. al.*, 1997, Reed *et al.* 2005, Hemphill & Hemphill, 2007, Mintzes & Wallace, 1990), but none have combined these three pedagogies and analyzed their effects on learning and attitude gains. Therefore, these studies should bring new insights to the literature.

Biology concept survey

The three concepts that were most frequently ranked by professors as most important were: scientific reasoning (3.78 average ranking), the cell (4.11) and evolution (5.38). The bottom three concepts were viruses (13.95), immunology (13.52) and embryonic development (12.95). These data differed significantly from the Biology 100 and 120 students who both ranked (on average) as the top three concepts: the cell (3.15 non-majors, 3.32 majors), cell division (5.82 non-majors, 5.95 majors), and biological molecules (5.5 non-majors, 5.37 majors). The bottom three were: history of science (13.15 non-majors, 11.76 majors), ecology (12.0 non-majors, 12.17 majors) and evolution (11.11 non-majors, 11.14 majors).

From the faculty, major, and non-major student treatments, there were 11 significant ($p \leq 0.05$) differences among the mean scores. The differences and their p values found were under

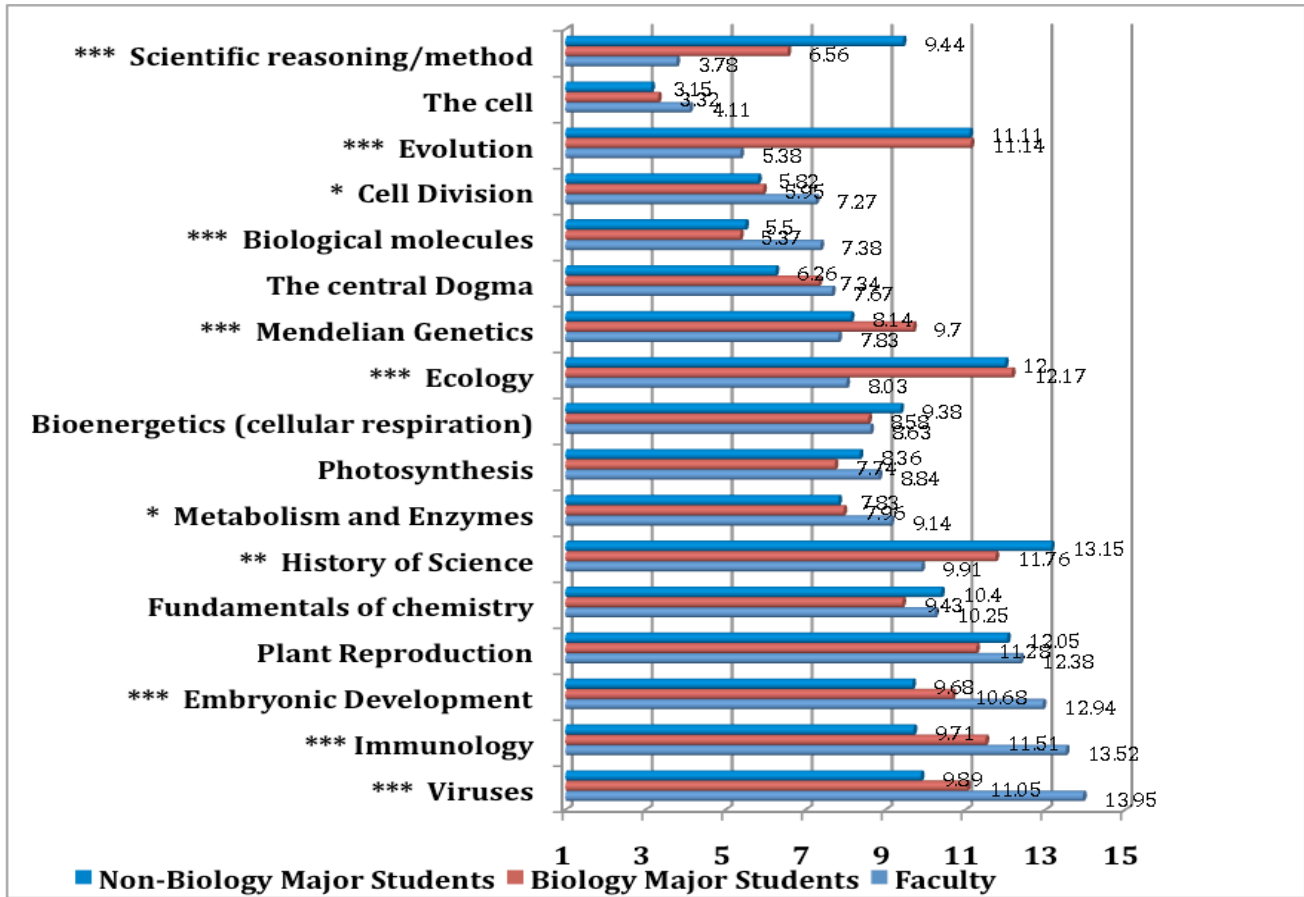
the following concepts: evolution (p=0.0001), immunology (p=0.0001), viruses (p=0.0001), cell division (p=0.014), mendelian genetics (p=0.0001), metabolism/enzymes (p=0.043), biological molecules (p=0.0001), embryonic development (p=0.0001), history of science (p=0.002), scientific reasoning (p=0.0001) and ecology (p=0.0001). Table 3 summarizes these concepts and significant p-values. Figure 1 below indicates the average rankings and those that were significant.

Table 3: Summary of p values for differences in average rankings for seventeen biology concepts among professors, non-major, and major students.

Concept	p value
Evolution	0.0001*
Fundamentals of Chemistry	0.248
The cell	0.116
Bioenergetics	0.348
The Central Dogma	0.231
Immunology	0.0001*
Viruses	0.0001*
Cell Division	0.014*
Mendelian Genetics	0.0001*
Metabolism and Enzymes	0.043*
Photosynthesis	0.076
Plant Reproduction	0.059
Biological Molecules	0.0001*
Embryonic Development	0.0001*
History of Science	0.002*
Scientific Reasoning	0.0001*
Ecology	0.0001*

*Significant $p \leq 0.05$

Figure 1: Average rankings for professors and major and non-major students for the seventeen biological concepts.



* p<.05 **p<.01 ***p<.001

The LSD post hoc indicated that there were significant differences ($p \leq 0.05$) between faculty and biology majors in all of the following 11 areas: evolution, immunology, viruses, mendelian genetics, metabolism and enzymes, biological molecules, embryonic development, history of science, scientific reasoning/method, and ecology. Many were highly significant ($p \leq 0.0001$; Table 4). Comparisons between faculty and non-major biology students also had significant differences ($p \leq 0.05$) in all of the areas listed above with the exception of mendelian genetics and metabolism and enzymes.

Table 4: Significant differences in the average rankings of seventeen biology concepts among faculty and major and non-major students.

Concept	P value	Faculty Average Ranking	Major Students Average Ranking	Non-major Students Average Ranking
Evolution*	0.0001	5.38	11.14	11.11
Immunology	0.0001	13.52	11.51	9.71
Viruses	0.0001	13.95	11.05	9.80
Cell Division	0.013, 0.042**	7.27	5.95	5.82
Mendelian Genetics*	0.001 (Majors only)	7.83	9.70	8.14
Metabolism and Enzymes	0.041 (Majors only)	9.14	7.96	7.83
Biological Molecules	0.001, 0.01 **	7.83	5.37	5.5
Embryonic Development	0.0001	12.94	10.68	9.68
History of Science*	0.026, 0.001**	9.91	11.76	13.15
Scientific reasoning/method*	0.0001	3.78	6.56	9.44
Ecology*	0.0001	8.03	12.17	12.0

*Faculty ranked these concepts as more important than students did

**Differences between faculty and major students and faculty and non-major students, respectively

There were also significant differences between average rankings from the non-major and the major students for the following concepts: immunology, viruses, mendelian genetics, history of science and scientific reasoning/method (Table 5).

Table 5: Significant differences in the average rankings of seventeen biology concepts of major and non-major biology students.

Concept	P value	Major Students Average Ranking	Non-major Students Average Ranking
Immunology	0.0001	11.51	9.71
Viruses	0.015	11.05	9.89
Mendelian Genetics	0.003	9.70	8.14
History of Science*	0.047	11.76	13.15
Scientific Reasoning/Method*	0.0001	6.56	9.44

*Biology 120 students ranked these concepts as more important than Biology 100 students did.

Further analysis was conducted by comparing the mean scores for each department (Table 6). The departments in the College of Life Sciences at BYU were: Biology, Microbiology, Physiology and Developmental Biology, and Plant and Wildlife Sciences. UVU faculty was put into one category because their faculty is all considered a part of the Department of Life Sciences. There were no significant differences in rankings between UVU and BYU professors for any of the 17 concepts.

Table 6: Summary of p values for differences in average rankings of seventeen biology concepts among faculty departments.

Concept	p value
Evolution	0.013*
Fundamentals of Chemistry	0.034*
The Cell	0.145
Bioenergetics	0.876
The Central Dogma	0.128
Immunology	0.82
Viruses	0.259
Cell Division	0.774
Mendelian Genetics	0.007*
Metabolism and Enzymes	0.075
Photosynthesis	0.003*
Plant Reproduction	0.38
Biological Molecules	0.051
Embryonic Development	0.264
History of Science	0.137
Scientific Reasoning	0.087
Ecology	0.0001*

- $p \leq 0.05$

Professors ranked evolution and ecology as two of the most important concepts to teach; students ranked them as two of the lowest in importance. Evolution is the capstone of all biology and thus, it is disturbing to think that our students would place it near the bottom in terms of importance. However, this is not an uncommon concern (Alters and Nelson, 2002). It is imperative that professors teach and help students understand evolution, which they apparently have not done effectively thus far. Ecology is another great concern. Ecology helps students see the “big picture” instead of learning random facts that often are the cause of students’ dislike toward science (Mason, 1992). In his book, *The Diversity of Life*, Wilson (1992) discusses the importance of ecology and speaks of biodiversity as priceless and an important part of humanity. He argues that there is a bond between humans and other species and that we subconsciously seek these connections with the rest of life (Wilson, 1992). The professors in this study

recognize the key role of ecology, but once again this study reveals that this key concept in biology is not adequately relayed to the students.

The discrepancy between faculty and student ratings on scientific reasoning/method is also alarming. Scientific reasoning skills are the foundation of experimental biology; however, Alters & Cerbin (1991) explained that teachers are often afraid of how to teach thinking-skills and how to incorporate them into their course without sacrificing content, although they recognize the importance of scientific reasoning. These data suggest that a more concerted effort should be placed on teaching scientific reasoning if the goal is to create more scientifically literate citizens.

There were significant differences in rankings between biology major and non-major students, but they were more consistent with each other than when compared to faculty. The most significant difference among the students was scientific reasoning/method, with majors ranking this topic as more important than did the non-major students. Major students are often more exposed to scientific research and perhaps have more opportunity to see the importance of the scientific method and reasoning skills. However, many students will only take an introductory biology course at college; therefore additional focus should be placed on using the scientific method and reasoning skills in all aspects of general education biology.

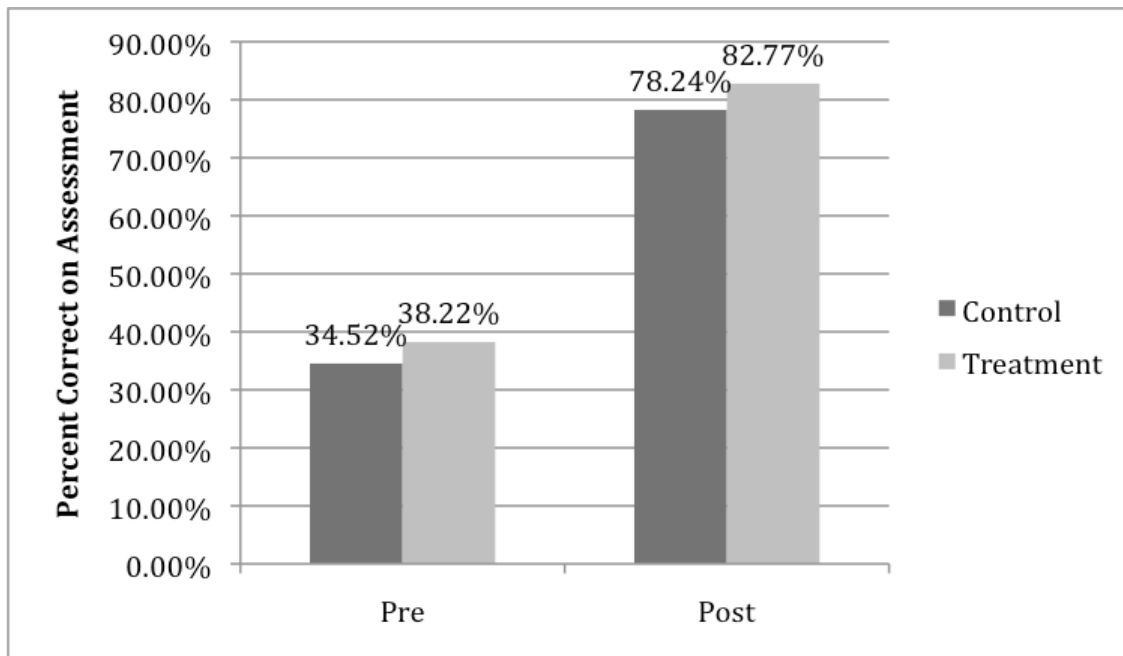
Biology 100 control and treatment (enriched) classes

First Year

Pre and post assessment

There were no significant differences between the two treatment groups ($p=0.6888$). The variable that had a significant impact was ACT math scores ($p=0.0305$); students with higher ACT scores had significantly greater increases in pre to post scores. In addition, there was a significant difference between the two classes on the pre and post scores, with the control class scoring higher on both ($p=0.0014$) but the control increase from pre to post was not significant ($p=0.6279$) from the treatment class. Both classes improved from pre to post ($p<0.0001$; Figure 2).

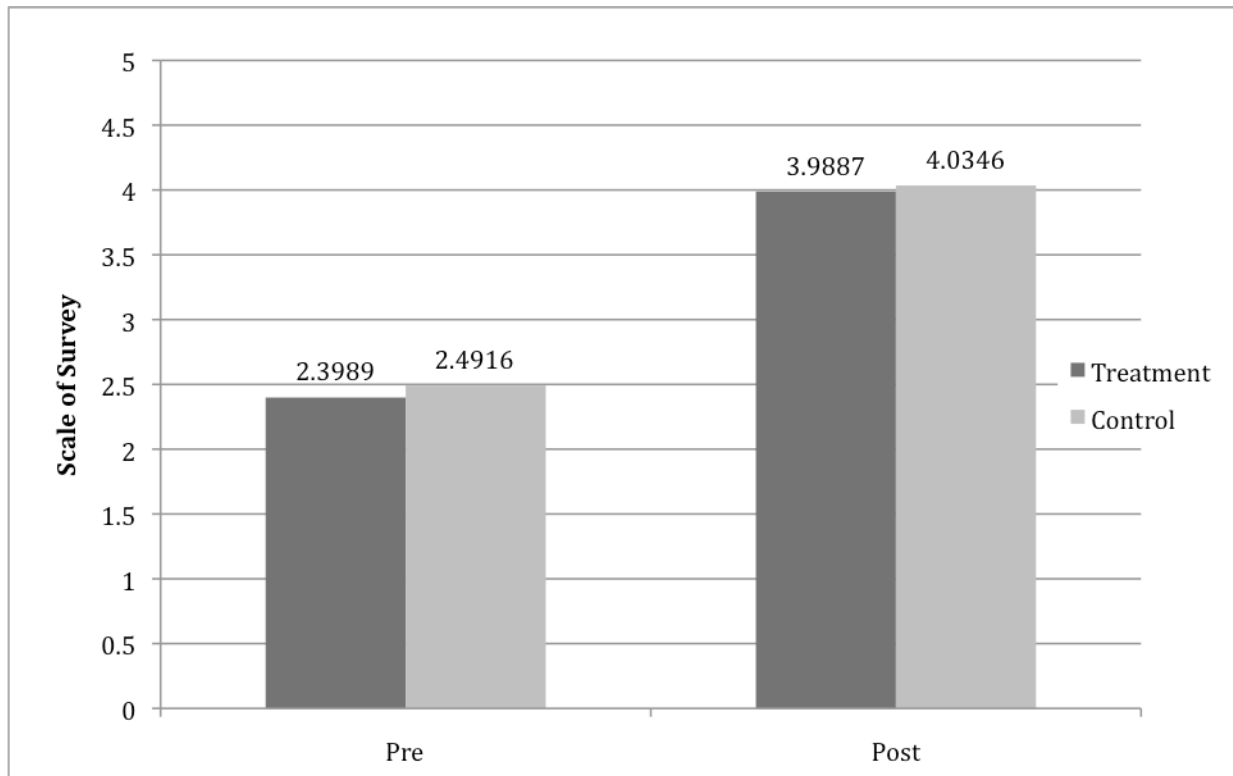
Figure 2: Fall 2008 pre and post biology assessment for control and treatment classes: percentage correct



SALG understanding

The understanding section of the SALG survey also did not have significant differences ($p=0.6270$) between the two classes in the change between mean pre and post scores. ACT composite score was the only indicator that showed significance ($p=0.0004$); students with higher ACT composite scores, on average, had a greater increase between pre and post scores in the understanding section. Again, both classes significantly increased from pre to post ($p<0.0001$; Figure 3).

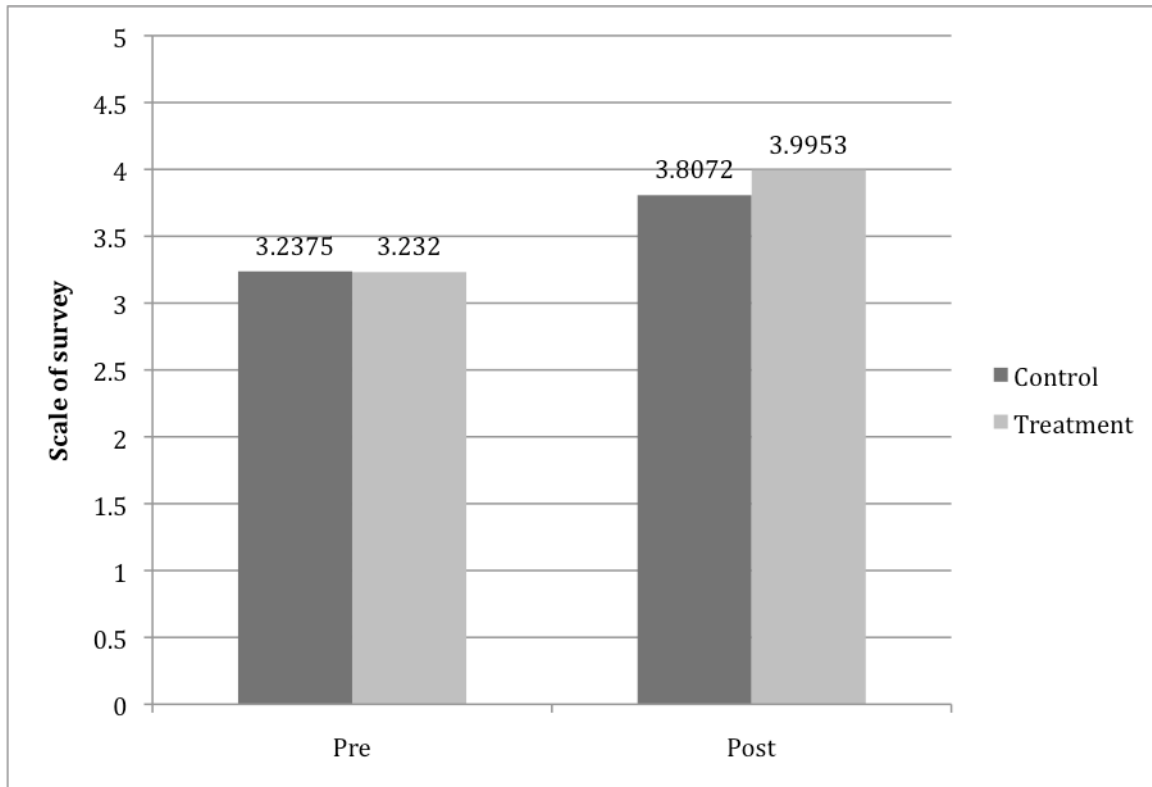
Figure 3: Fall 2008: Comparison of Understanding: Average pre and post scores for control and treatment classes.



SALG attitude

There was a significant difference between the control and treatment class in attitude gains from pre to post ($p=0.0374$). However, it was the control class that had greater gains (with an average increase of 0.7633) than the treatment class (with an average increase of 0.5697). ACT composite scores also had an impact on attitude gains ($p=0.0018$; Figure 4) and students that were science majors had significant increases from pre to post in comparison to non-majors ($p<0.0001$).

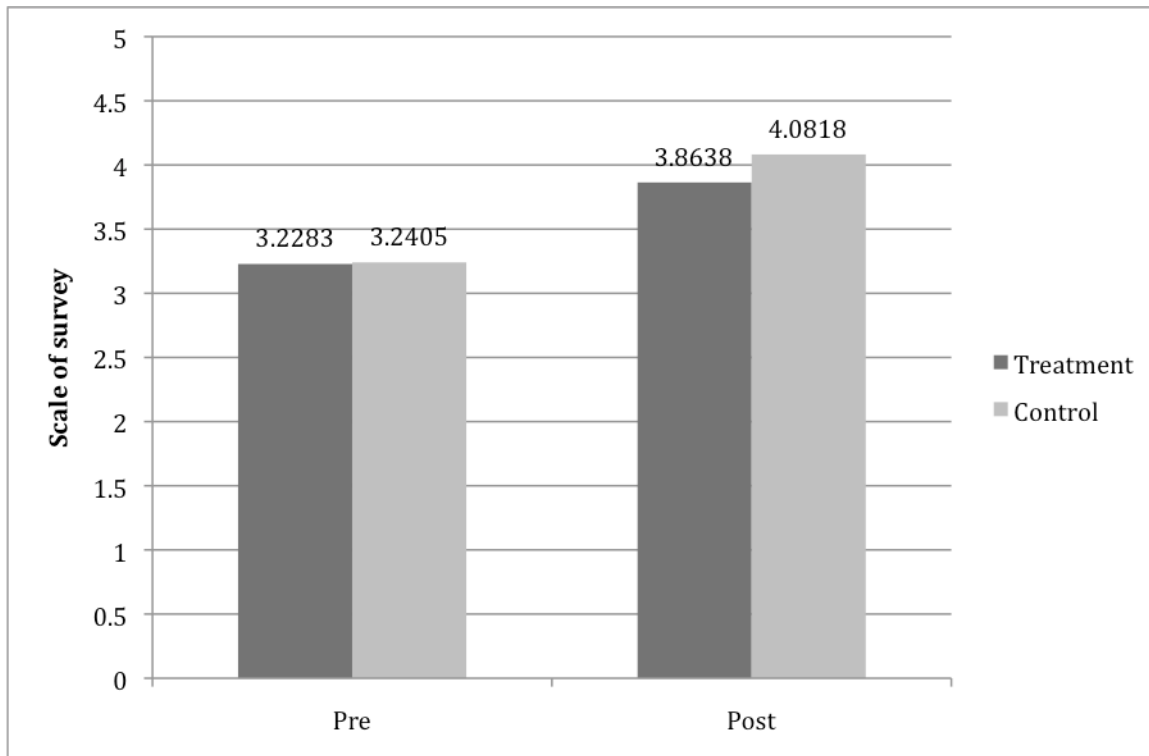
Figure 4: Fall 2008 Comparison of Attitudes: Average pre and post scores for control and treatment classes.



SALG skill

As shown in Figure 5, there was a significant difference between the control and treatment class and increases in skill from pre to post, with the control class having the greatest skill gains ($p=0.0238$). ACT composite also significantly contributed to skill gains, with higher ACT composite scores having higher skills gains ($p=0.0048$). Both classes significantly increased their skills from pre to post in skills ($p<0.0001$).

Figure 5: Fall 2008 Comparison of Skills: Average pre and post scores for control and treatment classes.

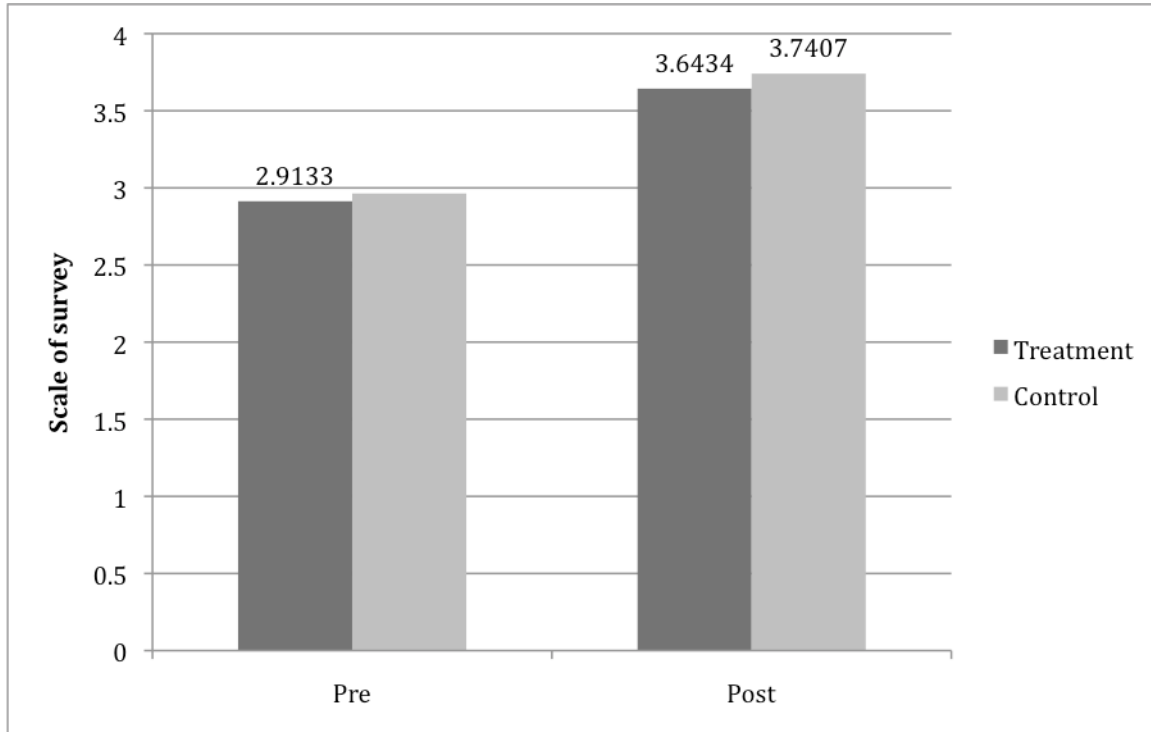


SALG integration of learning

When comparing student desire to integrate what they learned in class with other aspects of their lives, there was no significant difference between the two classes ($p=0.6463$) and the only variable that had a significant impact on changes between the pre and post scores was ACT

composite; i.e., those that had higher ACT composite scores tended to have greater increases from pre to post ($p=0.0016$). There was a highly significant increase ($p<0.0001$, Figure 6) in both classes from pre to post.

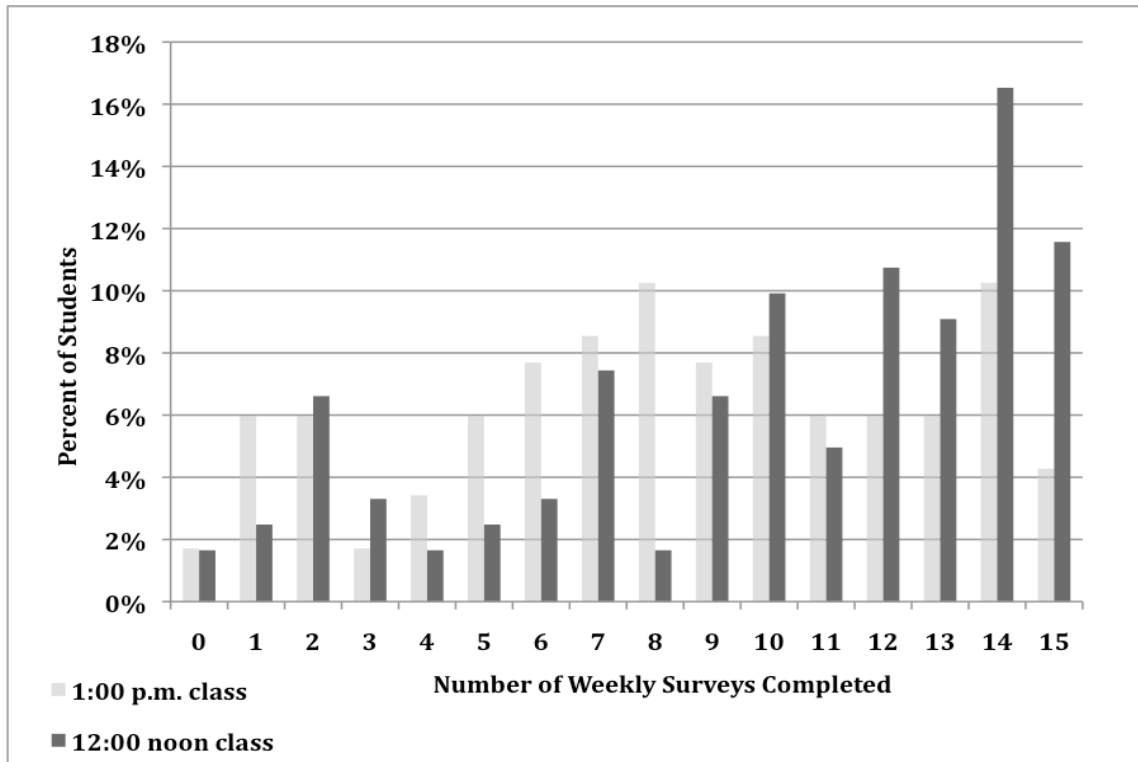
Figure 6: Fall 2008 Comparison of Integration: Average pre and post scores for control and treatment classes.



Freshman Academy weekly surveys

We compared the number of surveys completed by the treatment class and control class as shown in Figure 7. The mean number of surveys completed by the treatment class was significantly greater than the mean number completed by the control group (p value 0.01). The control group completed an average of 8.32 surveys out of the 15 total, while the treatment class completed an average of 9.95 surveys. Gender also made a difference, with females completing a significantly greater number of surveys than males ($p=0.01$; females completing 9.95 surveys and males completing 8.05 surveys; Figure 7).

Figure 7: Fall 2008 Percentage of weekly Freshman Academy surveys completed by control and treatment classes.



Second Year Results

For the second year, we decided to only use ACT composite as an indicator rather than using the subdivisions of the ACT test: math and English. The indicators had so much overlap that we felt the composite adequately represented the effects of ACT on student results. We also removed one student who did not have an ACT score and one student with a high GPA (3.97) but a failing score on the final (52/100). These two students appeared to be outliers and hence, may have confounded the results.

Final Exam

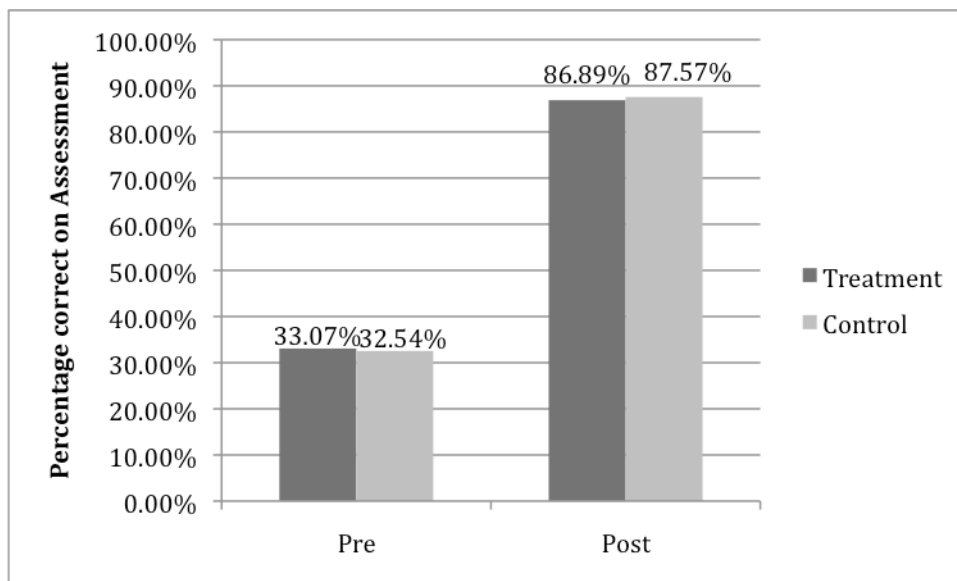
We removed one the three lowest student scores on the post assessment. This is because these students appeared to be outliers, with one student having no GPA, one with no ACT and the other with a high GPA yet extremely low score on the final.

Pre and post assessment

After adjusting for the important predictors such as ACT scores and GPA, the combinations of pedagogies did not make a difference in the average biology exam scores. Both classes had about the same increase from pre to post ($p=0.7362$). The only predictor that had a significant impact was the ACT composite; those having a higher ACT score showed a greater increase from pre to post ($p=0.0168$). Both classes significantly improved from pre to post ($p<0.0001$).

These results were very similar to the previous year (See Figures 2 and 8).

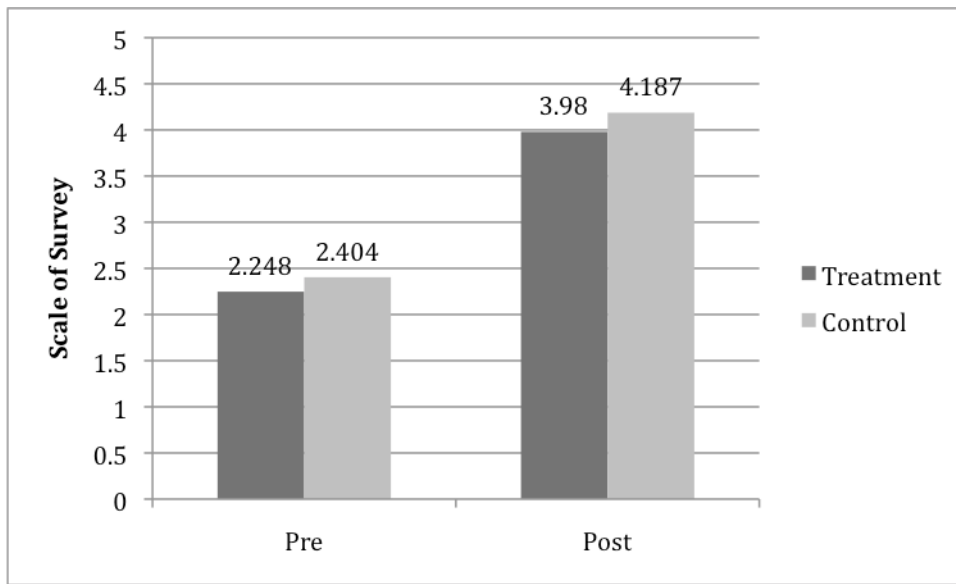
Figure 8: Fall 2009 pre and post biology assessment for control and treatment classes: percentage correct



SALG understanding

Although both classes significantly increased their perception of their understanding from pre to post ($p < 0.0001$), there were no significant differences between the increases of the two classes ($p = 0.7525$). High school GPA did have a positive effect on increased understanding from the pre to the post; those with higher GPAs had greater increases from pre to post ($p = 0.0612$; Figure 9).

Figure 9: Fall 2009 Comparison of Understanding: Average pre and post scores for control and treatment classes.

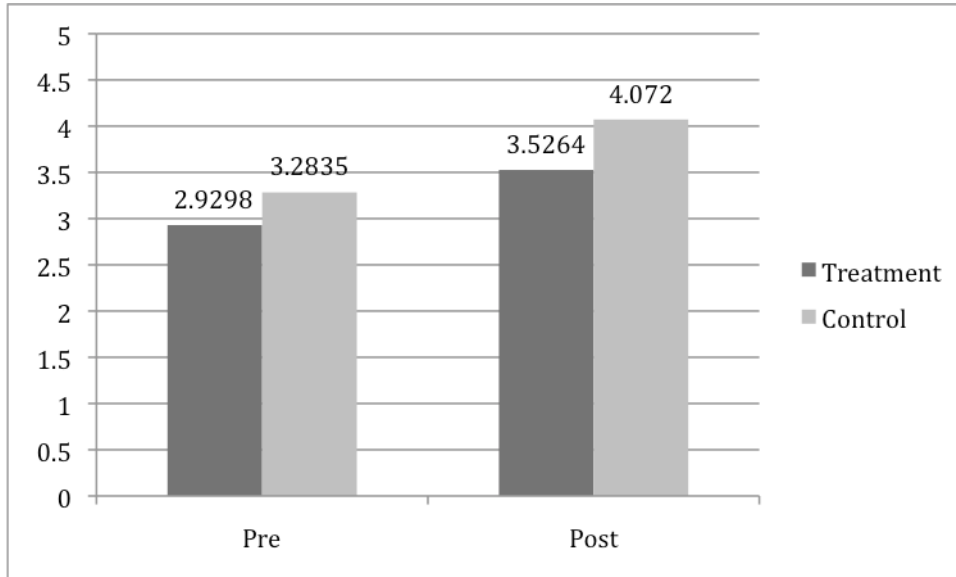


SALG attitude

There were no significant differences between the control and treatment groups in relation to the increases from pre to post ($p = 0.2986$). The previous year did have a significant increase in favor of the control group. The control class had significantly higher pre and post scores ($p = 0.00098$) for unexplained reasons, but the increase from pre to post was no different than the treatment class the second year. The only significant indicator was if the student had declared a science major at the beginning of the semester. Those that were science majors had

highly significant increases from pre to post ($p=0.0003$). Both classes had significant increases in attitudes ($p<0.0001$; Figure 10).

Figure 10: Fall 2009 Comparison of Attitudes: Average pre and post scores for control and treatment classes.



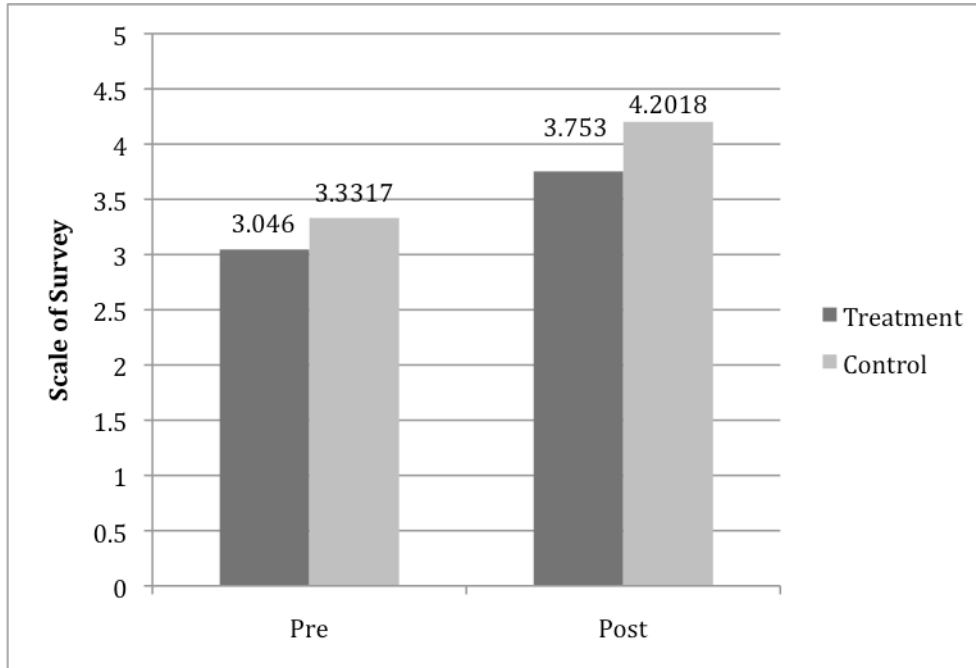
When analyzing the effect of the treatment on both the mean attitude score and the variance of the attitude scores, the students in the treatment class displayed a significantly greater increase in variance for the attitude score than students in the control class ($p=0.007$) with the variance for the pre survey at 0.4541 and the variance for the post survey at 0.7224 for the treatment class. In fact, the control class displayed a decrease in variance with their pre survey variance being 0.3588 and post survey variance at 0.2940. In other words, random people, not associated with low GPA or gender or any of the other indicators we accounted for, tended to display more of a decrease or more of an increase in their attitude score in the treatment class than in the control class at the end of the semester. The Fall 2008 data showed the same trend for variances, but the effect was not statistically significant ($p=0.141$).

It is common for students to exhibit greater variability in areas such as attitude after experiencing a course than they do early on in the course (Hilton, *et. al.*, 2004); however this study is unique in that the treatment class exhibited significantly greater variability than the control. This leads to many interesting questions, such as what are possible reasons some students have such a positive experience with enriched activities whereas others have a negative experience? Perhaps personality differences contributed to these results and personality tests could be used to further analyze if specific types of personalities enjoy these enriched activities better than others.

SALG skill

There were no significant differences between the control and treatment classes in skill gain ($p=0.2922$) and none of the other indicators had a significant role in skill gain. Both classes did significantly improve from pre to post ($p<0.0001$). The control class had a significantly higher pre and post score than the treatment class ($p=0.0154$) but the increase from pre to post was not significantly different ($p=0.2922$; Figure 11).

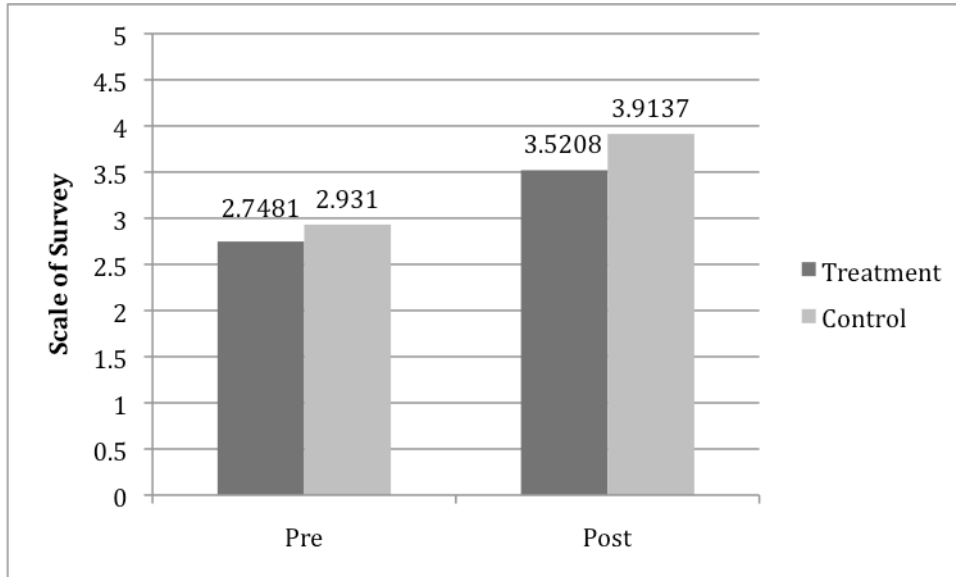
Figure 11: Fall 2009 Comparison of Skill: Average pre and post scores for control and treatment classes.



SALG integration of learning

Although both classes increased significantly from pre to post in how well they integrate concepts learned in biology to other aspects of their lives ($p < 0.0001$), there were no significant differences between the two classes ($p = 0.2289$). The only indicator that marginally ($p = 0.0548$) affected the increase from pre to post was if the students were a declared science major (Figure 12).

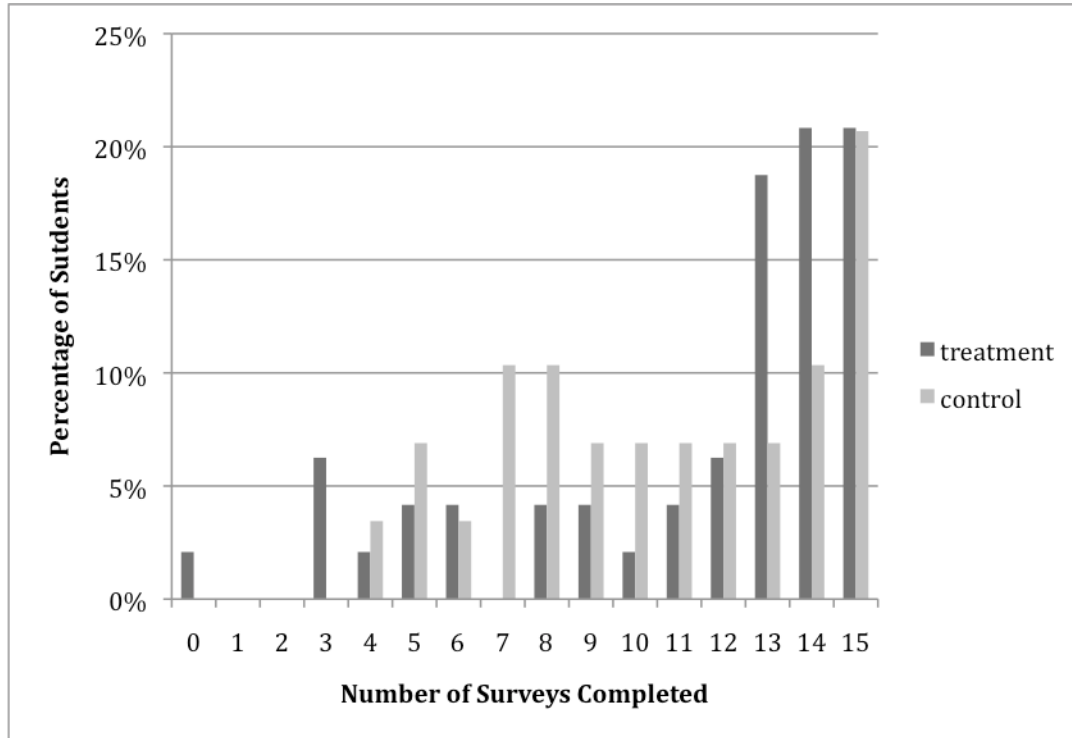
Figure 12: Fall 2009 Comparison of Integration of Learning: Average pre and post scores for control and treatment classes.



Freshman Academy Weekly Surveys

This year, there were no significant differences between the average number of surveys completed by the control and treatment classes ($p=0.415$). Figure 12 shows there were more in the treatment group that completed most of the surveys, but there were also more in the treatment group that completed few to none of the surveys, thus averaging out the same as the control group.

Figure 12: Fall 2009 Percentage of weekly Freshman Academy surveys completed by control and treatment classes.



Although there were no significant differences in the number of surveys completed by the two classes in Fall 2009, Fall 2008 did have significant differences, with the treatment class completing more surveys than the control. Perhaps those in the treatment class had more involvement with biology (service learning, guest lectures, etc.) and thus biology was a greater part of their daily lives. If this is the case, the data may support the argument that enriched activities can benefit students purely because it helps them become active learners, rather than passively “receiving” (Yager, 1991).

Multiple factors could have contributed to the lack of significant differences between those that were involved in the enriched activities (treatment class) and those that were not (control class) on both the biology exam and SALG survey.

Small sample size between the control and treatment classes may have contributed to the results. Small sample sizes often lack statistical power; however, they can still be meaningful and are found in the literature in similar research studies (Reed *et al.* 2005). We tried to keep other variables the same, and the best way to accomplish this was to limit the study to Biology 100 classes taught by Professor Booth. It is difficult to implement the same pedagogical methods among different professors.

Although Freshman Academy helped keep many variables the same between the two classes, it also gave the students in both classes opportunities for help that would not typically be available in most general education biology classes. Freshman Academy classes provide a unique environment that steers away from the lecture-oriented, high enrollment courses taught in amphitheater settings that commonly lead to high anxiety and poor attitudes toward science (Mallow 1981). Freshman Academy encourages students to interact with each other and with their professors, whereas the typical college teacher-centered lectures often alienate students from their professors and discourage interaction (Tobias, 1986). The benefits of Freshman Academy available to both the control and treatment classes possibly masked the impact of concept mapping, service learning and guest lectures.

The length of the semester and time exposed to the enriched pedagogies may also have affected the results. However, the time needed for these pedagogies is not clear. For example, many studies showed significant improvements due to the use of service learning only after months of exposure (Strange, 2004, Astin & Sax, 1998, Brindle & Hatcher, 1996), yet, Reed *et al.* (2005) demonstrated positive results after only a one-week exposure to service learning. In the four months the students were enrolled in Biology 100, they had eight hours of service

learning, less than 16 weeks to learn and create concept maps, and only four guest lectures. Perhaps more time was needed to see the full impact of the treatment pedagogies.

In addition, most students are accustomed to courses with traditional class instruction and assignments. Some students expressed frustration and impatience in not immediately understanding concept mapping and found it time consuming. Clearly there are some students who do not find enriched pedagogies helpful (Heinze-Fry & Novak, 1990). Other students expressed frustrations with attending guest lectures in the evenings. Some of the service learning projects were long and in some cases, personal items such as cell phones were damaged. Some students had difficulty in adjusting to new learning methods and perhaps this frustration masked the potential long-term benefits of using these enriched pedagogies. Again, a longer duration of involvement could remedy this problem.

These data indicate that there is a possible teacher effect. Both classes improved significantly in all areas over the semester ($p < 0.0001$), and an important constant variable in both classes was the teacher. Further investigation should be conducted as to the teacher effect and the role of a teachers' ability to connect to students in relationship to student learning and attitude gains.

Conclusion

Biology 100 control and treatment (enriched) classes

This study demonstrated that pedagogical methods did not play a significant role in student learning and attitude gains, despite the significance of the individual pedagogical methods in other studies (Blyth *et al.*, 1997, Reed *et al.* 2005, Hemphill & Hemphill, 2007,

Mintzes & Wallace, 1990). However, these results were consistent with the study conducted by the BYU statistics department (Hilton & Christensen, 2002).

Perhaps the treatment pedagogies did make a significant difference for some students, because there was significantly greater variability in attitudes post-semester in the treatment class in comparison to the control class. Enriched pedagogies did have a significant effect for certain students for unknown reasons. One hypothesis is that student personality makes a difference in how well the student connects with enriched pedagogies. Additional investigation of this hypothesis could be conducted with personality tests.

In addition, GPA and ACT scores proved to be valuable indicators of student learning and attitude gains, which is consistent with the literature (Rose, 1999). Students in both classes significantly improved in all areas from pre to post. Further investigation should analyze teacher effect, as this was a key consistent variable in both classes. It is possible that the teacher effect masked the possible benefits of enriched pedagogies on student learning and attitude gains. It is important to note that enriched activities did not detract from student learning of “core” concepts, which is a concern expressed by educators who question whether enriched pedagogies should be used (Strange, 2004). In short, the enriched pedagogies did not detract from student learning or hurt student learning in any way.

Furthermore, a larger sample size and a longer time frame would be helpful in increasing statistical power and also providing more evidence and valuable insights as to the effects of enriched pedagogies.

Biology concept survey

Professors ranked 11 of the 17 biology concepts significantly different than the students. Ecology and evolution were ranked as two of the most important concepts for professors, whereas students ranked them as two of the least important concepts to teach. Scientific reasoning/method was also ranked by professors as one of the top three most important concepts to teach, but was ranked significantly lower in importance by students. These results indicate that students are not learning or understanding the importance of what professors view as the key concepts in biology. Evolution is the keystone of biology and ecology is vital for understanding the “big picture” of biology (Wilson, 2006). Scientific reasoning and the scientific method drive all experimental biology. These differences may reflect previous student exposure or experience to these biological concepts as well. This study should be repeated on a larger-scale, with professor and student participants from across the nation to evaluate the significance of the discrepancy between faculty and students. It is hoped that our students leave their biology course with the ability to apply principles of biology in their lives to help them see the relevance of biology and to help them solve real world problems in their community and state, thus becoming more scientifically literate.

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Appendix A

SALG SURVEY Questions

Answered on a scale:

Not at all (1), just a little (2), somewhat (3), a lot (4), a great deal (5)

Number	Question
	Understanding
1	Presently, I understand...
1.1	The following concepts that were explored in this class
1.1.1	The parts and functions of the cell
1.1.2	Basic Chemistry
1.1.3	Cellular Respiration
1.1.4	The Central Dogma
1.1.5	Bacteria and Diseases
1.1.6	Viruses
1.1.7	Mitosis and Meiosis
1.1.8	Mendelian Genetics
1.1.9	Evolution
1.1.10	Photosynthesis
1.1.11	Ecology
1.2	The relationships between those main concepts
1.3	How ideas we explored in Biology 100 relate to ideas I have encountered in classes outside of this subject area
1.4	How studying biology helps people address real world issues
1.5	It what ways did Biology 100 meet (or fail to meet) your expectations of what you wanted to learn/know?
	Skills
2	Presently, I can...
2.1	Find articles relevant to a particular problem in professional journals or elsewhere
2.2	Critically read articles about issues raised in class
2.3	Identify patterns in data
2.4	Recognize a sound argument and appropriate use of evidence
2.5	Develop a logical argument
2.6	Write documents in a scientifically appropriate style and format
2.7	Work effectively with others
2.8	Comfortably discuss scientific matters with others
2.9	What are you able to do now that you could not do before taking this course?
	Attitudes
3	Presently, I am...
3.1	Enthusiastic about science
3.2	Interested in discussing science with friends or family
3.3	Interested in taking or planning to take additional classes in science
3.4	Interested in engaging in community projects related to science
3.5	Confident that I understand biology
3.6	Confident that I can do science

- 3.7 Comfortable working with complex ideas
- 3.8 Willing to seek help from others (teacher, peers, TA) when working on academic problems in this class
- 3.9 Please comment on your present level of interest in science

Integration of learning

- 4 Presently, I am in the habit of...
- 4.1 Connecting key ideas I learn in my classes with other knowledge
- 4.2 Applying what I learn in classes to other situations
- 4.3 Using systematic reasoning in my approach to problems
- 4.4 Using a critical approach to analyzing data and arguments in my daily life
- 4.5 Doing service activities related to what I have learned in my classes
- 4.6 Please comment on how you expect the material from Biology 100 to integrate with your studies, career, and/or life?

Major

- 5 Describe what best characterizes your major in college.
- 5.1 Major in the sciences
- 5.2 Not a major in the sciences
- 5.3 Undecided at this time
- 5.4 Plan on becoming a major in a field of science
- 5.5 Plan on becoming a major in another area

GPA

- 6 Answer this question about your GPA which assumes a 4.00 as an A (highest score possible)
- 6.1 What was your high school GPA?

Personal information

- 7 Please write your name, student ID number and email address in the box
- 7.1 Name (first and last)
- 7.2 Student ID number
- 7.3 Email address

Appendix B

Dr. Booth's Biology 100 Class "Student Concept Map Training Packet"

1. Purpose of Concept Mapping
2. What is a Concept Map – Example of a Concept Map
3. Elements of a Concept Map
4. Fill in the Blank Concept Mapping Assignment
5. Construct a map from a list of concepts (C-map) Assignment (Starting Lecture 8)

1. Purpose of Concept Mapping

In order to “really” understand a subject like Biology we must engage in the learning of-

- Biological **Facts** – *Watson and Crick discovered the structure of a DNA.*
- Biological **Concepts** – *DNA or mRNA*
- How Biological **Concepts are Interrelated** – *mRNA is a mobile transcription of DNA*

Learning occurs when you bring order / structure to the information you are receiving. Concept mapping is one of many ways you can facilitate for yourself an organized understanding of a subject.

In Dr. Booth's class this Fall you will learn Facts, Concepts, and how these Concepts interrelate with one another. We will use Concept Mapping as a way to see how the concepts you learn this semester are interrelated.

2. What is a Concept Map – Example of a Concept Map

A concept map is a graphic representation intended to reveal a student's understanding of how the concepts within a content domain are interrelated. An example of a concept map is shown in Figure 1

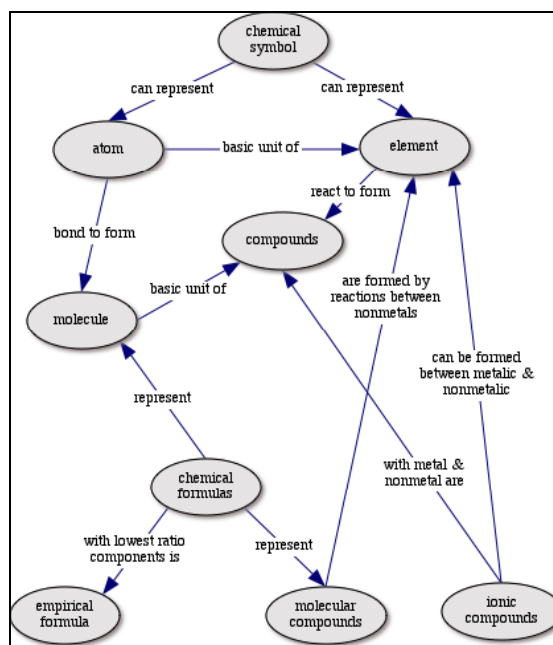


Figure 1. Example of a concept Map

3. Elements of a Concept Map

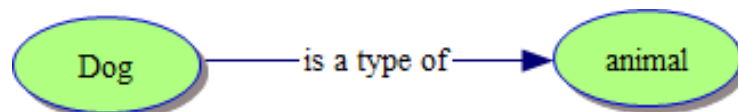
A concept map has –

- **words** representing **concepts** that you write in an ellipse



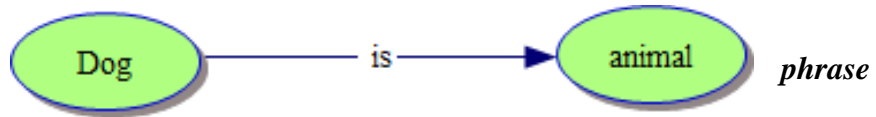
- **linking phrases** which specify a relationship between two concepts. The concepts and linking phrase form a **proposition**, e.g. “Dog is a kind of animal”. The proposition should communicate a complete thought.

Good Example of a proposition



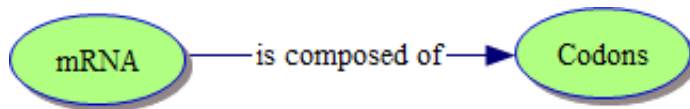
Bad example of a proposition

Linking Training

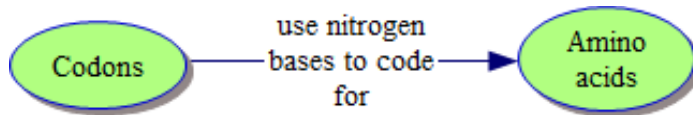


The linking phrase should communicate a complete and accurate *relationship* between two concepts. Linking phrases can describe how two concepts are related by their involvement in an important process, their structure, and/or organization. You may add new concepts in the linking phrase only if absolutely necessary, and only if this helps make the relationship between concepts complete and accurate.

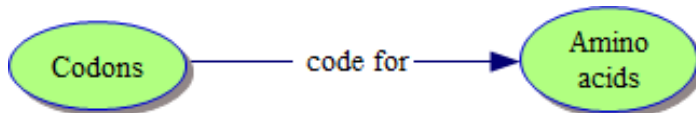
Example of structural relationship



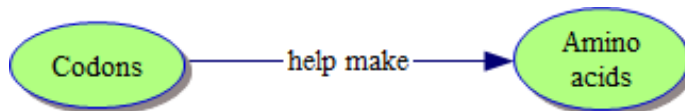
Example of relationship by involvement in a process



Even if we remove the “use nitrogen bases to” element of the linking phrase, the most important element that describes the process remains.

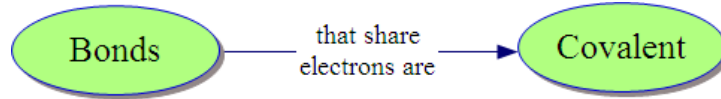


Example of a less effective relationship by involvement in a process



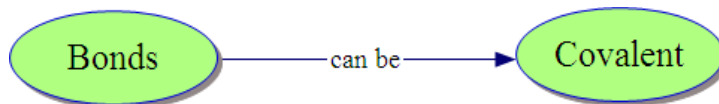
A linking phrase that serves to establish a relationship between concepts should form a proposition that is important, accurate and complete. While necessary in some cases, students should avoid excessive use of redundant and less meaningful linking phrases such as “can be”, “is a type of” or “follows” when more meaningful relationships can be expressed. Consider the following linked concepts:

Good Example



Notice that the concept “electrons” is in the linking phrase, because it is a critical part of the relationship between the concepts “bonds” and “covalent”

Bad example



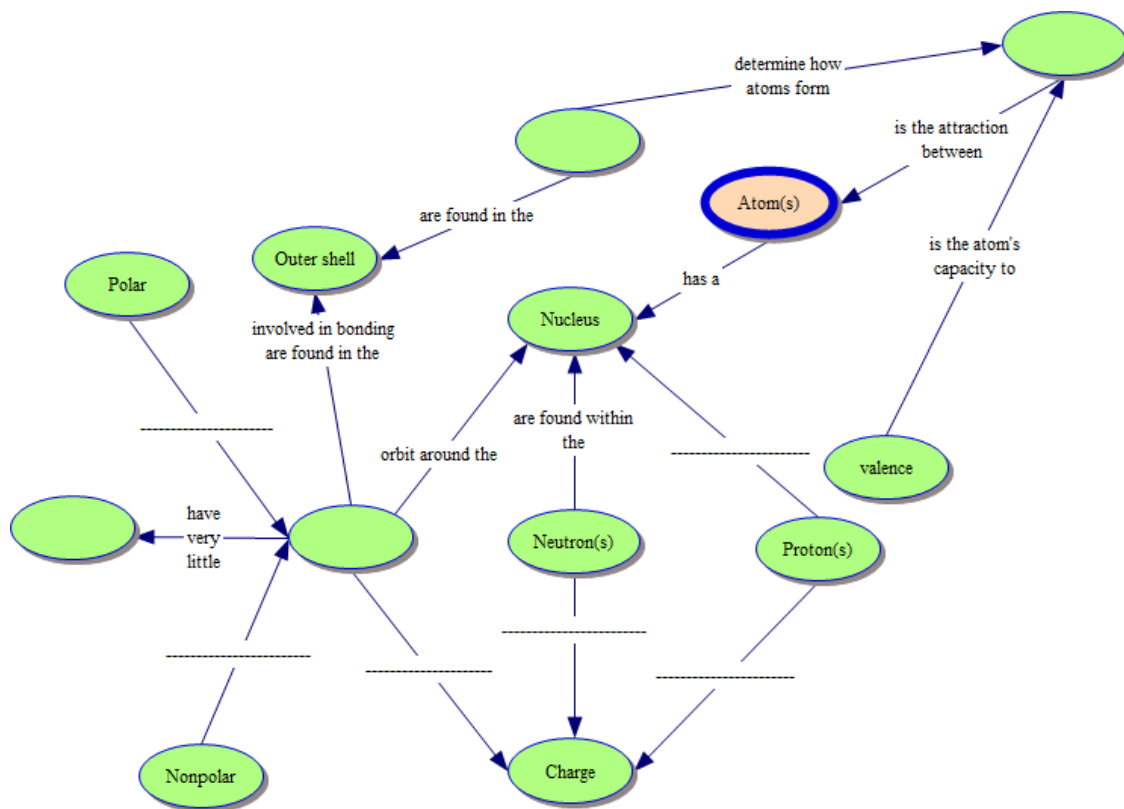
Although important and accurate, this linking phrase is incomplete. The student has not demonstrated adequate understanding of the relationship between the two concepts in a meaningful way.

4. Fill in the Blank Concept Map Assignments

For Lectures 3-7 you will be given assignments to complete skeletal concept maps by filling in blank nodes and linking phrases as shown in the following example.

Concept Map assignment for Lecture # 3

The skeletal concept map below includes some blank nodes and blank links. The Lecture’s central concept is highlighted with a thicker line. Your assignment is to fill in the blank nodes and blank links from the list of concepts and linking phrases provided at the bottom of the page. After your concept map is completed, it should reflect the content provided in Lecture 3. This assignment is worth ten (10) points. You will be given one point for each correctly labeled concept node and link.



List of Concepts

1. Mass
2. Electron(s)
3. Valence electrons
4. Bond

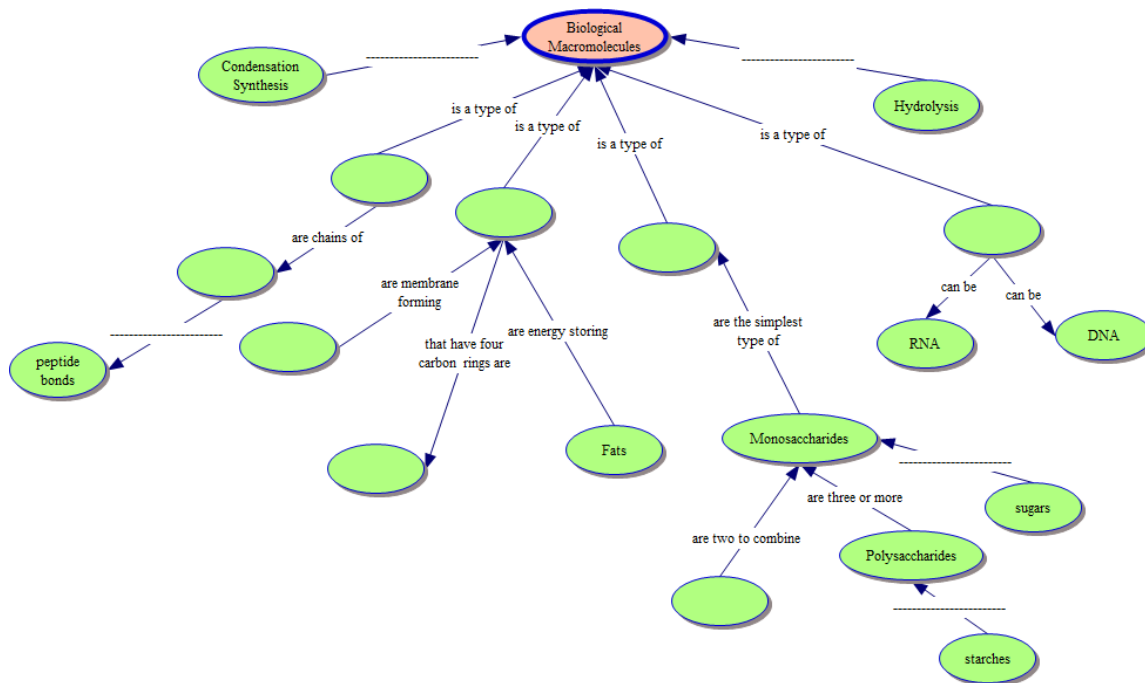
List of Linking Phrases

1. is a molecule with an equal distribution of
2. have a negative
3. is a molecule with an unequal distribution of
4. have no
5. have a positive
6. are found within the

Concept Map assignment for Lecture # 4

The skeletal concept map below includes some blank nodes and blank links. The Lecture's central concept is highlighted with a thicker line. Your assignment is to fill in the blank nodes and blank links from the list of concepts and linking phrases provided at the bottom of the page. After your concept map is completed, it should reflect the content provided in Lecture 4. This assignment is worth ten (10) points. You will be given one point for each correctly labeled concept node and link. If the number of empty

nodes and blank links are more than 10 your score will be converted into a percentage so that each assignment is worth (10) points.



List of Concepts

1. Phospholipids
2. Lipids
3. proteins
4. amino acids
5. nucleic acids
6. carbohydrates
7. Disaccharides
8. Steroids

List of Linking Phrases

1. are held together by
2. removes water to creates bonds within
3. adds water to breaks bonds within
4. are an example of
5. in the simplest form are

5. Construct a map from a list of concepts (C-map) Assignments Starting Lecture 8
 After the seventh lecture your assignments will consist in constructing your own concept map from a list of concepts. More details about this assignment will be discussed later.

Appendix C

MASTERS RESEARCH SURVEY

Dr. Gary Booth, Professor of Wildlife and Sciences at Brigham Young University, and his graduate student Jessica Rosenvall are performing a Masters thesis research project developed around ten biological concepts that should be taught in an introductory General Education biology class.

Please fill out the following information:

Your name (first and last) _____

University where you work _____

Your Department _____

Are you currently teaching? _____

If yes, which courses? _____

If not, what do you do at the University? _____

Your age _____

Please rank the following list by what you would consider to be the most important concepts to teach in **an introductory non-major General Education biology class**,

Rank the terms with:

1= most important concept to teach through 17= least important to teach.

Write the numbers on the lines preceding these concepts.

___ Evolution

___ Fundamentals of chemistry

___ The cell

___ Bioenergetics (cellular respiration)

___ The Central Dogma

___ Immunology

___ Viruses

___ Cell Division (mitosis and meiosis)

___ Mendelian Genetics

___ Metabolism and Enzymes

___ Photosynthesis

___ Plant Reproduction

___ Biological molecules (carbohydrates, proteins, lipids, nucleic acids)

___ Embryonic Development

___ History of Science

___ Scientific Reasoning/scientific method

___ Ecology

___ Please **put an X on this line** if you give your consent to use your answers in our study. We will not attach names to the study but will review the data as a whole.

Thank you for your help. You can put this survey in Dr. Booth's box in the PWS office, sent it to his office (419 WIDB) or **email it to us at gary_booth@byu.edu**

Sincerely,

Dr. Gary Booth

801-422-2458

gary_booth@byu.edu

Jessica Rosenvall Howell

801-995-0548

jrosenvall@gmail.com

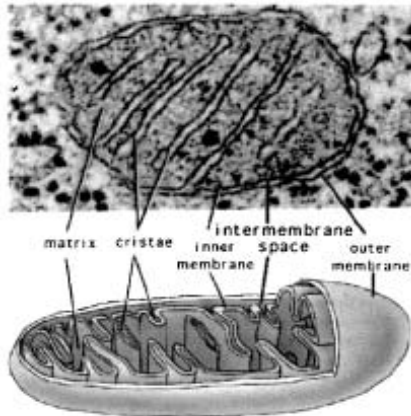
Appendix D

Name _____ Lab Section _____ TA: _____

Pre-Assessment of Biology Principles Freshman Academy Fall 2008

Preface: Remember, this is not a pass/fail examination. It is to help your professor, TAs, and peer mentors understand how much background you have in biology. Please write your answers as complete as you can without being wordy. Use only the space provided. I promise you that this assessment will help us to better understand your background and to help you learn biology. Enjoy!

1. **Identify** and **describe** the **function** of this organelle and **why it is important to all life**...WHAT happens in this organelle (include as much **detail** as possible)? What is the **difference in the 2 images**?



2. Explain the steps of the scientific method.

3. **Describe the three main bonding types.** For each bond type, give one **example** of where you may find this type of bond.

4. A DNA strand with the sequence C-G-A-T-T-G would be complementary to:

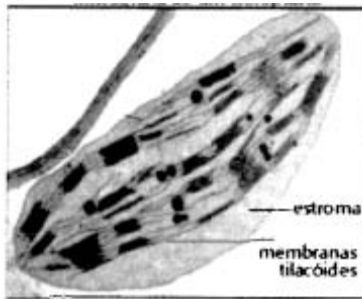
- a. C-G-A-T-T-A
- b. G-C-T-A-A-G
- c. T-A-G-C-C-T
- d. G-C-T-A-A-C

5. Use the following words in a meaningful paragraph: **Macromolecules, carbohydrates, proteins, DNA, lipids, and nucleic acids.**

6. Use the following words in a meaningful paragraph: **transcription, translation, DNA, RNA, and proteins.**

7. If a cell has a diploid number of 4 chromosomes, how many molecules of DNA are found in metaphase I of meiosis? **Show your work.**

8. What is this **organelle** and **why is it important to life?** Explain the **important process** that occurs here in **as much detail as possible.**



9. **Draw** a picture of the energy pyramid and **explain** why it is shaped the way it is.

10. In a paragraph, explain how the terms **evolution**, **natural selection**, and **species** relate.

12. Explain why enzymes are crucial to life and what exactly they do. If we didn't have enzymes, how would it affect the central dogma?

13. Describe five major biological issues facing humanity in the next 20 years.

Appendix E

RESEARCH PAPER COVER SHEET

(staple to front page of paper)

(No clips/plastic covers/plastic dillybobs-just an old fashioned staple.)

Section #: _____

TA: _____

Research Paper Grading Breakdown

Total Points: 100		Points Allotted
Format 5 points	<ul style="list-style-type: none"> • Overall neatness • Title • Margins/spacing (1" margins all around, Times New Roman font 12pt, double spaced) • Page numbers (6-8 pgs, name not included on page #'s) 	
Content 75 points	<ul style="list-style-type: none"> • Introduction (provides context for research; states thesis clearly; suggests organization of paper) • Appropriate Depth of research for a paper of this size and type • Topic Appropriate for course (STRONG Biological base) • Overall organization (clear, logical, effective sequence...do you follow a clear "plan of attack"?) • Coherence (ideas connect to each other clearly) • Paragraphing (Does each paragraph represent a clear subset of the thesis? Are the paragraph's neat, logically developing stages of the argument as a whole?) • Conclusion (Sums up the paper.) 	
Mechanics 10 points	<ul style="list-style-type: none"> • Spelling • Punctuation • Grammar • Effective Sentences 	
Use of Research Sources 10 points	<ul style="list-style-type: none"> • Accurate Citation (work cited page included & footnotes or endnotes) • No Plagiarism • Current Research: Evidence that write has searched thoroughly for available sources on topic. 	
Total Points (100)		

INSTRUCTIONS:

Write your name on the very **back page** of your research paper—make sure it appears nowhere else in the paper. (This is our impartial grading technique.) ©
(Minus 5 points for every late day. Sundays not included.)

DISCLAIMER: THE GRADER RESERVES THE RIGHT TO ADJUST THE PERCENTAGE POINTS IN DIFFERENT CATEGORIES IF DEEMED NECESSARY.