# BRIDGES TO SCIENCE: EFFECTS OF A SCIENCE OUTREACH PROGRAM ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF SCIENCE CONCEPTS

by

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# ABSTRACT

Many of my students are not prepared for postsecondary education because they feel unprepared in terms of experience and knowledge. This project focused on evaluating the impact the Bridges to Science outreach program had on students' understanding of science concepts. Students' level of understanding, attitude and motivation, and thoughts about science careers were considered as well. This project also investigated the impact on classroom teachers' professionalism, on the program staffs' pedagogy, and on my own professionalism and involvement with the program.

The Bridges to Science program offered by the University of Lethbridge targets urban high school students in biology, chemistry, and physics, and attempts to increase their interest in science by providing engaging lab activities implemented by graduate students. Students' understanding of science concepts was assessed by comparing nontreatment lab activities conducted by classroom teachers to treatment lab activities conducted by the outreach volunteers. Pre and postassessment data for nontreatment and treatment units were collected using concept questions, interviews with concept maps, and teacher observations.

Other forms of data collection such as surveys, journals and personal observations were used to assess students' level of understanding, attitude and motivation, knowledge about career options, teachers' professionalism, volunteers' pedagogy, and my own professionalism and involvement with the outreach program.

The results indicated a greater increase in students' understanding and level of understanding through the implementation of the program compared with classroom activities. Not only did students' motivation and attitude improve, but their knowledge of career options increased as well. Pedagogical improvement occurred with volunteers, but there was little impact on teachers' sense of professionalism. My involvement with Bridges to Science had a positive impact on my relationships, professionalism, and involvement with the program.

# INTRODUCTION AND BACKGROUND

For most of my teaching career, I have noticed a lack of continuity between high school science and postsecondary science. My students have expressed how apprehensive they are about pursuing science in college or university because they feel unprepared in terms of experience and knowledge. Many of my students have not experienced the caliber of science labs found in postsecondary institutions because public school funding is inadequate. Many school districts do not have the budget for expensive lab equipment, so students are unfamiliar with modern science techniques and technologies. I did not want my students to avoid postsecondary science opportunities because they felt intimidated or unprepared as a result of their K-12 education, so I started looking for a program that would help my students' transition out of high school.

I joined Bridges to Science (BTS), which is a new science outreach program offered by the University of Lethbridge (U of L), Alberta, Canada. Since its inception in the fall of 2009, the BTS program has provided southern Alberta high school students with the opportunity to participate in exciting, hands-on science lab activities in their own classrooms. The goals of the program are to improve students' understanding of science and technology, while building critical life skills such as problem-solving, communication, and team work. In addition to student activities, the BTS program provides professional scientists, educators, and graduate students with training opportunities that allow them to engage in science outreach with youth. The BTS program is attempting to build continuity between high school science and postsecondary science by exposing students to engaging, meaningful lab activities that will prepare them for future academic studies.

My project focus question was: What is the impact of the BTS program on high school students' understanding of science concepts? My project subquestions were as follows: what are the effects of the BTS program on the levels of understanding of concepts; what are the effects of the BTS program on students' attitude and motivation to learn; what are the effects of the BTS program on students' thoughts about their career options; what are the effects of the BTS program on the classroom teachers' sense of professionalism; what are the effects of the BTS program on the program staffs' pedagogy; what are the effects of evaluating the BTS program on my relationship with the people involved with the program, my professionalism, and my involvement with the program? For the purpose of this project, motivation refers to interest in learning.

Students participated in biology, chemistry, and physics labs implemented by their classroom teacher followed by labs directed by the BTS staff. The activities led by the teacher consisted of a photosynthesis and cellular respiration lab, a decomposing malachite lab, and measuring pulses in a spring lab. A yeast fermentation activity, enzymes lab, measuring citric acid lab, and investigating the speed of sound activity were implemented by the BTS staff.

This study was conducted at the Lethbridge Collegiate Institute (LCI) in Lethbridge, Alberta. This public school serves grades 9 through 12, and offers main stream as well as advanced placement science courses. My study included grade 11 students in mainstream biology, chemistry, and physics.

My project is significant to me because I want to provide the best learning opportunities and experiences for my students. Not only do I want my students to be excited about science, I want them to gain confidence in their knowledge and abilities, so they can make informed decisions about their futures. Using the results of this project, I hope to provide insightful feedback for BTS development and suggest methods for improving the science outreach program. Encouraging other educators, parents, and administrators to get involved or support the BTS program, will result in more students benefiting from the outreach experience.

Members of my validation team, Chris Orr, DDS., Jessica Firkus, and Jenn Scott served as editors and provided valuable insight during the development of my capstone. Elinor Pulcini, Ph.D. of Montana State University Center for Biofilm Engineering gave constructive feedback as my science reader. My Master of Science in Science Education (MSSE) cohort offered helpful advice and support throughout the writing process. Jewel Reuter, Ph.D. was my MSSE instructor and advisor. She provided support, guidance, and direction during the development of my project.

## CONCEPTUAL FRAMEWORK

Research shows that active-learning lab activities increase students' motivation to learn, enthusiasm about science, and overall understanding of science concepts (Freedman, 1997; Taraban, Box, Myers, Pollard, & Bowen, 2007). One method of introducing lab activities to a classroom is by utilizing a science outreach program. Science outreach programs have successfully operated in elementary, middle, and high schools (Shuda & Kearns-Sixsmith, 2009). These programs not only benefit the students, but also the teachers and outreach staff involved in the program's implementation.

An important student benefit of outreach programs is an increase in the understanding of science concepts. When involved with science outreach programs, students gain an increased understanding of science, including curriculum-based outcomes and general science knowledge (Bleicher, 1996; Knox, Moynihan, & Markowitz, 2003; Rodriguez, Jones, Pang, & Park, 2004). Findings from a study conducted by Beck, Morgan, Strand, and Woolsey (2006) show that when graduate science students from a university conduct hands-on lab activities with high school students, increases in science content knowledge in specific subject areas occur. Not only does basic knowledge of science concepts increase, but the level of knowledge increases as well.

A recent study of short-duration science outreach interventions in secondary schools found that students not only gained basic conceptual knowledge, but also higher level understanding of science concepts (Laursen, Liston, Thiry, & Graf, 2007). These learning gains included scientific skills such as critical thinking, problem solving, and laboratory skills. Under the guidance of science graduate students, high school students were able to make connections between the lab activities and everyday life. Understanding of concepts increases when students are motivated and excited about science (Freedman, 1997; Olesik, 2009).

Participation in science outreach programs can enhance attitude, engagement, and motivation of K-12 students (Luehmann, 2009; Luehmann & Markowitz, 2007; Smaill, 2010). According to Laursen et al. (2007), students concentrate on the activities at hand, ask questions, and express enthusiasm towards the outreach experience. All students are empowered by the outreach lab activities, regardless of low or high-achieving academic ability (Luehmann & Markowitz, 2007). Findings by Markowitz (2004) showed that outreach opportunities motivated grades 8 -12 students to excel in their everyday science classes, which lead to increased student achievement. Students' beliefs about who can be a scientist and erroneous stereotypes are alleviated by interactions with outreach staff (Shuda & Kearns-Sixsmith, 2009). An increased curiosity and excitement about science can translate into an interest in science as a career (Laursen et al., 2007).

Science outreach spawns discussions among staff, students, and teachers regarding careers in science and helps students understand the steps required to pursue those careers (Markowitz, 2004; Shuda & Kearns-Sixsmith, 2009; Trautmann, Avery, Krasny & Cunningham, 2002). Students are often uninformed about science careers and outreach staff can answer their questions or provide ways students can find out the information they require. Not only can outreach staff share career ideas with students, but they can also serve as role models for pursuing science at postsecondary schools (Habash & Suurtamm, 2009; Olesik, 2009).

Classroom teachers benefit from interacting with the science outreach staff and students. Educators not only learn new pedagogical methods from program staff, such as inquiry-based teaching, but they learn the importance of connecting science with real-world situations (Lott, 2003; Tan et al., 2010). Collegial interactions between staff and teachers develop a community of professional partnerships where the exchange of ideas and information can flow (Olesik, 2009; Krasny, 2005). Laursen et al. (2007) explained how teachers can benefit from taking a break from their everyday classroom routines and focus on learning together with their students. Of the 16 teachers involved in the study, half reported a break from routine as beneficial for student learning because the science outreach staff presented the curriculum in a novel way that increased student interest (Laursen et al., 2007). Partnerships between teachers and outreach programs serve to validate teachers' role in science education. Teachers feel the program lends credibility to their classroom teaching because of their collaborative work with scientists and post-secondary institutions (Luehmann & Markowitz, 2007). In addition to benefiting educators, science programs also have positive impacts on outreach staff.

The outreach staff can gain skills in communication, teaching, organization, and management from participating in outreach programs. According to Laursen et al. (2007), of the 24 graduate student outreach staff involved in the study, 83% reported gains in teaching, communication, and management. Communicating complicated science ideas requires outreach staff to use multiple-teaching strategies to meet the learning needs of all students (Gutstein, Smith, & Manahan, 2006). Most staff members do not have a background in teaching, so they collaborate with the classroom teacher to develop a personal pedagogy that includes lesson planning and classroom management (Gutstein et al.; Miranda & Hermann, 2010). The outreach members gain an understanding of what the teaching profession entails, such as the difficulties faced by teachers and the diverse learning needs of students. Some members have enjoyed teaching so much that they have altered their career paths to become more heavily involved in outreach programs, or to become educators themselves (Moskal et al., 2007; Gutstein et al.; Laursen et al., 2007; Olesik, 2009). Not only do staff members serve as effective role models for students, but they are also advocates for their respective universities or colleges (Moskal et al., 2007; Jeffers, Safferman & Safferman, 2004). Teachers and outreach staff form collegial relationships in which they discuss lesson successes and failures, share their different levels of expertise and develop a professional community of science educators.

Evaluating a science outreach program increases professionalism as new relationships are forged with outreach staff and other teachers (Laursen et al., 2007). Involvement with an outreach program results in a deeper understanding of science concepts and the development of new methods for effectively teaching students (Olesik, 2009). As described by Laursen et al., interest and willingness to participate in science outreach intensifies as involvement with the program increases.

My review of the literature addressed how science outreach impacts students and the professionals involved with the program. Students become motivated to learn, enhance their understanding of science concepts, and learn about careers in science as a result of these programs. Outreach staff and teachers develop professional skills and form collegial relationships that ultimately improve student learning.

# METHODOLOGY

## Project Treatment

In order to evaluate the impact the BTS program had on students' understanding of science concepts, I collected data from nontreatment and treatment units for comparison. The nontreatment units consisted of lab activities conducted by the classroom teacher and the treatment units involved lab activities conducted by the BTS program staff. I compared these nontreatment and treatment units because the activities were similar in difficulty for the students.

The nontreatment units consisted of lab activities facilitated by the classroom teacher in the subject areas of biology, chemistry, and physics. Labs were frequently implemented as a regular part of the teachers' instructional strategies, and were carried out under the direction of the classroom teacher. The activities were conducted in classrooms, using the lab equipment available at the school. The nontreatment labs for biology, chemistry, and physics are found in Appendices A, B, and C, respectively. A photosynthesis and cellular respiration activity was the nontreatment unit for biology, a malachite decomposition activity was the nontreatment unit for chemistry, and a wave properties activity was the nontreatment unit for physics.

The teacher began the photosynthesis and cellular respiration lab by distributing a copy of the lab to each student and having them silently read through the purpose and procedure. After the students had read the lab independently, the teacher assessed the class for understanding by asking clarifying questions such as, "Why do you cut the stems off under water?"  The students were then placed into groups of three to five to carry out the activity under the observation of the teacher.  The lab was divided up into two class periods because the results required 24 hours to appear.  The teacher circulated through the class responding to questions and students requiring help.  After 24 hours, the students recorded their results and shared them in a class discussion directed by the teacher.  Unless a student initiated a conversation, there was no formal discussion by the teacher involving science careers or postsecondary education.

The teacher introduced the decomposing malachite lab by reviewing stoichiometry and the law of conservation of mass.  A copy of the lab was distributed to each student and the teacher read the procedure as the class followed along.  Safety procedures were discussed and modeled, such as eye protection.  The teacher reviewed each piece of equipment used in the activity and demonstrated the procedure for the class.  Students were assessed for understanding using questions posed by the teacher such as, "Why are the large lumps of malachite broken up?"  The students were divided into groups of three or four to carry out the activity.  During the lab, the teacher circulated through the classroom helping students and enforcing safety procedures.  When students finished the lab, the entire class discussed and compared results.  No formal discussion involving science careers or postsecondary education occurred during the activity.

The teacher began the pulses in a spring activity by dividing the students into groups of 3 or 4 and distributing a copy of the lab to every group.  Within their groups, students read through part I and II of the procedure and the teacher checked the class for understanding by asking questions such as, "What is the difference between a transverse pulse and longitudinal pulse?" The students carried out Part I of the procedure and then the class reconvened to discuss the results. Then Part II was carried out by the students followed by a class discussion of the results. The teacher observed the class during the activity to offer guidance and suggestions. No formal discussion involving postsecondary education or science careers occurred during the activity.

The treatment units for biology, chemistry, and physics involved lab activities conducted by the BTS program staff instead of classroom teachers. In pairs, graduate students from the U of L implemented lab activities with the students while the classroom teacher observed and helped with classroom management.

Before BTS staff entered the classroom, they underwent a three hour training session facilitated by a faculty member from the U of L. The BTS training session lesson plan is found in Appendix D. The training session was based on the *Let's Talk Science* outreach program volunteer manual (Let's Talk Science, 2006) but tailored to meet the needs of high school students. The BTS volunteers participated in seven exercises that addressed topics such as why science outreach is important, how students learn, how to introduce yourself to the class, how to lead group discussions, and how to describe your career. At the end of the workshop, volunteers discussed what they learned and asked any remaining questions.

The BTS activities for biology, chemistry, and physics are found in Appendices E, F, and G, respectively. Students participated in two treatment biology labs, one pertaining to yeast fermentation, and the other a catalase enzyme activity. The chemistry lab allowed investigation of the citric acid level in chewing gum, and the physics lab helped students to explore sound waves.

BTS volunteers traveled in pairs to LCI during class time to conduct the activities. They began the biology fermentation lab by introducing themselves to the class and talking about their research and careers as scientists. Students were asked if they had any questions about the volunteer's research, postsecondary education, or careers in science. A copy of the lab was distributed to each student; the volunteers described the purpose and procedure to the class. The students conducted Experiments 1 and 2 under the supervision of the volunteers and classroom teacher, and completed the data tables provided. When the students completed the activities, they handed in their results to the program staff. A group discussion of the results and any remaining questions about the lab or the BTS staff concluded the program experience.

The volunteers began the biology catalase activity by introducing themselves and discussing their research at the university. They placed the students into groups of three, distributed a copy of the lab to each group, and had the students read through the two procedures independently. After reading the procedure, the volunteers answered questions about the lab. While the students completed both parts of the activity, the BTS staff and classroom teacher circulated through the room helping the students and answering questions. At the conclusion of the activity, the volunteers lead a class discussion using the thought questions associated with the lab. Students were also invited to ask questions about the volunteers schooling, interests, and career aspirations.

The chemistry BTS activity began with the volunteers introducing themselves and discussing their career plans and education. The lab was introduced with a discussion about chewing gum and how the amount of citric acid in gum might be determined. Each student received a copy of the lab activity and followed along as the volunteers read through the procedure answering any student questions. Students were placed into groups of four to complete the titration and to determine the amount of citric acid in their gum sample. The classroom teacher and BTS staff supervised the students to ensure safety and to offer assistance. Class results were recorded on a whiteboard, so students could compare the amount of citric acid in each gum sample. BTS volunteers concluded the program by asking if the students had any questions regarding the lab or their careers.

The program staff began the speed of sound physics lab activity by introducing themselves and discussing their field of science and career aspirations. Lab materials and technologies unavailable at the school, such as oscilloscopes and resonance tubes, were brought into the classroom for the activity. Each student received a copy of the lab including diagrams on how to set up the equipment. The volunteers demonstrated to the class how the equipment is used while describing the procedure. In groups of five, the students performed the activity. The classroom teacher and BTS staff offered a lot of assistance because the students were inexperienced with the equipment and the calibrations were difficult. The activity commenced with a class discussion centered on the thought questions found at the end of the lab. Students were invited to ask questions about the lab or about the volunteers.

Every participating student experienced the BTS program once, with the exception of the biology class. Two lab activities were developed by the program for biology, so I exposed this class to two treatment units. The purpose of using two treatment units was to determine the impact of a more sustained experience.

The BTS program will attempt to increase students' understanding of science concepts with its exciting new program that attempts to motivate students to learn. The program is taught by young, enthusiastic university graduate students who will have more in common with high school students compared with their classroom teachers because the volunteers have more recently graduated from high school. New materials and technologies are integrated into the labs, with the goals of increasing student interest and engagement. The strategies attempt to help increase students' enthusiasm about learning science concepts by providing them excellent laboratory opportunities.

## Data Collection Instruments

Lethbridge is a prairie city of 87, 882 people and is located in the southern part of Alberta, in Western Canada. The city is close to the Canadian Rockies and an hour north of the Montana, USA border. Originally built around agriculture and coal mining, Lethbridge now has a diverse range of industries and has two postsecondary institutions, including the U of L.

Opening in 1957 as a junior college, the U of L is now home to approximately 8,000 students and offers undergraduate and graduate programs in many disciplines. The BTS program consists of 31 graduate students all of whom are pursuing science master's degrees in disciplines such as physics, chemistry, biochemistry, biology, and kinesiology.

The majority of volunteers are Caucasian, between the ages of 22 and 25 years old, and from Lethbridge. Two volunteers are not originally from Canada, one is from India and the other from France, and speak English as a second language. Of the program staff, 19 are female and 12 are male. For most volunteers, this was their first year with the BTS program. The high school where the BTS program is conducted is 6 km from the U of L.

The Lethbridge Collegiate Institute (LCI) is a public, urban high school serving grades 9 through 12. LCI is the largest of the three high schools in the city and offers a wide range of nonacademic and academic courses, catering to students' varied ability levels and interests. Most of the 894 students are from middle-class families residing in south Lethbridge, Alberta. My project sample included 91 grade 11 students from three separate classes of biology, chemistry, and physics. The majority of the students were Caucasian, English-speaking 16 year olds. Male students represented 55% and females represented 45% of the students in my sample. The participating students were in an academic stream, which leads to postsecondary school opportunities such as college or university. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

I implemented various collection methods to accumulate data for each of my project questions. Data were gathered from both nontreatment and treatment units to allow for comparison. The collection instruments used are included in the data triangulation matrix in Table 1. I investigated my project questions with a broad perspective by using a variety of data collection instruments, which included multiple participant viewpoints. Triangulating my data provided a comprehensive assessment regarding the effects of the treatment and reduced the likelihood of misinterpreting a single source of data.

Table 1
*Triangulation Matrix*

| Research Questions | Data Source 1 | 2 | 3 |
|---|---|---|---|
| Increases understanding | Pre and Postunit Assessment with Concept Questions | Pre and Postunit Interviews with Concept Map | Teacher Observations |
| Students'attitude and motivation | Pre and Postunit Interviews | Pre and Postunit Surveys | Teacher Observations |
| Level of understanding | Pre and Postunit Assessment with Levels of Questions | Pre and Postunit Interviews | Teacher Observations |
| Career options | Pre and Postunit Interviews | Pre and Postunit Surveys | Teacher Observations |
| Teachers' professionalism | Pre and Postunit Interviews | Pre and Postunit Surveys | Personal Observations |
| Program staffs' pedagogy | Pre and Postunit Interviews | Pre and Postunit Surveys | Personal Observations |
| My relationships, professionalism and involvement | Personal Journal | Pre and Postunit Personal Surveys | Teacher Observations |

Implementation and data collection for each unit took a total of 5 weeks, with the duration of the study equaling 10 weeks. The project timeline is found in Appendix H.

To assess the impact the BTS program had on students' understanding of science concepts, I conducted interviews incorporating concept maps (Appendix I), developed pre and postunit concept questions (Appendix J), and used teacher observations (Appendix K). I compared the results of the nontreatment and treatment unit data by looking at the percent change in student understanding.

Students were interviewed individually during class time; before and after each unit. I selected 10 students from each class to participate: 3 low, 4 average, and 3 high-achieving students. All interviews throughout the study were conducted with the same 10 students. Students were provided key terms to construct their concept map and an overall concept question to answer using their map.

The following concept map questions were used in nontreatment and treatment biology units: Describe how photosynthesis and cellular respiration are related, explain the process of fermentation, and describe how enzymes react under various conditions. The chemistry concept questions were as follows: Explain why reactions are stoichiometric, and explain how the concentration of citric acid can be determined using titration. The physics concept questions were as follows: Describe the mechanics by which pulses move through a spring, and discuss string properties in an open and closed column. A rubric (Appendix L) created by Novak and Gowin (1984) was used to assess the student's oral explanation and concept map.

Pre and postunit concept questions were distributed in class to every student. They were given as much time as needed to complete the six question handout. To assess the impact the lab had on students' understanding, their responses were evaluated using a rubric (Appendix M) based on Bloom's taxonomy: knowledge and comprehension, application and analysis, and synthesis, and evaluation.

Additionally, teacher observations were used to assess the students' understanding of concepts. Using a Likert scale for reference, classroom teachers observed the same 10 students throughout the study and recorded comments regarding student understanding during the activities.

Conducting interviews incorporating concept maps and concept questions not only allowed students to express what they learned during the activities, but allowed me to assess what concepts the students understood. Teacher observations provided another perspective on student understanding. Together, these three sources of data were used to evaluate and compare the impact of a classroom lab activity with a BTS lab activity.

To assess the level of understanding of concepts among students, I implemented the following data collection instruments: pre and postunit interviews (Appendix I), pre and postunit assessment using Bloom's taxonomic question levels (Appendix J), and teacher observations (Appendix K).

In order to evaluate students' level of understanding, individual interviews during class time were conducted prior to and after the completion of nontreatment and treatment units. The six concept questions mentioned previously were evaluated using the rubric in Appendix M and focused on the level of understanding the students attained. During the activities, teachers observed and commented on what level they felt students understood concepts. The use of student, teacher, and my own perceptions provided a well rounded examination of the level of student understanding.

For assessing the attitude and motivation of students, and their thoughts on career options, I used pre and postunit interviews (Appendix I), teacher observations (Appendix K), and student surveys (Appendix N) to collect data.

I individually interviewed the group of 10 students before and after the lab activities to gauge attitude and hear their ideas regarding science careers. Teachers made observations on students' demeanor and whether they expressed interest or asked questions about careers. Surveys were given to all students upon completion of the activities to self-assess their own attitude, motivation, and knowledge of careers. Students were asked to complete the survey independently during class and to provide as much feedback as possible to the open-ended questions. The student survey was important to my project because it allowed me to gather data on students' thoughts and feelings and compare them to observations made by the teacher.

Teachers' professionalism was analyzed using pre and postunit interviews (Appendix O) and surveys (Appendix P). I interviewed the classroom teacher prior to and immediately after the activities. Three teachers in total were interviewed, one for each class of biology, chemistry, and physics. The teacher surveys were distributed following the interview and collected at the end of the school day. I also made personal observations using prompts (Appendix Q) during the activities. It was important to have the teacher's and my own perspective when gauging professionalism because we may have different ideas of what it means to be a professional.

The programs staffs' pedagogy was analyzed using interviews (Appendix R) and surveys (Appendix S). I interviewed both volunteers the day before and immediately after the lab activities to obtain feedback on their teaching strategies. After interviewing the BTS staff, I distributed the surveys and collected them the following day. During the lab activities, I made personal observations (Appendix Q) using prompts and took notes regarding pedagogy. It was important to gather data from the volunteers and from my own observations regarding pedagogy because our teaching strategies varied. The volunteers are not professional teachers and, therefore, did not recognize some of the teaching methods they used in the classroom.

The data collection instruments I used to assess my relationships, professionalism, and involvement were teacher observations (Appendix K), personal journals (Appendix T), and personal surveys (Appendix U). Classroom teachers observed my interactions with BTS staff during the lab activities and commented on how my involvement in the program influenced my sense of professionalism. After each activity, I made reflections using the following prompts: Describe your professional relationship with the classroom teachers, describe your professional relationship with the BTS program staff, describe your sense of professionalism, and describe your level of involvement with the BTS program. I also used a personal survey before and after each activity to record my feelings and observations. Combining peer evaluation with self-reflection provided a better understanding of how connected I am with the BTS program.

The data gathered from this study were qualitative in nature, but I transformed some into quantitative data using various analytic methods. The combination of qualitative and quantitative data provided a more accurate delineation of the treatment than relying on one type of data analysis. Qualitative data were analyzed to reveal trends and patterns, whereas, quantitative data were evaluated to determine information such as the mean.

Qualitative data were gathered from interview questions, personal observations, and journal prompts.  Investigating small groups of individuals allowed me to identify commonalities and outliers that I interpreted as important to this study.

Quantitative data were generated from concept questions and concept maps using scoring rubrics, and surveys and observations using Likert scales.  Descriptive statistics were employed to describe and present the data in terms of summary frequency such as the mean.

Data were gathered from nontreatment and treatment units to assess the impact the BTS intervention had on students and individuals involved with the program.  Data from the nontreatment units established a baseline by which the treatment units were compared.  Using pre and postassessments, I compared the percent change in nontreatment and treatment units regarding student learning and level of understanding. Qualitative data regarding attitude and motivation, knowledge of career options, teachers' professionalism, program staffs' pedagogy and my professionalism, were used to compare the nontreatment and treatment units directly.  Student data were recorded to evaluate the impact the intervention had on individuals as well as the impact the intervention had on the entire class.

# DATA AND ANALYSIS

Data from nontreatment and treatment units were compared in order to determine the effects of the BTS program on student learning and my subquestions. To assess the impact of the program on students' understanding of science concepts, I triangulated the data by implementing three collection instruments. The use of pre and postassessments enabled me to compare the percent change in student understanding of concepts for the nontreatment and treatment units. The data are displayed in Table 2.

Table 2
*Comparison of Pre and Postunit Understanding of Science Concept Questions (Physics N = 31, Chemistry N = 28, Biology N = 32)*

| Description of Data | Nontreatment (%) | | | Treatment (%) | | |
|---|---|---|---|---|---|---|
| | Pre | Post | Change | Pre | Post | Change |
| Physics | 45.83 | 48.66 | 6.17 | 13.99 | 42.20 | 201.64 |
| Chemistry | 44.08 | 68.50 | 55.40 | 30.33 | 51.52 | 69.86 |
| Biology | 59.11 | 69.02 | 16.77 | | | |
| Biology (Fermentation) | | | | 50.00 | 54.17 | 8.34 |
| Biology (Enzyme) | | | | 58.33 | 66.11 | 13.34 |

The results show a greater increased understanding of concepts by students in the physics and chemistry treatment units compared to the nontreatment units. Although an improvement was seen in the biology treatment labs, the students' understanding was greater with the nontreatment lab. Students were exposed to photosynthesis and cellular respiration in younger grades and are more familiar with the topic compared to the treatment units; this may account for the higher nontreatment scores. The second biology treatment lab results exceeded those of the first treatment indicating that students may be getting use to the level of difficulty of the labs.

To gain insight into how the nontreatment and treatment units affected students of varying academic levels, I conducted interviews. Table 3 shows the percent change observed in concept maps and questions based on academic level.

Table 3
*Percent Change in Pre and Postunit Student Concept Maps and Questions According to Academic Level (Physics N = 31, Chemistry N = 28, Biology N = 32)*

| Description of Data | | Nontreatment (%) Change | Treatment (%) Change |
|---|---|---|---|
| Physics | Low | 73.20 | 152.60 |
| | Middle | 29.08 | 46.81 |
| | High | 1.65 | 25.00 |
| Chemistry | Low | 179.17 | 585.52 |
| | Middle | 31.67 | 135.33 |
| | High | 10.08 | 19.24 |
| Biology | Low | 50.00 | |
| | Middle | 23.35 | |
| | High | 6.37 | |
| Biology (Fermentation) | Low | | 60.12 |
| | Middle | | 18.57 |
| | High | | 11.36 |
| Biology (Enzyme) | Low | | 188.28 |
| | Middle | | 22.22 |
| | High | | 11.92 |

When the units were compared the majority of scores were higher with the treatment labs, the exception being the middle-academic students in the biology treatment units; the results for this group were slightly lower. During the interviews, these students struggled with connecting the overall ideas of the lab; their concept maps showed little branching and lacked descriptive explanations. For example, during an interview a biology student said, “I know the words, but I don’t know why they go together.”

The greatest impact occurred with low-academic students. During the preunit interview, these students had difficulty placing most of the words on their maps; they were not familiar with the vocabulary. After the BTS lab, most students appropriately placed all words on their maps and included descriptions with some branches. Some students included formulas and pictures when describing the relationships between the terms. A physics student demonstrated that he understood the connection between frequency and velocity by explaining that, “to figure out wavelength, you have to divide the velocity by the frequency, and the velocity will change depending on what the wave is moving through.”

There was a smaller change with high-academic students. Their nontreatment assessments were accurate and complete; they achieved the basic requirements of the concept maps, but they did not go beyond the basics. A few treatment assessments showed the incorporation of new terminology and improvements in explanations. For example, a chemistry student explained the difference between the endpoint and equivalence point using examples from the BTS lab.

The classroom teachers observed the students during the lab activities to assess their understanding. The results are in Figure 1.

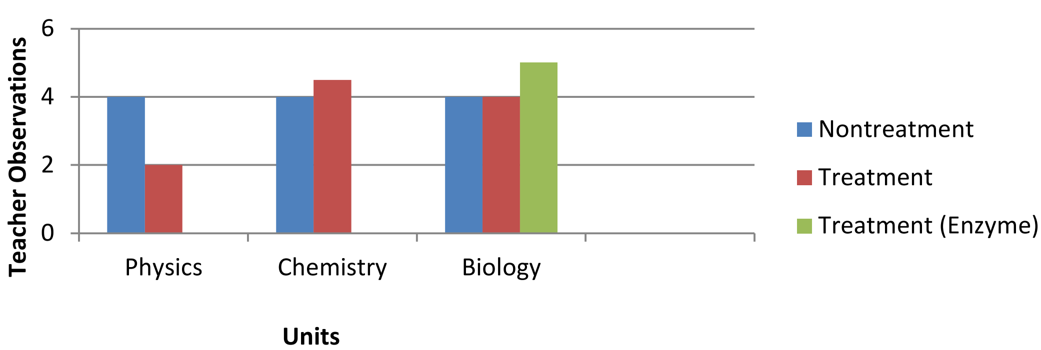


*Figure 1*. Teacher response to observation prompt of students’ understanding of concepts, (*N* = 3).
*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

The physics teacher slightly disagreed that students understood the BTS lab concepts and procedures. He wrote, “The students had difficulty with understanding wave forms on oscilloscopes.” There were many problems associated with the BTS physics lab. Some of the equipment stopped working part way through the lab and the ambient noise in the classroom interfered with the oscilloscopes causing inaccurate results. The teacher’s perception is contrary to the other data collected; however, student learning may have increased to a greater extent if the lab activity had gone as planned.

The chemistry teacher agreed that the students’ understanding improved and this is supported by the data collected from the student assessment results and interviews. According to the teacher, “The volunteers did an excellent job explaining and demonstrating the lab, and correcting the students’ techniques.”

The observations made by the biology teacher upheld the data collected from student assessments and interviews. She wrote, “This class is below average, so they needed some additional instruction as they worked through the lab.” Although student performance was greater with the nontreatment lab, students’ understanding did increase with the BTS activity.

The results from the three collection instruments suggest BTS labs were more effective overall in increasing student understanding in the short and long term than labs implemented by the classroom teacher. The most dramatic change observed in the treatment lab was the low-achieving students’ ability to make connections among the terms during the interviews.

In addition to determining if BTS labs increased overall conceptual knowledge, I was interested in knowing if students' attitude and motivation to learn science was greater with the treatment units compared with nontreatment units. Data were gathered and analyzed through the use of pre and postunit student surveys, interviews, and teacher observations.

Students were surveyed in order to determine what factors influenced their attitude and motivation in science class. Table 4 shows the average results of questions 1 through 7 on the student survey for nontreatment and treatment units.

Table 4
*Comparison of Postunit Student Survey Questions on Attitude and Motivation (Physics N = 31, Chemistry N = 28, Biology N = 32)*

| Description of Data | Nontreatment | Treatment | Change (%) |
|---|---|---|---|
| Physics | 3.61 | 3.81 | 5.54 |
| Chemistry | 4.05 | 4.07 | 0.49 |
| Biology | 3.39 | | |
| Biology (Fermentation) | | 3.59 | 5.90 |
| Biology (Enzyme) | | 3.64 | 7.37 |

*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

The survey results show attitude and motivation increased to a greater extent in all treatment units compared with the nontreatment units. Many students commented on how the BTS labs increased their motivation to learn because they were more interesting, hands-on, and related to the real world. One student wrote, "It was cool to see how a titration is actually performed and to use scientific instruments that we've never used before." A few students were motivated by the graduate student volunteers and wrote, "I liked their young age. I could relate to some things they said."

The second biology treatment activity showed an even greater increase in attitude and motivation. Many students wrote how much "fun" they had during the lab because it was "interactive, unlike copying and writing notes." When responding to the question regarding what motivates them specifically about the enzyme treatment lab, some students wrote how the lab applied to real life. For example, one student explained, "The lab motivated me because I got to see what I have learned applied in real life scenarios."

Three main themes emerged from the pre and postunit interviews with students which supported the data previously discussed. Students' motivation was enhanced by the hands-on and interactive nature of the BTS labs, by using equipment not available at the school, and because the activities had real world or career applications.

The majority of students' explained how the treatment labs were more interactive than the nontreatment labs. The BTS labs were designed to have all students engaged in hands-on learning. A physics student expressed, "I liked the university lab because everyone was involved and we actually got to perform the tasks." A student from the biology class said, "The labs let us have hands-on experience for things we only discuss in class."

With declining budgets, many schools cannot afford expensive lab equipment and supplies. Many students mentioned that they were excited to use new and expensive equipment not available at their school. The physics equipment for the BTS lab exceeded $30,000 and this interested a student who said, "It was cool to use really expensive stuff. I'd like to use it again once I understand how it works better." This opinion was expressed in the chemistry and biology labs. Students were excited to perform an actual titration with "real lab equipment."

The students explained how classroom lab activities often lacked a real-life connection, whereas the program volunteers made a point of explaining how the BTS labs related to the world. A physics student explained, "They apply the concepts to real life. It's not just an experiment." Some students were excited by the treatment labs because the volunteers discussed how the activity related to careers. A chemistry student said, "I liked hearing about the real life jobs we can do with the concepts we learned."

One student was motivated by the BTS labs because he felt, "When experts come in to explain concepts, I learn them better and enjoy it more." It was interesting to hear that the student did not see his teacher as an expert or a scientist, although the BTS volunteer and the classroom teacher had similar academic backgrounds. When I explained this to the student during the interview, he was very surprised to learn his teacher had a chemistry degree in addition to an education degree.

The data collected from the teachers' observations closely resembled the other data for this subquestion concerning the students' attitudes and motivation. The results are in Figure 2.

The physics teacher observed an increase in student motivation during the treatment lab and described how, "The students like to use the equipment and try the activity." The chemistry teacher felt the students showed the same level of enthusiasm, although the student survey data showed a slight increase during the treatment lab. She wrote, "The students are focused and appear comfortable asking questions of the U of L

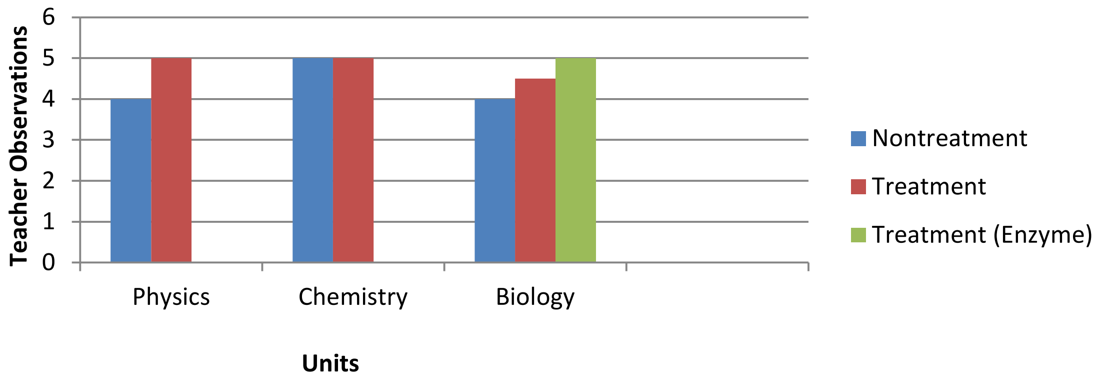


*Figure 2*. Teacher response to observation prompt regarding students' attitude and motivation, ($N$ = 3).
*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

students during the lab activity." The biology teacher observed a steady increase in motivation from the nontreatment to treatment labs. She observed how the students' "positive attitudes" elevated from the first to second treatments. She felt the students became increasing comfortable with the program volunteers and that it contributed to increased motivation.

For each unit, students' attitude and motivation increased to a greater extend with the BTS labs compared with the classroom labs. Not only did motivation increase with one treatment exposure, but both students and the teacher felt it increased even greater with the second exposure.

The effects of the BTS labs on students' level of understanding were also considered. Teacher observations, pre and postunit student surveys, and assessment questions based on Bloom's Taxonomy were used to collect nontreatment and treatment data to answer this subquestion. Pre and postassessment data for the different cognitive levels were separated into three levels ranging from comprehension to evaluation. The results are shown in Table 5.

Table 5
*Comparison of Pre and Postassessment for the Different Cognitive Levels (Physics N = 31, Chemistry N = 28, Biology N = 32)*

| Description of Data | | Nontreatment (%) | | | Treatment (%) | | |
|---|---|---|---|---|---|---|---|
| | | Pre | Post | %Change | Pre | Post | %Change |
| Physics | Level 1 | 53.9 | 58.9 | 9.28 | 10.71 | 29.84 | 178.62 |
| | Level 2 | 46.9 | 50.0 | 6.61 | 22.32 | 58.06 | 160.13 |
| | Level 3 | 37.1 | 39.1 | 5.39 | 8.93 | 38.71 | 333.48 |
| Chemistry | Level 1 | 77.08 | 91.30 | 18.45 | 39.77 | 52.27 | 31.43 |
| | Level 2 | 36.46 | 67.39 | 84.83 | 37.50 | 69.32 | 84.85 |
| | Level 3 | 19.79 | 46.74 | 136.18 | 13.64 | 63.64 | 366.57 |
| Biology | Level 1 | 79.67 | 91.13 | 14.38 | | | |
| | Level 2 | 63.28 | 66.13 | 4.50 | | | |
| | Level 3 | 36.72 | 46.77 | 27.37 | | | |
| Biology (Fermentation) | Level 1 | | | | 47.58 | 64.29 | 35.12 |
| | Level 2 | | | | 41.13 | 50.89 | 23.73 |
| | Level 3 | | | | 36.29 | 47.32 | 30.39 |
| Biology (Enzyme) | Level 1 | | | | 70.54 | 77.50 | 9.87 |
| | Level 2 | | | | 55.36 | 62.50 | 12.90 |
| | Level 3 | | | | 47.32 | 58.33 | 23.27 |

*Note*. Level 1 = Knowledge and Comprehension, Level 2 = Application and Analysis, Level 3 = Synthesis and Evaluation.

Overall, the percent change was higher for the treatment units compared with the nontreatment units, with the greatest impact occurring at the highest cognitive level. The only discrepancy occurred with the second biology treatment lab, where the first and third level data were comparatively lower. There was a sense of apathy with the class during this assessment which both the classroom teacher and I noticed. This may have been the result of students returning from a fall break and not focused on their work. Their questions appeared rushed and incomplete.

In addition to assessment questions, I analyzed data from student interviews. The majority of students in all subject areas agreed that treatment labs deepened their understanding of concepts more than class labs. The students attributed their deeper understanding to the hands-on and visual components of the labs. This was expressed by one interviewee, “Seeing a concept take place and applying the knowledge made it much easier to get a deeper understanding.” Only one student said the BTS labs, “did not really help me understand the concepts better,” compared to the classroom lab. She preferred how the classroom teacher explained concepts compared to the volunteers. I asked a student if there was anything else she wanted to add and she said, “The labs we did were fun and enjoyable and I would like to do a similar thing in grade 12 to help me learn science concepts at a deeper level.” This student was already interested in experiencing more BTS labs in the future.

Teachers made observations regarding the level of learning achieved by students during the nontreatment and treatment labs. The results of question 2 from the teacher observation prompts are shown in Figure 3.

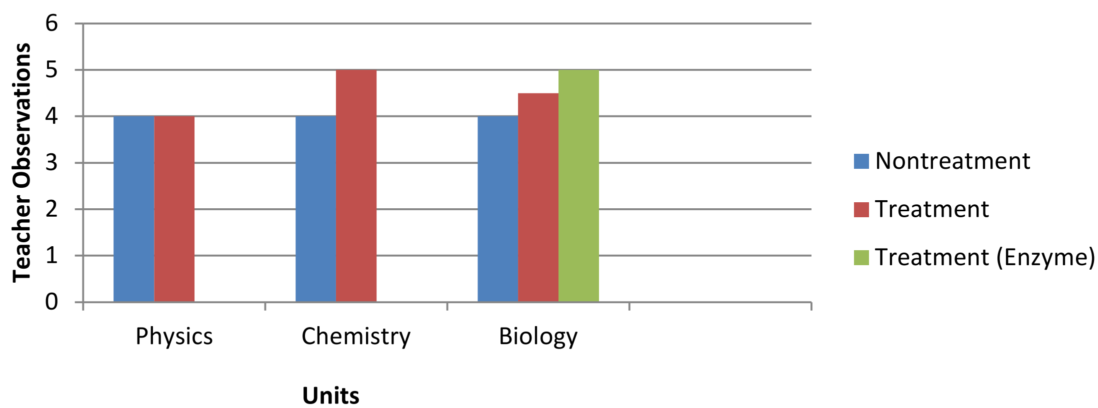


*Figure 3*. Teacher response to observation prompt regarding students’ levels of understanding, ($N$ = 3).
*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

The physics teacher did not perceive a difference in the depth of student learning between the class and the BTS lab. This could be a result of the problems associated with the BTS lab as previously described. Although he did not observe a change in student learning, analysis of the other sources of data suggest otherwise.

The results of the chemistry teacher's response aligned with the other analyzed data. She strongly agreed that the BTS lab deepened student understanding and wrote, "Students seem to appreciate being able to do a titration rather than just watch one; their understanding has greatly increased."

Results from the biology teacher's observations showed an increase in the level of students' understanding. Student interviews supported her observations as did the data from the first treatment unit; however, the results from the second treatment unit conflict with the chemistry teacher's observations. The students may have been engaged by the lab, but not taken the assessment questions seriously and this could account for the discrepant data.

The findings indicate that BTS labs had a greater impact on the depth of student understanding compared with class labs. Gains were made at all levels, but the most dramatic change occurred at the higher cognitive levels.

Data were obtained and analyzed through the use of interviews, surveys, and teacher observations to help answer the subquestion regarding students' knowledge about career options. Interviews and surveys were given before and after the completion of nontreatment and treatment units.

Surveys were used in order to determine how the class and BTS labs influenced students' awareness of science-related careers. Table 6 shows the average results of questions 1 through 8. Data indicate the treatment labs were the most influential in increasing students' career option knowledge.

Table 6
*Comparison of Postunit Thoughts about Career Options (Physics N = 31, Chemistry N = 28, Biology N = 32)*

| Description of Data | Nontreatment (%) | Treatment (%) | Change (%) |
|---|---|---|---|
| Physics | 67.0 | 69.6 | 3.88 |
| Chemistry | 72.2 | 79.0 | 9.42 |
| Biology | 58.8 | | |
| Biology (Fermentation) | | 64.6 | 9.86 |
| Biology (Enzyme) | | 78.8 | 34.01 |

Many physics students commented that they were already aware of many science careers; however, one student wrote, "We were explicitly told what careers we could have involving wave physics." Students became more informed about specific careers that were directly related to the BTS lab activities and this did not occur with the class labs.

Some chemistry students became interested in science careers after hearing about the volunteers' research. One volunteer was pursuing a graduate degree, so she could work for a cosmetic company. Many students mentioned this and one wrote, "I like makeup too, so I can do work just like the female instructor- whoa!" Other students were excited to hear about career options that were unfamiliar to them such as fluorine chemistry and pyrotechnics, while others were motivated by the volunteers themselves. One student explained, "I liked seeing how excited the volunteers got when they talked about their research."

A large increase occurred between the first and second treatment units in the biology students' knowledge about career options. The effects of the first treatment were comparable to the percent change in the other subject units, whereas the second treatment unit showed a large increase in career awareness. Referring to the second BTS lab, one student wrote, "I didn't know of many careers before and I learned about some from the volunteers." More students wrote comments about learning new careers in the second treatment compared with the first.

Findings from student interviews reinforced the survey data that BTS labs contributed to students' knowledge about careers more than class labs. The treatment results revealed four major themes: Students were able to identify more science careers, volunteers were included as sources for career information, more students expressed an interest in science careers, and many students explained that science looked more interesting.

Not only did students mention more science career opportunities following the treatment lab, but they included the volunteer's career aspirations as well. For example, after the nontreatment a student discussed requiring science to become a "doctor or physiotherapist," but after the treatment they mentioned, "fluorine chemist and makeup chemist" as possible careers. After the classroom lab, many students identified traditional science professions, whereas after the BTS lab many students were able to identify nontraditional and more specific science careers.

Family members, television, and the internet were described after the class lab as sources of information for students to learn about science careers. Following the BTS lab, students included, “the volunteers, programs like this, and the university” as information sources. Participating in the treatment unit exposed students to more science career options.

There was an increase in the number of students wanting to pursue science careers after the BTS labs compared with the class activities. A chemistry student said,” I would like a career in science because there are many different areas to study.” She had not wanted a career in science after the nontreatment lab because she was under the impression that there were limited career opportunities in science.

Following the treatment labs, many students commented that science was more interesting; the BTS labs would influence their decisions to pursue science in the future. A biology student expressed, “I am interested now because science looks like a lot of fun.” Another biology student said, “A science job seems like it would be fun and useful to society.” Many students considered or reconsidered a career in science due to the interesting treatment labs.

Classroom teachers made observations during nontreatment and treatment units regarding students’ interest and knowledge of science careers. The results of question 4 from the prompts are found in Figure 4. Overall, teachers noticed an increase in student career knowledge and interest following treatment units. For example, after the nontreatment the physics teacher wrote, “Very few show knowledge of careers in science or an interest; more so in grade 12’s than in lower grades.” After the treatment lab the teacher described, “Some students have a career in mind and the science classes they need for that career.”

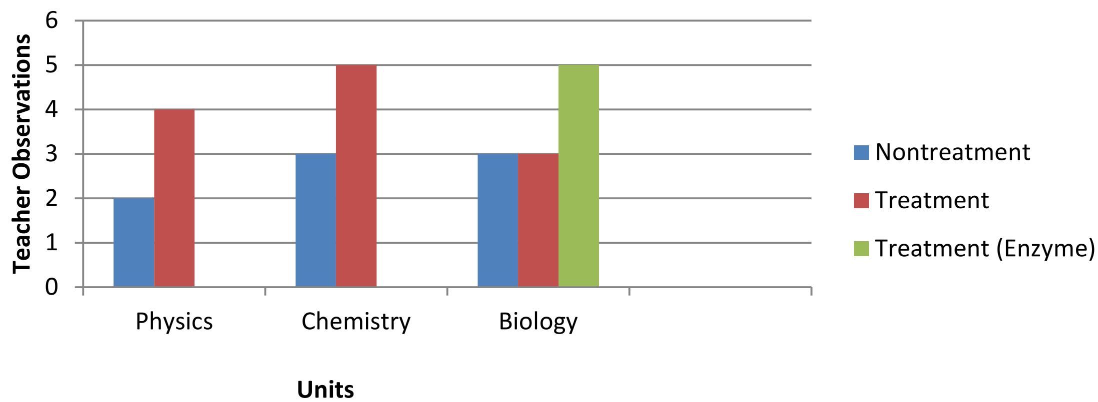


*Figure 4*. Teacher response to observation prompt regarding students' thoughts about career options, (*N* = 3).
*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

The biology teacher did not observe a difference in career knowledge for the first treatment lab, but noticed an increase for the second. Her initial observation was, "This group of students is not very science oriented; many are taking this class to get the science credit they need to graduate." After the second treatment, the teacher noticed students "discussing the volunteers' career aspirations" and asking them questions about postsecondary education.

BTS labs helped increase students' knowledge and interest regarding science careers. Not only were students able to identify more career possibilities after the treatment labs, but some changed their minds about pursuing science in the future because volunteers invoked discussion and excitement about science.

To determine the impact the treatment labs had on teachers' sense of professionalism, I analyzed data from surveys, interviews, and personal observations.

Table 7 illustrates the percent change showing the teacher survey results of the nontreatment and treatment units.

Table 7
*Comparison of Postunit Effects on Teachers' Professionalism (N = 3)*

| Description of Data | Nontreatment (%) | Treatment (%) | Change (%) |
|---|---|---|---|
| Physics | 95 | 90 | -5.26 |
| Chemistry | 95 | 100 | 5.26 |
| Biology | 100 | | |
| Biology (Fermentation) | | 100 | 0 |
| Biology (Enzyme) | | 100 | 0 |

The physics teacher observed a decrease in his overall sense of professionalism after the treatment lab. He wrote, "My sense of professionalism is based on being an effective classroom teacher which is only partially formed in the lab." He felt the BTS lab did not achieve the results he was hoping for and, therefore, felt his sense of professionalism decreased.

Although she had a strong sense of professionalism before using the BTS program, the chemistry teacher felt her professionalism increased as a result of the treatment lab. Forming professional relationships with scientists in the community impacted her teaching. She wrote, "I have learned some new things from the U of L students that I will use in my class."

There was no change for the biology teacher. Although she feels a strong sense of professionalism without the BTS program, she wrote, "Having the volunteers in my class allows the students to hear the same information in a different way and the program helps with my ongoing development and learning."

The results of the teacher interviews provided further insight into the impact the treatment had on their sense of professionalism. The teachers agreed that they felt very professional in terms of “preparation and knowledge,” and that their pedagogy and student learning is positively impacted by these feelings.

However, not all the teachers felt the BTS activity influenced their professionalism. The physics teacher said, “Implementing this lab activity did not influence my professionalism because we do a similar lab without the fancy equipment.” He felt his students would experience the same caliber of lab if he implemented his own class activity.

All teachers expressed the importance of relationships and their impact on teacher professionalism. They discussed the importance of establishing connections with the university graduate students and staff to create a science community. One teacher said, “Communicating with the U of L grad students gets me excited and inspired about chemistry and teaching chemistry, and this influences my sense of professionalism.” Another teacher expressed, “Being able to talk with the grad students and get further explanations or new information on the topics discussed builds my sense of professionalism.”

One teacher mentioned how implementing the BTS program in her classroom allowed her to connect with students in a way that she is not able to when conducting a class lab. She said, “I didn’t realize how much time I spent doing things for students in the lab, instead of talking with them. The conversations I had with my students were more meaningful when the U of L students ran the lab.” She felt a deeper sense of professionalism because she could take the time to discuss the lab with students without having to conduct the activity.

Findings from my personal observations reinforced the ideas expressed by the classroom teachers. Most of the teachers appeared to enjoy the BTS labs and were engaged by the activity. I noticed the biology and chemistry teachers learning new methods for teaching concepts. For example, the volunteers showed the chemistry class a new visual method for understanding the difference between precision and accuracy; the classroom teacher commented how she will use that method in the future. In addition to enjoying the BTS experience, teachers were also able to help students individually and this appeared to increase their sense of professionalism as well.

The physics teacher had a different experience compared with the other teachers. The treatment lab had some issues and did not have the desired impact on students. He did not appear engaged in the activity and seemed frustrated because he spent his time trying to fix the equipment instead of working with students individually. However, the teacher seemed to enjoy talking with the volunteers and planned to use the program in the future.

Overall, the treatment labs did not have a large impact on the teachers' sense of professionalism. The teachers perceived themselves as very professional before implementing the BTS program, so there was not a lot of room for improvement. Although their professionalism was not greatly influenced, teachers found it beneficial to forge relationships with the BTS staff to create a larger learning community.

The impacts of the BTS program on volunteers' pedagogy were also considered. Data were gathered before and after the treatment using surveys, interviews, and personal observations. Results of the volunteers' survey are shown in Table 8.

Table 8
*Comparison of Pre and Postunit Effects on Program Staffs' Pedagogy* (*N* = 8)

| Description of Data | Preunit (%) | Postunit (%) | Change (%) |
|---|---|---|---|
| Physics | 80 | 85 | 6.25 |
| Chemistry | 80 | 85 | 6.25 |
| Biology (Fermentation) | 75 | 82.5 | 10.00 |
| Biology (Enzyme) | 70 | 82.5 | 17.86 |

The staffs' pedagogy was positively impacted by their involvement with the BTS program. Before volunteering, many of the graduate students had little or no experience teaching science. One staff member wrote, "After doing the BTS labs a few times, I found it much easier to gauge the students and explain at a level they understand." Involvement with the program not only allowed volunteers to develop a personal pedagogy, but gave them a venue to implement it.

All staff described how their ability to communicate science improved, along with an increased knowledge of teaching skills and strategies. Most volunteers described using a "variety of teaching strategies" during their presentations. For example, one staff member wrote, "Different students require different strategies and being able to address each learning style helps to keep all the students engaged." The staff realized the importance of differentiating their instruction to maximize student learning.

Interviews with the staff offered valuable insight into how the BTS program influenced their pedagogy. After volunteering with the BTS program, the staff felt they could communicate science effectively with high school students. A few staff said they would "improve even more with practice." The volunteers felt they had ample science knowledge before their involvement with the BTS program, but lacked skills for teaching science.

The greatest impact the BTS program had on the volunteers was improving their science teaching strategies. The staff said their questioning techniques improved, along with implementing different teaching techniques to engage all students. One volunteer commented, "I learned different ways to deliver the information- visuals, demonstrations, lectures and videos."

Many volunteers stressed the importance of hands-on activities. A staff member said, "Science is easy to grasp when you can visualize something, therefore hands-on experience is super important to really engage students at a young age." The volunteers also learned the value of tying lab information to real life situations; one staff commented, "I learned to connect the science concepts to real world examples. For example, heating up proteins and how that relates to fevers in humans."

During my observations of the BTS labs, I made comments that reflected the statements made by the staff. Not only was the staff implementing effective teaching strategies, but they would change strategies if they found them ineffective. I noticed the staff would apply different teaching strategies when they recognized the students were confused or losing interest. For example, one volunteer was lecturing about how to use a piece of equipment, but changed to a demonstration when he noticed the students' confusion. The volunteers also related labs to real life situations and I saw how that positively impacted student engagement. I wrote, "The students asked more questions when the volunteers related the lab to real-world examples, such as cell phones and computers."

Triangulation of the data indicates program staff benefited from their involvement with the BTS program. The volunteers' improved their ability to implement effective teaching strategies and learned the importance of embedding the lab curriculum into real-world situations.

What were the effects of the BTS program on my relationships, professionalism, and involvement with the program? Data from teacher observations, journaling, and personal surveys were used to answer this subquestion. Information from the teacher observations is displayed in Table 9.

Table 9
*Comparison of Pre and Postunit Observations of my Relationships, Professionalism and Involvement* (*N* = 3)

| Description of Data | Preunit | Postunit | Change (%) |
|---|---|---|---|
| Relationships | 4.33 | 5 | 15.47 |
| Professionalism | 4.17 | 4.5 | 7.91 |
| Involvement | 4.33 | 4.75 | 9.70 |

*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

Teachers observed positive impacts on my relationships, professionalism, and involvement with the program. One teacher described that I "really enjoyed working with the grad students and didn't know them very well before this program; now they are working together a lot." The teachers observed how my professionalism had increased because I was spending more time "learning new methods for teaching lab activities that would benefit students." The impact on my involvement with the program was also mentioned by a teacher who wrote that I "attended teacher information nights, extra meetings, and prepared information for teachers' convention."

My journal responses supported the teacher observations. Prior to the treatment unit, I did not know the volunteers. After the treatment, I formed professional and personal relationships with most of the staff. We communicated on a weekly basis, sharing interesting science articles and brainstorming new lab activities for the program. My professionalism increased because "I became involved in other science classrooms and learned about other science curriculum. I had meaningful conversations about science teaching with colleagues; this rarely occurred before implementing the program." My involvement with the program has escalated to the point where I attend monthly meetings, contribute ideas for new labs, offer suggestions for improving existing labs, and encourage other teachers to use the program.

The results of my personal survey responses support the data mentioned above and are displayed in Figure 5. Positive impacts on my relationships, professionalism, and involvement were recorded after implementation of the treatment units.

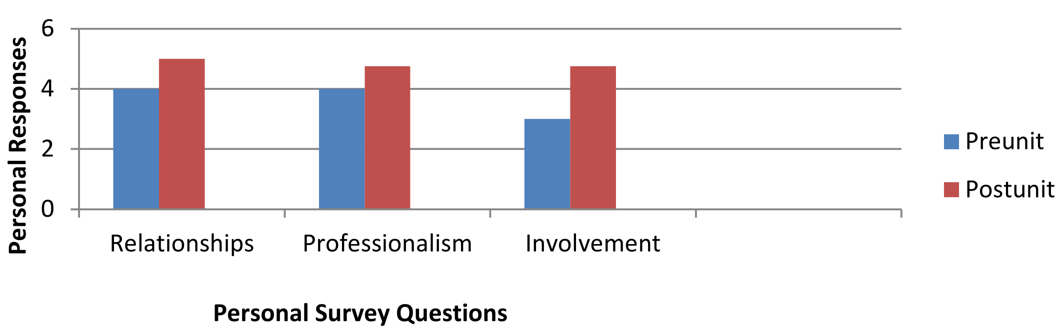


*Figure 5*. Personal survey responses to my relationships, professionalism and involvement, (*N* = 1).
*Note*. 5 = Strongly Agree, 4 = Slightly Agree, 3 = Undecided, 2 = Slightly Disagree, 1 = Strongly Disagree.

My relationships with the classroom teacher improved because "We had more time to discuss teaching philosophies because the volunteers were administering the lab." Before my involvement with the program, I did not have many connections with the scientific community. After the treatment units I wrote, "Not only have I forged new relationships, but I have become a part of a large scientific community. I have new connections with people and access to resources for improving my teaching." Informing my teaching practice increased my sense of professionalism because "I have learned how to increase my students' interest and knowledge about science." My involvement will continue because "This is a worthwhile program that inspired children. I want to continue my involvement because I have witnessed firsthand how this program helped students."

Findings from the data sources showed an improvement in my relationships with classroom teachers and program staff, an increase in my professionalism, and an elevated involvement with the BTS program. The effects of the treatment have influenced my teaching philosophy and allowed me to connect with scientists in the community; this will ultimately enhance student learning.

## INTERPRETATION AND CONCLUSION

Evaluation of the triangulated data revealed that students' understanding of science concepts increased to a greater extent with the implementation of the BTS program compared with classroom labs. Analysis of the data collected from pre and postunit assessments showed an improvement in student learning at all academic levels, but a greater impact was noted for low-academic students. Most notably, the BTS program improved the ability of low-academic students' to explain connections among science concepts. Although the physics classroom teacher felt the BTS lab did not enhance student understanding due to complications with the equipment, the results from the assessments and interviews suggested otherwise.

When the results of the nontreatment and treatment units were compared, students' attitude and motivation to learn science increased to a greater extent with the BTS program. Students were motivated by the hands-on activities, use of new equipment, and real world applications. The positive impact on students' attitude was amplified by the second treatment exposure because students became more comfortable with the program and volunteers.

The BTS program had a greater impact on the students' depth of understanding compared with classroom labs. Students' assessment results increased with the exception of some biology students, which can be attributed to poor assessment timing. Most teachers observed students' depth of knowledge increased; however, the physics teacher felt the lab did not due to lab equipment problems. Gains were made at all cognitive levels, but the greatest impact was observed at the synthesis and evaluation level.

Compared with the nontreatment, the treatment unit had a greater impact on students' thoughts about science career options. Students were able to list more careers and expressed an interested in pursuing science related jobs after experiencing the BTS program. The volunteers also positively influenced the students' knowledge by sharing their career knowledge and aspirations.

The BTS program had little impact on teachers' sense of professionalism. There was little room for improvement because the teachers felt a strong sense of professionalism before implementing the program. However, during the interviews they mentioned the importance of forming a science community with volunteers and university professors. The teachers recognized the importance of forming these relationships, but did not feel it impacted their professionalism.

BTS volunteers felt the program contributed positively to improving their pedagogical practices. Most notably, the staff mentioned an increase in their knowledge and implementation of diverse teaching strategies. Volunteers also realized the importance of tying the lab concepts to real world scenarios, to hold students' attention.

The BTS program has positively impacted my relationships with other teachers and volunteers, and increased my sense of professionalism. Establishing new relationships and forming a community of science educators informed my teaching practices. My involvement has greatly increased because I realized the value of the program for my students.

As an educator, this project has been beneficial to my own teaching because it has sustained the knowledge that science outreach programs, such as BTS, help students learn. I no longer consider BTS labs superfluous, or something to do when I have extra class time. The program activities are effective and necessary teaching strategies that benefit students at all academic levels. Watching students participate and learn from the volunteers energized my teaching and motivates me to become involved in developing additional BTS labs I could do with my classes.

In the future, there are a few changes I would make to the data collecting process for this project. The first would be increasing the amount of time I set aside for interviews. I was rushed to complete them within one class period and this led to less descriptive student answers. I would also encourage students to go beyond the basic required elements of the concept maps by adding additional vocabulary terms and descriptions as they deem appropriate. The interviews were the most valuable data collection instrument and setting aside more time would result in more detailed responses to questions and concept maps.

The second change would be adding the following question to the postassessment concept map interview, "Do you feel you improved on your concept map after the lab activity? Please explain." This would be a quick method to assess how students were feeling about what they learned from the activity and would be useful in comparing the nontreatment with the treatment units. Adding the additional interview question would enhance the quality of the data collected for this project.

To obtain more accurate data for the pre and postassessment concept questions, it would be helpful to use three units that students have similar levels of background knowledge. For example, I would not use the photosynthesis nontreatment lab because students are familiar with the topic from previous grades. The preassessment scores were artificially high and skewed the data because they were compared to the results from an unfamiliar unit. Attempting to standardize the background knowledge for the units would prevent inflated assessment scores and result in more precise data.

Lastly, I would avoid assessing students immediately following a holiday from school. The students were not as focused and the resulting data was influenced by the poor timing. Extending the data collection timeline would obviate the need to assess following a break.

Increasing the amount of time allocated to interviews, adding an additional question to the concept maps, standardizing background knowledge, and adjusting the timing of assessments will help to improve the quality of data collected. Implementing these changes will help to improve the quality of data collected in order to better assess the impacts of the BTS program on student learning.

## VALUE

This project has provided me with the opportunity to develop professionally by analyzing the impact of the BTS program on student learning. Observing and evaluating students during this project allowed me to reflect on my own teaching practices and solidify the importance of using the outreach program to increase students' understanding of science.

Prior to completing my capstone, I had limited interactions with science professionals and activities outside of my classroom. As a result of my project, I have had the opportunity to meet and form relationships with scientists in my community. My involvement in extracurricular science activities, such as science fairs and synthetic biology competitions, has increased. The students in my classes will have more opportunities to become involved in science inside and outside of the classroom as a result of my newly formed relationships and involvements with the BTS program.

Part of my professional philosophy includes motivating students to learn through interactive teaching strategies. Including BTS lab activities as a regular part of my teaching not only supports my personal philosophy, but increases student engagement, which leads to gains in student learning. The BTS program encourages questions about science careers and postsecondary opportunities, so students can make informed decisions about pursuing science in the future.

The BTS program staff benefited greatly from their experience with the BTS program. Prior to their involvement, many of the volunteers had few skills communicating science to the general public and developing pedagogical and leadership strategies. The program enhanced their skills and prepared them for future activities, such as presenting research at conferences.

Sharing the results of this project helped other classroom teachers reflect on their teaching philosophies as well. Many did not realize the positive impact science outreach had on student learning and motivation, and plan on utilizing the BTS next semester. Not only were future plans made to increase the use of activities by the school, but also to suggest additional labs that address curricular outcomes that are difficult to meet due to lack of school resources. Some teachers mentioned using professional development time to research and create more ideas for BTS labs for students at all grade levels. Discussions focused on developing activities for grade 9 classes because teachers feel it is important to motivate students earlier in their education. My project focused on grade

11 students; however, students at all grade and academic levels would benefit from lab activities.

As part of my future investigations, I would like to explore the most beneficial types of lab activities for student learning. During my interviews with students, they mentioned characteristics of labs they enjoyed and ones they did not. I would like to evaluate different types of activities and establish a list of criteria that distinguishes an effective lab. Next semester I would like to conduct surveys and interviews to ask students to describe what elements of labs they enjoy the most. Increasing the quantity and quality of BTS labs is an important next step in my research.

This project has made me reevaluate the importance of motivating students by implementing science outreach activities in the classroom. Watching students engage in meaningful educational experiences has encouraged me to explore new opportunities for bringing interactive labs into my classroom.

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# APPENDICES

# APPENDIX A

## NONTREATMENT BIOLOGY LAB ACTIVITY

Biology Lab Activity: A Nontreatment Lab

Gases Released During Photosynthesis and Cellular Respiration

Chemical reactions during photosynthesis and cellular respiration produce gas by-products. How can you identify what gases are released?

Question: How can you identify the gases released by plants and animals during photosynthesis and cellular respiration?

Materials:
600 mL beaker
$NaHCO_{3(s)}$
Elodea (or other aquatic plant)
Grow light
Test tube and stopper
Short stemmed funnel
Wooden splint
Matches
0.1 mol/L NaOH(aq)
50 mL Erlenmeyer flask and stopper
Bromothymol blue
Straw

Procedure:
Part I: Gases Released by Plants

1. Fill a 600 mL beaker with tap water and add 2 g of $NaHCO_{3(s)}$ to the water.
2. Hold the Elodea (or other aquatic plant) under the water and cut off the stem ends so no air is trapped in the plant's vessels.
3. Place the cone of the funnel over the plant's branches.
4. Fill a test tube with water and cover the top with your thumb while you invert it. Hold it underwater and place it overtop of the funnel's stem. Be sure there is no air in your test tube.
5. Place the apparatus under a grow light and wait at least 24 hours.
6. After 24 hours, remove the test tube, keeping it inverted, put your thumb over the mouth of the test tube and stopper it.
7. Light a wooden splint. Let it burn briefy and then blow out the flame. The splint should still glow.
8. Gradually insert the glowing splint into the test tube.
9. Observe the results.
    - If the gas is hydrogen, you will hear a loud popping sound.
    - If the gas is carbon dioxide, the splint with go out.
    - If the gas is oxygen, the splint will burn faster and you will see a flame.

Part II: Gases Released by Animals

1. Add 35 mL of water to the Erlenmeyer flask. Add a few drops of bromothymol blue to the water and swirl.
2. Add sodim hydroxide one drop at a time and swirl the flask until the water turns a greenish-blue color.
3. Using a straw, gently blow into the flask until you can no longer see a color change.

Reference

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# APPENDIX B

## NONTREATMENT CHEMISTRY LAB ACTIVITY

## Chemistry Lab Activity: A Nontreatment Lab

### Decomposing Malachite

Malachite is a double salt that decomposes completely when heated to $200^{o}$C.

Purpose: To test that a chemical reaction is stoichiometric.

Materials:
Lab apron
Eye protection
Crucible
Ring stand
Hot plate
Glass stirring rod
Malachite (1-3 g)
Balance
Scoop

Design:
A known mass of malachite is heated until the color changes from green to black. Use the glass stirring rid to break up lumps of powdered malachite and mix the contents of the dish while they are being heated. Large lumps may decompose on the outside, but not on the inside. The mass of black copper(II)oxide is determined.

Reference
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# APPENDIX C

## NONTREATMENT PHYSICS LAB ACTIVITY

Physics Lab Activity: A Nontreatment Lab

Pulses in a Spring

Questions:
Part I: What are the mechanisms by which pulses move through a medium?
Part II: What is the relationship between the amplitude, length, and speed of a pulse?

Materials:
Light spring
Masking tape
Stopwatch
Tape measure or metre-stick

Procedure:
Part I:
1. Have one team member hold the end of the spring while another stretches it until it is moderately stretched.
2. Place strips of masking tape on the floor at either end of the spring to mark this length. Near the middle of the spring, attach a strip of tape about 5 cm long to one of the coils.
3. Have one of the team members holding the spring generate a transverse pulse. Do this by moving your hand to one side and back to its original position.
4. Make a longitudinal pulse by moving your hand toward the person holding the spring at the other end and then back to its original position.

Part II:
1. Measure the speed of a transverse pulse as it moves along the spring. Measure the time from the instant the front edge of the pulse leaves the hand of the person generating it until the front edge arrives at the hand at the other end.
2. Have the person holding one end of the spring move so that the spring is stretched about 1 m farther. Generate a pulse and measure the speed of the pulse in the spring at a higher tension.
3. Make a transverse pulse by moving your hand a different distance sideways. Try to keep the time used to make the pulse the same as before.
4. Make several transverse pulses by moving your hand to a given amplitude but change the speed at which you move.

Reference

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# APPENDIX D

## BRIDGES TO SCIENCE TRAINING SESSION LESSON PLAN

# Bridges to Science Volunteer Training- Lesson Plan

**Outline:**

Based on Let's Talk Science Outreach Program training manual (http://www.letstalkscience.ca/), but focusing the training for high school students (grades 9-12).

| Exercises in the training manual | Time, min | Activity | Comments/Goal | Person Responsible for teaching |
|---|---|---|---|---|
| Introduction | 10 | What to expect | To introduce the workshop goals and logistics<br>(LTS workshop) | Ute |
| Exercise 1 | 17 | Why outreach? | To establish the relevance – the "WHY" – for this workshop<br>(LTS workshop) | Ute |
| Exercise 2 | 20 | Getting Started | To choose and refine a concept for a class visit<br>(LTS workshop) | Ute |
| Exercise 3 | *25* | How we learn *(adjusted)* | To develop an understanding of the constructivist theory of learning<br>(LTS workshop) | Ute |
| Exercise 4 (new) | 13 | Entering a high school classroom | To practice introducing yourself and raising interest for the activity | Ute |
| | **10** | **Break *(pizza and pop?)*** | | |
| Information 1 | 15 | How to use the portal & How to conduct a visit (organizational aspects) | To describe procedures at UofL and to prepare volunteers for visit | Breanne |
| Exercise 5 (new) | 20 | Group discussions and conversations in a high school class | To practice active engagement with high school students | Ute / Kim Helena |
| Exercise 6 (new) | 15 | How to describe your career | To develop an interesting description of your career and field of research | Ute |
| Information 2 | 10 | Science day (May 2011) | To introduce event and gather support in developing activities | Laura & Kirsten |
| Exercise 7 | 6 - 10 | What Have I Learned | To reflect on what you've learned during the workshop<br>(LTS workshop) | Ute |

| | | | | |
|---|---|---|---|---|
| Closure | 10 | Concluding Remarks / Evaluation | To describe the hallmarks of an effective educator<br>To have participants complete a questionnaire related to the workshop (BTS workshop) | Ute |
| **Total** | **180** | | | |

**Introduction (10 min)**

- Have participants prepare name tags (name + discipline)
- Introduce Ute, Breanne, Laura, Kirsten, Kim, Helena
- Show visual 1: Goal of Workshop
- Show modified visual 2: What to expect in this workshop
- Explain participant workbook, point out “Group Management Strategies”, “Presentation Strategies” and appendices
- Science with Impact DVD Segment 1 (2:41 min): “An Introduction by Dr. Alan Bernstein, President, Canadian Institutes of Health Research”

**Exercise 1: Why Outreach? (17 min)**

- Introduce exercise and refer to workbook
- Have participants respond to questions (3 min)
- Have them discuss their responses with their nearest neighbor (2 min)
- Collect responses and note on board (5 min)
- Science with Impact DVD Segment 2 (6:02 min), only beginning and end (3 min): “Abena, a graduate student, visits a community group”<br>Question: “How does Abena establish context and relevance for her community audience?”
- Take up the responses following the video

**Exercise 2: Getting Started (20 min)**

- Introduce exercise and refer to workbook
- Show visual 4: Presentation Concept Examples
- Stress importance of this task, aim at age 13 to 15
- Allow participants 15 min to complete task (describe in 25 words or less a fundamental concept for an activity, edit it to 10 words or less, think about how this concept could be presented, time permitting share with neighbor)
- Ask for volunteers to share their outline
- Debrief

**Exercise 3: How We Learn (30 min)**

- Introduce exercise
- Show visual 5: "Essentials of Constructivist Theory of Learning"
- Task 1 (visual 6): read and discuss importance of perception (2 min)
- Task 2 (visual 7): read and discuss importance of context (2 min)
- Task 3 (visual 8): read and discuss importance of prior knowledge (3 min)
- Show Science with Impact DVD Segment 3 (7:10 min): "Patrick, a physicist, visits a group of 15 and 16-year-old students in a high school science laboratory"
  have participants analyze the presentation with reference to constructivist theory using table provided (9 min) *(don't use video 4)*
- Show Science with Impact DVD Segment 5 (6:45 min): "Cameron, a paleontologist, welcomes a group of 13 and 14-year-old students to his university laboratory"
- Debrief

**Exercise 4 (new): Entering a science classroom (13 min)**
*(similar to exercise in Grad TA workshop)*

- Introduce exercise, refer to introductions in DVD segments
  Task: prepare how you will enter a high school science classroom including (prepare worksheet) (2 min)
  a) introducing yourself (write your name on board)
  b) explaining UofL's Let's Talk Science Program
  c) exciting introduction of the activity

- Have participants develop their introduction (3 min)

- Have 2 volunteers present their introduction (4 min)

- Collect feedback (3 min)

- Debrief (1 min)

**Exercise 5 (new): Group discussions and conversations in a high school class (20 min)**

- Goal: to learn how to use group discussion strategies to include all students in active discussions, to learn to talk to students individually during activities and group discussions as an effective way of engagement, to experience difficulty of directly asking questions to the whole class in discussions after experiment

- Act out "bad" discussion strategy: "After we have done all these activities on science outreach, can you tell me about scientifically proven benefit of investing time and money into these science outreach activities?"

- Brainstorm with participants / in small groups on other ways of stimulating discussions

- Discuss, explain how to set up group discussions (clear task, clear group size, limited time, ask group not individuals for answers)

- Discuss how to get in individual contact with students, review how instructor behaved during hands-on activities in this setting (approaching groups, checking on progress with individuals, providing positive feedback, encouraging)

**Exercise 6 (new): How to describe your career (15 min)**

- Introduce exercise, explain importance of highlighting career perspectives in the high school using personal examples (2 min)
- Have participants develop their career description answering the following questions in simple words (prepare worksheet) (4 min)
  a) Why did you study which science subject?
  b) What is your current research and why did you choose it?
  c) Describe one potential job available with a graduate degree in your area.
- Have 2 volunteers present their introduction (5 min)
- Collect feedback (3 min)
- Debrief (1 min)

**Exercise 7: What Have I Learned (6 - 10 min)**

- Introduce exercise emphasizing key points: reflection is a valuable learning tool, we learn by sharing ideas and opinions,
- Allow participants 5-7 min to complete task in workbook
- Ask for volunteers to share their experience (optional) (3-4 min)
- Debrief

**The end: Concluding Remarks (10 min)**

- Show visual 14: concluding remarks on effective educators
- Concluding remarks (will be available for questions)
- Hand out evaluation form
- Show Science with Impact DVD Segment 6 (5:51 min): “Testimonials”
- Collect evaluation forms

# APPENDIX E

## TREATMENT BIOLOGY LAB ACTIVITIES

Biology Lab Activity# 1: A Treatment Lab

# Experiment 1-The effect of glucose concentration on the rate of fermentation in yeast

1. Remove six falcon tubes (containing yeast suspension) from the water bath, and label them as follows: 0% (water), 0.1%, 0.2%, 0.3%, 0.4% or 0.5% glucose.

2. Fill each tube with the appropriate glucose solution, extending the fluid level above the top of the tube.

3. Screw the cap on the falcon tube, and invert to mix the contents (do not be concerned if a few drops come out of the hole in the cap). Make sure you do not have an air bubble at this point. If you do, remove the lid and top up the tube with the appropriate solution.

4. Place the inverted tubes into a plastic container in the water bath.

5. At 5 minute intervals, lift the tube out of the container and hold your finger over the hole in the cap. Dry the tip of the tube with the paper towel provided and mark the level of the bubbles at the end of the tube with the marker. Invert the tube to mix the contents before placing the tube back in the water bath.

6. Continue readings every 5 minutes for 30 minutes. You should have 6 measurements for each tube.

7. At the end of 30 minutes, use the tube template to measure the volume of carbon dioxide produced at each time point. Empty the contents of your tubes into the container labeled “waste”.

8. Record your data in the data table below. Hand in your sheet to the instructor.

**Table 1:** The effect of various glucose concentrations on the amount of carbon dioxide produced during fermentation in yeast.

| Time | $CO_2$ Collected by Displacement of Yeast/Sugar Solution (in mL) | | | | | |
|---|---|---|---|---|---|---|
| (min) | Water | 0.1% Glucose | 0.2% Glucose | 0.3% Glucose | 0.4% Glucose | 0.5% Glucose |
| 5 | | | | | | |
| 10 | | | | | | |
| 15 | | | | | | |
| 20 | | | | | | |
| 25 | | | | | | |
| 30 | | | | | | |

# Experiment 2-The effect of different sugars on the rate of fermentation in yeast

1. Remove six falcon tubes from the water bath, and label them as follows: 0% (water), 0.5% sucrose, 0.5% maltose, 0.5% lactose, 0.5% glucose or 0.5% aspartame.

2. Fill each tube with the appropriate sugar solution. Ensure that the volume of liquid is right to the very top.

3. Screw the cap on the falcon tube, and invert to mix the contents (do not be concerned if a few drops come out of the hole in the cap). Make sure you do not have an air bubble at this point. If you do, remove the lid and top up the tube with the appropriate solution.

4. Place the inverted tubes into a plastic container in the water bath.

5. At 5 minute intervals, lift the tube out of the container and hold your finger over the hole in the cap. Dry the tip of the tube with the paper towel provided and mark the level of the bubbles at the end of the tube with the marker. Invert the tube to mix the contents before placing the tube back in the water bath.

6. Continue readings every 5 minutes for 30 minutes. You should have 6 measurements for each tube.

7. At the end of 30 minutes, use the tube template to measure the volume of carbon dioxide produced at each time point. Empty the contents of your tubes into the container labeled “waste”.

8. Record your data in the data table below. Hand in your sheet to the instructor.

**Table 2:** The effect of sugar source on the amount of carbon dioxide produced during fermentation in yeast.

| Time (min) | $CO_2$ Collected by Displacement of Yeast/Sugar Solution (in mL) | | | | | |
|---|---|---|---|---|---|---|
| | Water | Aspartame | Glucose | Lactose | Maltose | Sucrose |
| 5 | | | | | | |
| 10 | | | | | | |
| 15 | | | | | | |
| 20 | | | | | | |
| 25 | | | | | | |
| 30 | | | | | | |

Biology Lab Activity #2: A Treatment Lab

## Effect of Temperature

1. Work in groups of 3. Assign one member of the group to be responsible for setting up and reading the reactions, one member to set up the water baths, and one member to be responsible for timing and recording and graphing data collected.
2. Pipette 1 mL of potato homogenate (containing catalase enzyme) into 5 test tubes.
3. Prepare your first temperature treatment using the information below. Incubate a test tube containing potato catalase at this temperature for 2 minutes.

   ~0$^{o}$C – fill container with ice and a small amount of water.

   ~10$^{o}$C – add a small amount of ice to a container filled with water

   Room temperature – set test tube in rack on the bench

   ~30-35$^{o}$C – fill container with warm water from the tap

   ~45-50$^{o}$C – fill container with hot water from the tap

   In each case, use the thermometer provided to record the actual temperature tested in the table below.
4. After the 2 minute incubation period, add 1 mL of 3% $H_20_2$ to the tube.
5. Wait 1 minute, then record the height of the bubbles in the tube in cm in the table below. Calculate the volume of $0_2$ produced using the following equation: $V=\pi r^2 h$ (where $r^2 = 0.64$ cm).
6. Repeat Steps 2-5 for the other temperature treatments.
7. Rinse out all test tubes and place them back in the test tube rack provided.
8. Plot the volume of $0_2$ produced at each temperature on the graph grid provided on page 3.

**Table 1:** The effect of temperature on the production of oxygen by the decomposition of 1 mL of 3% hydrogen peroxide by 1 mL potato catalase.

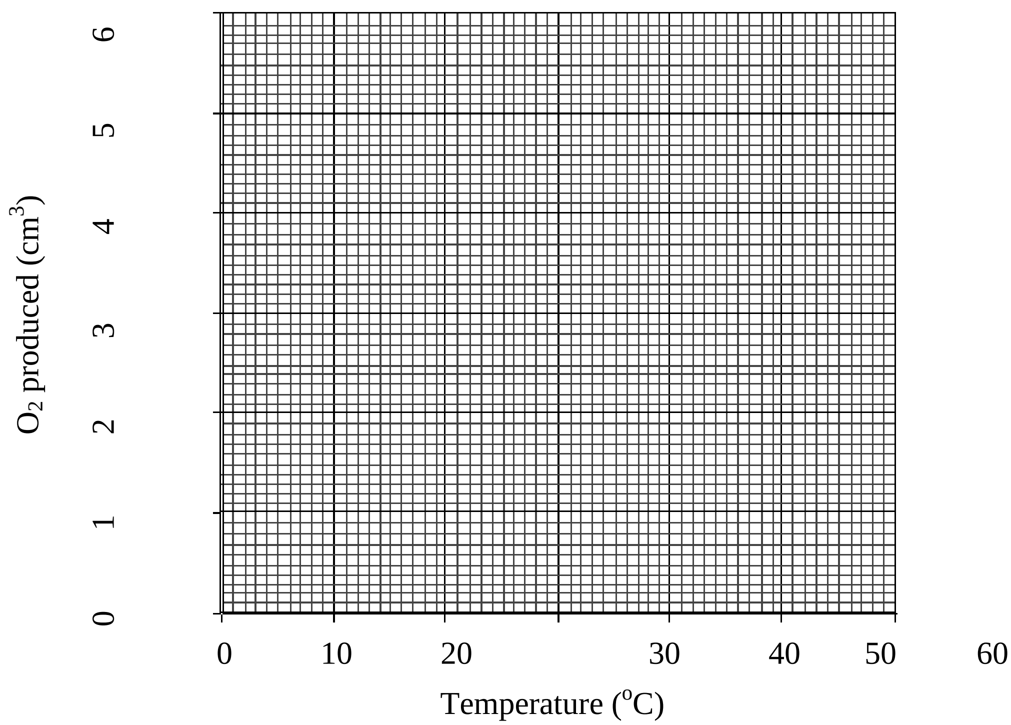
| **Temperature ($^{o}$C)** | **Height of bubbles (cm)** | **Volume of $O_2$ produced ($cm^3$)** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

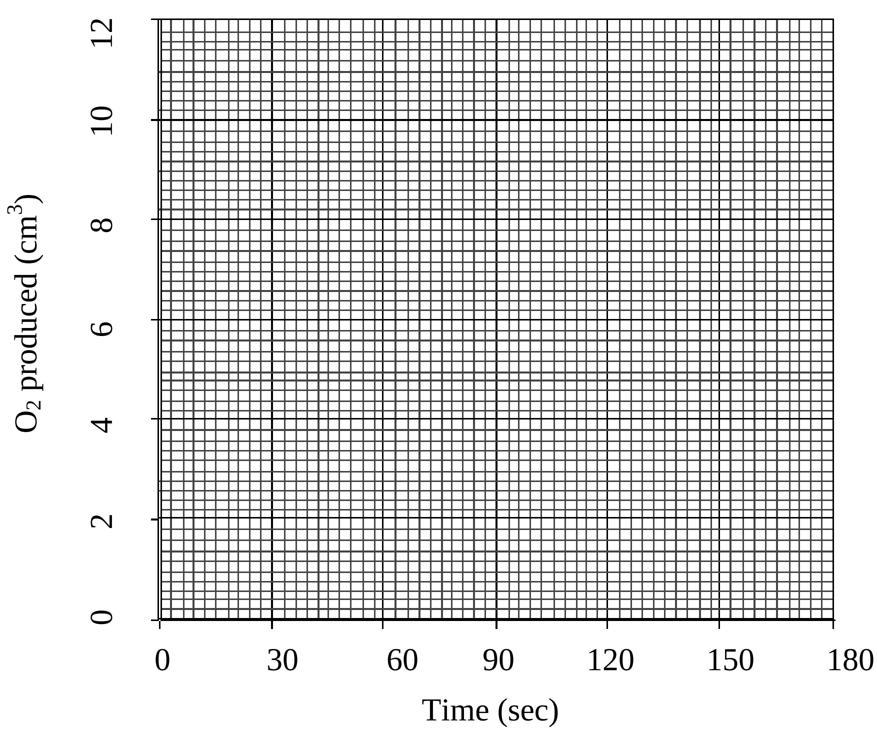
# Effect of $H_2O_2$ Concentration

1. Work in groups of 3. Assign one member of the group to be responsible for setting up and reading the reactions, one member to time, and one member to be responsible for recording and graphing data collected.
2. Add 1 mL of potato catalase to a test tube.
3. Add 1 mL of 1.5% $H_2O_2$ to the tube with the potato catalase and start timing immediately.
4. Record the height (in cm) of the bubbles in the tube every 15 seconds for 3 minutes in the table below. Calculate the volume of $0_2$ produced at each time point using the following equation: $V=\pi r^2 h$ (where r = 0.8 cm).
5. Repeat Steps 2-4 using 3% $H_2O_2$.
6. Rinse out all test tubes and place them back in the test tube rack provided.
7. Plot the volume of $O_2$ produced over time for both concentrations of $H_20_2$ on the graph grid provided on page 3.

**Table 2:** The effect of $H_20_2$ concentration on the production of oxygen by the decomposition of 1 mL of hydrogen peroxide by 1 mL potato catalase.

| | **Height of bubbles (cm)** | | **Volume of $O_2$ produced ($cm^3$)** | |
|---|---|---|---|---|
| **Time (sec)** | **1.5% $H_20_2$** | **3% $H_20_2$** | **1.5% $H_20_2$** | **3% $H_20_2$** |
| 0 | | | | |
| 15 | | | | |
| 30 | | | | |
| 45 | | | | |
| 60 | | | | |
| 75 | | | | |
| 90 | | | | |
| 105 | | | | |
| 120 | | | | |
| 135 | | | | |
| 150 | | | | |
| 165 | | | | |
| 180 | | | | |


O2 produced (cm3)
0
1
2
3
4
5
6
0
10
20
30
40
50
60
Temperature (oC)


O2 produced (cm3)
0
2
4
6
8
10
12
0
30
60
90
120
150
180
Time (sec)

**Thought Questions:**

1. What is the optimal temperature for potato catalase activity?

2. Explain why less oxygen is produced at temperatures other than the optimal temperature.

3. Our blood (and other tissues in our bodies) contains catalase. What would the optimum temperature for our catalase likely be? Why?

4. Calculate the rate at which oxygen is produced for each of the $H_2O_2$ concentrations tested (remember to calculate slope (rate) for the steepest part of your line of best fit). Which $H_2O_2$ concentration generates the most oxygen per unit of time? Why?

5. Examine your graph to see how much oxygen is produced at the end of the three minutes of measurements. Why are the values for the two $H_2O_2$ treatments different? What has happened in each instance?

6. Predict what you expect would happen to both the rate of oxygen generated and to the total amount of oxygen generated if you had tested (a) 0.75% $H_2O_2$ and (b) 6% $H_2O_2$.

7. Would you expect the rate of oxygen produced per unit of time to continue to increase as concentrations of $H_2O_2$ higher than 6% were tested? Provide an explanation for your answer.

# APPENDIX F

TREATMENT CHEMISTRY LAB ACTIVITY

Chemistry Lab Activity: A Treatment Lab

# HOW ACIDIC IS CHEWING GUM?

Chewing gum is composed of insoluble gum base and soluble flavourings and sweeteners, which are released as the gum is chewed. A common ingredient in chewing gum is citric acid, which gives a sharp, refreshing citrus taste. During quality control, it is the role of an analytical chemist to double-check the actual amount of citric acid in the gum.

Determining the amount of citric acid is done using an acid/base reaction between citric acid and sodium hydroxide. Using titration results, the citric acid content of the bubble gum can be calculated.

Materials;

- Lab coat and safety glasses
- scissors
- 250 mL flask and stopper
- 100 mL graduated cylinder
- 1 mL pipette
- 10 or 50 mL burette
- Funnel and beaker (to fill burette)
- balance
- distilled water
- citrus flavoured chewing gum
- 0.2 % phenolphthalein
- 0.1 mol/L sodium hydroxide

**Procedure:**

1. Cut one piece of chewing gum into small pieces, about the size of a grain of rice.
2. Weigh out 1.00 g of chewing gum pieces (repeat 3 times).
3. Add chewing gum to 100 mL of distilled water in a 250 mL flask (prepare 3 flasks).
4. Stir for 30 min.
5. Add 0.5 mL of phenolphthalein indicator to each flask.
6. Fill burette with 0.1 mol/L sodium hydroxide. Let some sodium hydroxide flow out of burette into beaker such that there are no air bubbles in the tip of the burette. Record the volume of sodium hydroxide in the burette.

7. Titrate with 0.1 mol/L sodium hydroxide in a burette. The end point is pink. Record the remaining volume of sodium hydroxide in the burette.
8. Repeat with other flasks.

CALCULATIONS:

Calculate the mass of citric acid present in a sample, given the amount of sodium hydroxide needed to complete the reaction during titration.

GENERAL INFORMATION FOR CALCULATION

For the calculation you can find below the structure and Molar Mass of citric acid along with the equation for the acid/base reaction with sodium hydroxide.

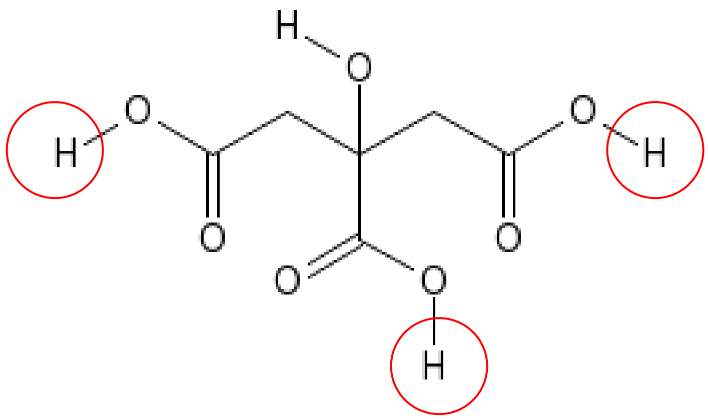


Figure 1: Structure of Citric Acid ($H_3C_6H_5O_7$). Notice the three protons that will be exchanged for sodium in the acid/base reaction.

$H_3C_6H_5O_7$ + $3NaOH$ → $3\ H_2O$ + $Na_3C_6H_5O_7$

m (citric acid) =? c (NaOH) =0.1 mol/L

M (citric acid) =210.14 g/mol V (NaOH) = ____ mL

# APPENDIX G

TREATMENT PHYSICS LAB ACTIVTY

Physics Lab Activity: A Treatment Lab

SPEED OF SOUND

OBJECTIVE:

- Determine the velocity of sound in air by measuring the resonant frequencies of an open tube
- Measure the signal distribution in a closed tube, calculate the wavelength and speed of sound from this data

INTRODUCTION:

Waves are an important part of our everyday lives. Without a good working knowledge of waves we would not have the wireless technology that allows us to browse the internet from a laptop or even talk on your cell phone. Waves allow us to listen to radio, use GPS and even text friends.

The equation of a wave can be expressed using a sine function which has the following form;

$$y = y_m \sin\left(\frac{2\pi x}{\lambda}\right)$$

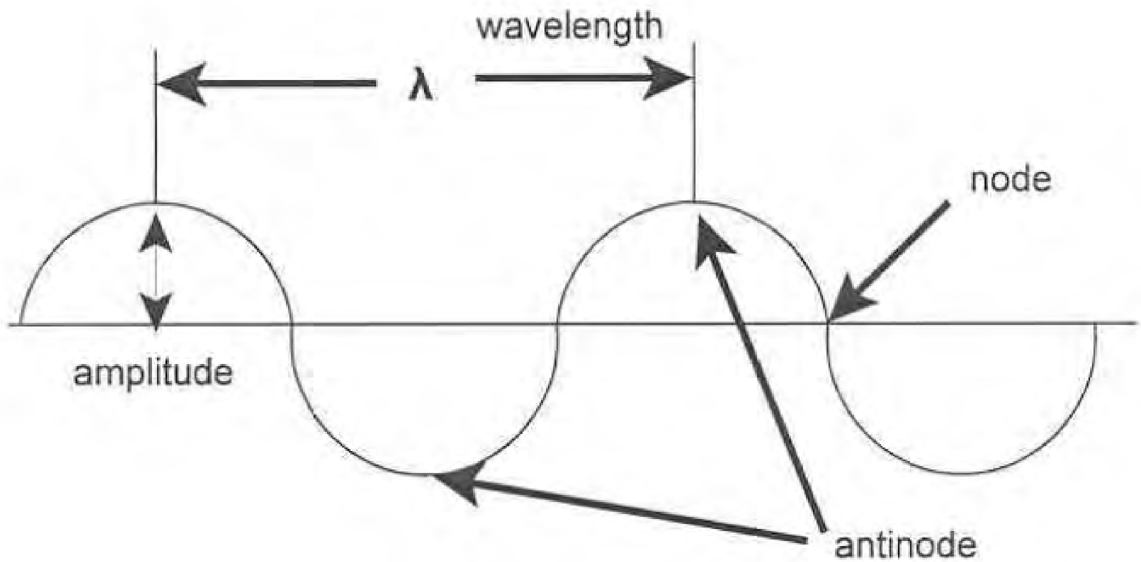
The fundamental components used to describe waves are:

<u>Amplitude:</u> Refers to the height of a wave and can be denoted by $y_m$ as seen in the equation above.

<u>Wavelength:</u> Refers to the physical length of the wave and is denoted by $\lambda$.

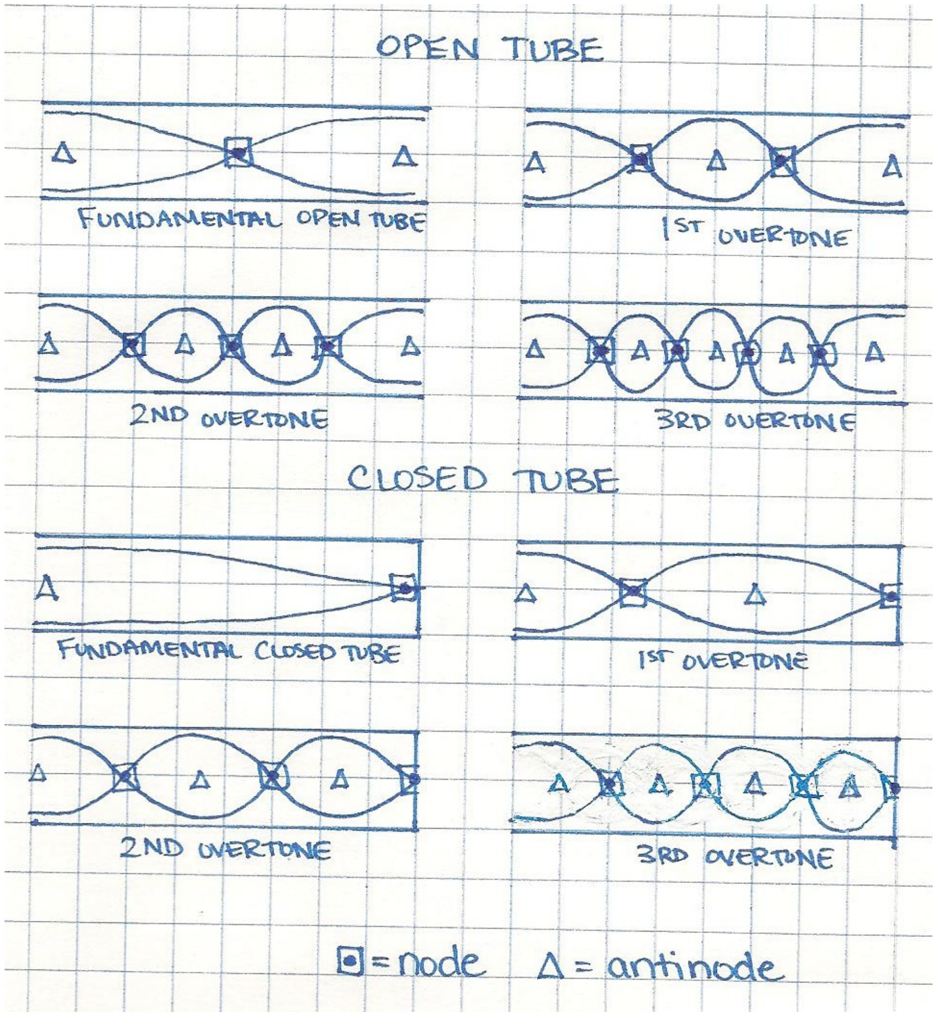
<u>Period:</u> Refers to the time it takes for one wavelength of the wave to pass a specific point and is denoted by T.

<u>Frequency:</u> Refers to how many wavelengths of a wave will pass a specific point in 1 second and is denoted by f where f=1/T.




Many musical instruments use vibrations in a column of air to produce musical tones. These vibrations resonate (are louder) at certain frequencies, dependent on the length of the tube. In this experiment, a resonance tube will be used to simulate the column of air, with a loudspeaker at an open end.

Standing waves are set up in the tube because the sound is reflected at both open and closed ends.




The resonance condition for an open tube of length L and diameter d is:

$$L+0.8d = n\frac{\lambda}{2}$$

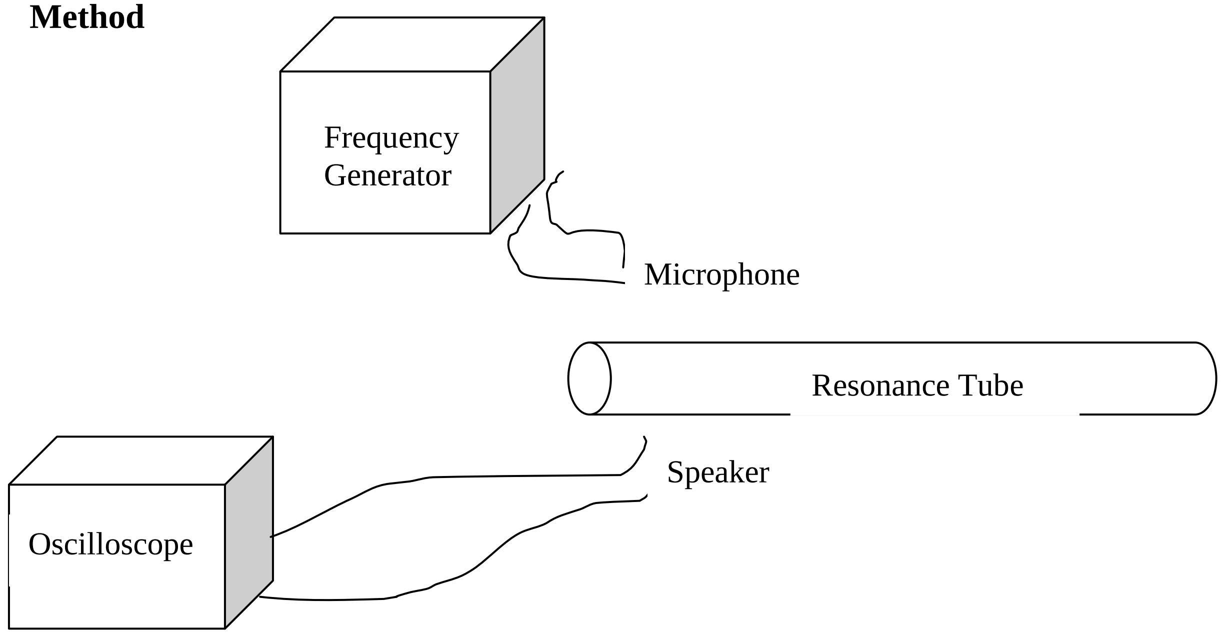
where n=1,2,3,4… and λ is the wavelength of the sound wave.

The resonance condition for a closed tube of length L and diameter d is:

$$L+0.4d = n\frac{\lambda}{4}$$

where n=1,3,5,7… and λ is the wavelength of the sound wave.

**Method**




- Set up the equipment as shown in the diagram above.
- Adjust the plunger in the tube so that it is positioned a distance L (between 20-50cm) from the speaker. Measure and record this distance, say 50cm, on the scale in the tube.
- Starting from 100Hz gradually increase the frequency of the signal generator.
- Using the auto-scale function on the oscilloscope, observe the signal on the screen as the frequency is increased. When resonance occurs you will notice a maximum amplitude on the screen.
- Record the frequency and amplitude of the signal. Be careful of the scaling factor.
- Continue in the same way to find successive resonant frequencies until you have reached **at least 3000Hz**. Use the table below to record your results.

| **Frequency Hz** | **Amplitude** |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

**Analysis**

- The frequency for the resonant modes for a closed tube can be found using the either of following equations:

$$f_n = \frac{n * 343}{4L}\ , f'_n = \frac{n * 343}{4(L + 0.4d)}$$

From these equations, determine what the frequencies are for the following harmonics $f_1$, $f_3$, $f_5$, $f_7$ are expected to be, and fill in the table below (here L is the length of your tube and d=0.0314m. The units of f are Hz = cycles/second). The second equation is a more physically meaningful equation because it includes the effects of a tube having a finite diameter.

| Harmonic | Frequency 1 (f) | Frequency 2 (f') |
|---|---|---|
| First ($f_1$) | | |
| Third ($f_3$) | | |
| Fifth ($f_5$) | | |
| Seventh ($f_7$) | | |

- Compare the two columns of the above table, how different are the frequencies from each other?
- Using the harmonic frequencies you have just calculated determine what frequencies from your recorded data correspond to the harmonics in the table above. For each harmonic select the closest frequency to it from your table. Then complete the table by determining the wavelengths using the equation for a closed tube, given below (here L is the length of the tube in meters and d=0.0314m).

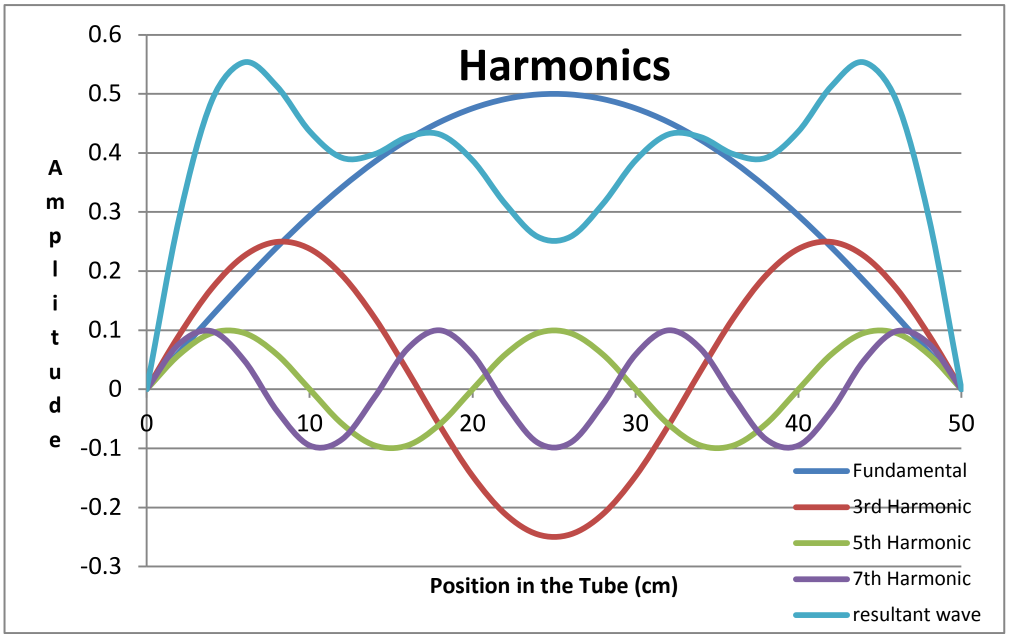
$$L+0.4d = n\frac{\lambda}{4}$$

| Harmonic | Frequency | Wavelength | Amplitude |
|---|---|---|---|
| First ($f_1$) | | | |
| Third ($f_3$) | | | |
| Fifth ($f_5$) | | | |
| Seventh ($f_7$) | | | |

- Calculate the speed of sound using the wave equation $v = f\,\lambda$ for each harmonic. Complete the following table.

| Frequency | Wavelength | Speed of sound |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Thought Questions:
1. Create a harmonics graph by graphing the wave function given above in terms of amplitude and position. Finally you should also be able to plot the sum of the first 4 modes to get a resultant wave.




2. Using your knowledge of sounds waves, explain the physics behind noise cancellation. How could you demonstrate this using the equipment in this lab?

# APPENDIX H

PROJECT TIMELINE

Project Timeline

Start Project Implementation: October 7th, 2011

**Nontreatment**

October 7th to October 14th

- October 7th: Visit biology 20 class
- October 7th: Distribute preunit assessment (Concept questions)
- October 7th, 10th: Interview 10 students (Concept maps) and teacher
- October 11th: Observe Photosynthesis/Cellular Respiration Lab (teacher and personal observations, personal journal, and personal survey)
- October 12th: Postunit assessment (concept questions)
- October 12th: Student surveys
- October 13th: Interview 10 students
- October 14th: Teacher interview

December 5th to December 8th

- December 5th: Visit chemistry 20 class
- December 5th:Distribute preunit assessment (concept questions)
- December 5th: Interview 10 students (concept maps)and teacher
- December 6th: Observe Decomposing Malachite Lab (teacher and personal observations, personal journal, and personal survey)
- December 7th:Postunit assessment (concept questions)
- December 7th: Student surveys
- December 7th: Interview 10 students
- December 8th: Teacher interview

December 12th to December 15th

- December 12th: Visit physics 20 class
- December 12th: Distribute preunit assessment (concept questions)
- December 12th: Interview 10 students (concept maps) and teacher
- December 13th: Observe Pulses in a Spring Lab (teacher and personal observations, personal journal, and personal survey)
- December 14th: Postunit assessment (concept questions)
- December 14th: Student surveys
- December 14th: Interview 10 students
- December 15th: Teacher interview

**Treatment**

October 17th to October 24th

- October 17th: Visit biology 20 class
- October 17th: Distribute preunit assessment (concept questions)
- October 17th: Interview 10 students (concept maps), BTS staff and teacher, and BTS survey
- October 19th: Observe BTS Fermentation Lab (teacher, BTS staff and personal observations, personal journal, and personal survey)
- October 19th: Interview BTS staff, and BTS survey
- October 20th: Postunit assessment (concept questions)
- October 20th: Student surveys
- October 20tht: Interview 10 students (concept maps) and BTS staff, and BTS survey
- October 24th: Teacher interview

November 7th to November 15th

- November 7th: Visit biology 20 class
- November 7th: Distribute preunit assessment (concept questions)
- November 7th: Interview 10 students (concept maps), BTS staff and teacher, and BTS survey
- November 9th: Observe BTS Enzyme Lab (teacher, BTS staff and personal observations, personal journal, and personal survey)
- November 14th: Interview BTS staff, and BTS survey
- November 14th: Postunit assessment (concept questions)
- November 14th: Student surveys
- November 14th: Interview 10 students (concept maps) and BTS staff, and BTS survey
- November 15th: Teacher interview

December 12th to December 15th

- December 12th: Visit Chemistry 20 class
- December 12th: Distribute preunit assessment (concept questions)
- December 12th: Interview 10 students (concept maps), BTS staff and teacher, and BTS survey
- December 13th: Observe BTS Acid/Base Chewing Gum Lab (teacher, BTS staff and personal observations, personal journal, and personal survey)
- December 13th: Interview BTS staff, and BTS survey
- December 14th: Postunit assessment (concept questions)
- December 14th: Student surveys
- December 14th: Interview 10 students (concept maps) and BTS staff, and BTS survey
- December 15th: Teacher interview

January 9$^{th}$- January 12$^{th}$

- January 9$^{th}$: Visit Physics 20 class
- January 9$^{th}$: Distribute preunit assessment (concept questions)
- January 9$^{th}$: Interview 10 students (concept maps), BTS staff and teacher, and BTS survey
- January 10$^{th}$: Observe BTS Speed of Sound Lab (teacher, BTS staff and personal observations, personal journal, and personal survey)
- January 10$^{th}$: : Interview BTS staff, and BTS survey
- January 11$^{th}$: Postunit assessment (concept questions)
- January 11$^{th}$: Student surveys
- January 11$^{th}$: Interview 10 students (concept maps) and BTS staff, and BTS survey
- January 12$^{th}$: Teacher interview

# APPENDIX I

STUDENT INTERVIEW QUESTIONS WITH CONCEPT MAPS

# Pre and Postunit Interview Questions
# Nontreatment Biology Lab: Cellular Respiration

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: photosynthesis, cell respiration, NaOH, bromothymol blue, oxygen, $CO_2$, plant, human, light, indicator, gas, and chemical reaction.
I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term photosynthesis to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, describe how photosynthesis and cellular respiration are related.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

Pre and Postunit Interview Questions
Treatment Biology Lab: Yeast Fermentation

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: cellular respiration, glycolysis, yeast, ATP, glucose, fermentation, ethanol ($C2H5OH$), $CO2$, and pyruvate.
I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term cellular respiration to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, explain the process of fermentation.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

Pre and Postunit Interview Questions
Treatment Biology Lab: Catalase Activity

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: catalase, enzyme, substrate, pH, temperature, substrate concentration, catalyst, reaction rate, and $H_2O_2$.
I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term enzyme to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, describe how enzymes react under various conditions.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

# Pre and Postunit Interview Questions
## Nontreatment Chemistry Lab: Decomposing Malachite

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: decomposition, mass of reactants, mass of products, law of conservation of mass, stoichiometry, malachite, CuO, $CO_2$, and $H_2O$.
I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term decomposition to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, explain why this lab activity can be used to prove that reactions are stoichiometric.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

# Pre and Postunit Interview Questions
# Treatment Chemistry Lab: Citric Acid in Chewing Gum

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: titration, endpoint, equivalence point, neutralization, citric acid, sodium hydroxide, stoichiometry, acid-base indicator.
I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term titration to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, explain how the concentration of citric acid can be determined using titration.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

# Pre and Postunit Interview Questions
## Nontreatment Physics Lab: Pulses in a Spring

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: waves, transverse, longitudinal, speed, wavelength, frequency, amplitude, period.
I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term waves to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, describe the mechanics by which pulses move through a spring.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

# Pre and Postunit Interview Questions
## Treatment Physics Lab: Sound Waves

Concept Map

A concept map is a diagram that shows the relationships among concepts. It is sometimes called a mind web, or mind map. I would like you to construct a concept map using the following terms: resonance, node, antinode, fundamental frequency, harmonic frequency, standing wave, wave velocity, wave length, open column, and closed column. I have provided you with a small whiteboard, colored markers, and a list of terms. Use the term resonance to begin your concept map. Arrange the terms from the list to show how they relate to one another. Include words on the connecting lines to explain the relationship between the words. Feel free to add words, point form notes, or talk aloud while constructing your map. When you are finished, you will explain your concept map to me.

Concept question: Using the concept map you created, discuss string properties in an open and closed column.

1. What motivates you to learn new science concepts? Explain.
2. Do you look forward to science lab activities?
    - Why or why not?
3. What lab activities make learning science more interesting? Explain.
4. Do lab activities help you understand science concepts?
    - Please explain.
5. Do lab activities help you understand science concepts at a deeper level?
    - Why or why not?
6. What careers in science have you heard about?
7. Where did you get your information about science careers?
8. Have you thought about a career in science?
    - Why or why not?
9. Do you want to add anything else?

# APPENDIX J

## CONCEPT QUESTIONS AND LEVELS OF QUESTIONS

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Nontreatment Biology Lab: Photosynthesis and Cellular Respiration

Please answer the following questions to the best of your ability.

Knowledge

1. List the gases released during photosynthesis and cellular respiration.

Comprehension

2. Classify the following organisms as undergoing photosynthesis, cellular respiration, or both:

   Sunflower ___________________________
   Burrowing owl ________________________
   Poplar tree ___________________________
   Mosquito ____________________________

Application

3. What factors would increase or decrease photosynthesis?  Why?

Analysis

4. Draw and label the cell organelle in which photosynthesis and cellular respiration occur. Explain why you selected this organelle.

Synthesis

5. Propose a method to identify the gases produced from photosynthesis and cellular respiration.

Evaluation

6. Compare and contrast (similarities and differences) photosynthesis and cellular respiration.

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Treatment Biology Lab: Yeast Fermentation

Please answer the following questions to the best of your ability.

Knowledge

1. Name an organism that carries out fermentation.

Comprehension

2. What is the main function of fermentation?

Application

3. Identify one factor that would cause an organism to switch from cellular respiration to fermentation?

Analysis

4. How would you distinguish between an organism that undergoes cellular respiration and one that undergoes fermentation? Explain your answer.

Synthesis

Create and describe a realistic environment where an organism would be forced to use fermentation over cellular respiration. Explain your answer.

Evaluation

Compare and contrast (similarities and differences) cellular respiration and fermentation.

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Treatment Biology Lab: Catalase Activity

Please answer the following questions to the best of your ability.

Knowledge

1. What is an enzyme?

Comprehension

2. Explain why enzymes are important to living organisms.

Application

3. What factors would increase or decrease enzyme activity?

Analysis

4. Diagram and label a graph comparing the energy required for a reaction with and without an enzyme.  Explain your answer.

Synthesis

5. Predict what would eventually happen to the reaction rate in an experiment involving unlimited substrate concentration and limited enzyme concentration. Explain your answer.

Evaluation

6. Using the information that you have gained about enzymes, explain why high fevers can be dangerous.

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Nontreatment Chemistry Lab: Decomposition of Malachite

Please answer the following questions to the best of your ability.

Knowledge

1. Describe a decomposition reaction.

Comprehension

2. Provide a balanced chemical equation from the following information: Malachite $Cu(OH)_2CuCO_{3(s)}$ decomposes completely into copper(II)oxide, carbon dioxide and water vapor.

Application

3. Given 1.0g of malachite, predict the mass of copper(II)oxide produced?

Analysis

4. Why is the predicted mass of copper(II)oxide different than the original mass of malachite?

Synthesis

5. What could be done to maximize the mass of product formed? Explain your answer.

Evaluation

6. Using a scientific law, justify the reduction in mass from reactant to product?

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Treatment Chemistry Lab: Citric Acid in Chewing Gum

Please answer the following questions to the best of your ability.

Knowledge

1. What is a titration?

Comprehension

2. Describe a neutralization reaction.

Application

3. Predict the products and balance the neutralization reaction for citric acid ($H_3C_6H_5O_7$) with sodium hydroxide.

Analysis

4. Draw the titration curve for a weak acid with a strong base.

Synthesis

5. What indicator could you use to determine the endpoint of this titration? Explain your answer.

Evaluation

6. Explain the difference between the endpoint and the equivalence point of a titration?

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Nontreatment Physics Lab: Pulses in a Spring

Please answer the following questions to the best of your ability.

Knowledge

1. List 3 properties of waves.

Comprehension

2. Compare transverse and longitudinal waves.

Application

3. Draw and label a wave with the following terms: crest, trough, and one wavelength.

Analysis

4. How is a reflected pulse different from an incident pulse?

Synthesis

5. How does the length of the pulse affect the speed and amplitude of the wave?

Evaluation

6. How could you determine the speed of a wave using wavelength and frequency?

Pre and Postunit Assessment
Concept Questions and Levels of Questions
Treatment Physics Lab: Sound Waves

Please answer the following questions to the best of your ability.

Knowledge

1. What is resonance?

Comprehension

2. Compare string resonance and resonance in open and closed air columns.

Application

3. Draw and label a standing wave using the following terms: node and antinode.

Analysis

4. What is the relationship between fundamental frequency and wavelength?

Synthesis

5. Determine the first, second, and third harmonic frequencies of a column that is open at both ends.

Evaluation

6. Based on fundamental frequencies of a string, how could you determine the velocity of a wave?

# APPENDIX K

## TEACHER OBSERVATION PROMPTS

Teacher Observation Prompts
Nontreatment and Treatment Lab Activities

Date:______________________________
Lab Activity:_______________________

Use the following scale to guide your observations and comments. Choose three high, middle and low achieving students to track and compare throughout the study.

**5**- Strongly agree **4**- Slightly Agree **3**- Undecided **2**- Slightly disagree **1**-Stongly disagree

1. Students understand lab activity concepts and procedures. **5 4 3 2 1**

   Observations and comments:

2. Students have a deeper level of understanding of science concepts. **5 4 3 2 1**

   Observations and comments:

3. Students are motivated and show positive attitudes during the activity. **5 4 3 2 1**

   Observations and comments:

4. Students express interest and knowledge of science careers. **5 4 3 2 1**

   Observations and comments:

**5.** People involved with the program are developing positive relationships with one another. **5 4 3 2 1**

   Observations and comments:

6. People involved in the program experience a greater sense of professionalism. **5 4 3 2 1**

   Observations and comments:

7. People participating in the program are increasing their involvement. **5 4 3 2 1**

   Observations and comments:

# APPENDIX L

## CONCEPT MAP RUBRIC

Scoring Rubric for Concept Map

| Map Component | Possible points | Awarded points | Special things noticed about map |
|---|---|---|---|
| Proposition | | | |
| Clear and meaningful to the central topic | 2 each | | |
| Beyond given set of terms | 3 each | | |
| Not properly linked | 1 each | | |
| Vague | 1 each | | |
| Branch | | | |
| Top | 1 | | |
| Successive branches | 3 each | | |
| Levels of hierarchy (general to specific) | 5 each level | | |
| Cross Links | 10 each | | |
| Examples | 1 each | | |
| Total | | | |
| Overall reaction to map and special things noticed. | | | |

Adapted from Novak and Gowin (1984).

# APPENDIX M

## CONCEPT QUESTIONS AND LEVELS OF QUESTIONS RUBRIC

Rubric: Concept Questions and Levels of Questions
Nontreatment and Treatment Units

| **CRITICAL THINKING RUBRICS** | |
|---|---|
| **CATEGORY ONE: KNOWLEDGE AND COMPREHENSION** (understanding the basics) | |
| **4** | The work consistently demonstrates clear, accurate, detailed and comprehensive understanding of the relevant facts, data, theories, or terms as well as the ability to organize the information for application, presentation, documentation, and/or further examination. |
| **3** | The work demonstrates an adequate understanding of the relevant facts, data, theories, or terms as well as the ability to organize the information for application, presentation, documentation, and/or further examination. |
| **2** | The work demonstrates an uneven and shaky understanding of the relevant facts, data, theories, or terms as well as a limited ability to organize the information for application, presentation, documentation, and/or further examination. |
| **1** | The work demonstrates an inadequate understanding of the relevant facts, data, theories, or terms as well as a limited ability to organize the information for application, presentation, documentation, and/or further examination. |

| CATEGORY TWO: APPLICATION AND ANALYSIS (attaining the concept) | |
|---|---|
| **4** | The work demonstrates confident ability to work with the key concepts, information, process, or theory and applying or extending them to a wide variety of new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons. |
| **3** | The work demonstrates adequate ability to work with the key concepts, information, process, or theory and applying or extending them to a variety of new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons. |
| **2** | The work demonstrates uneven and shaky ability to work with the key concepts, information, process, or theory and applying or extending them with mixed success to new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons. |
| **1** | The work demonstrates extremely limited ability to work with the key concepts, information, process, or theory and applying or extending them with very limited success to new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons. |

| CATEGORY THREE: SYNTHESIZING AND EVALUATING (going beyond the given) | |
|---|---|
| **4** | The work demonstrates surprising/insightful ability to take ideas. theories, processes, principals further into new territory, broader generalizations, hidden meanings and implications as well – as well as to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions. |
| **3** | The work demonstrates adequate ability to take ideas. theories, processes, principals further into new territory, broader generalizations, hidden meanings and implications as well – as well as to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions. |
| **2** | The work demonstrates uneven and superficial ability to take ideas. theories, processes, principals further into new territory, broader generalizations, hidden meanings and implications as well – as well as a limited ability to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions. |
| **1** | The work demonstrates little ability to take ideas. theories, processes, principals further into new territory, broader generalizations, hidden meanings and implications as well – as well as a limited and superficial ability to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions. |
| Adapted from: Source- http://www.nh.cc.mn.us/mydocs/1000007/ThinkRubric.doc<br>Based on a draft from Elaina Bleifield and the Paulus CT Group<br>http://academic.pgcc.edu/~wpeirce/MCCCTR/Designingrubricsassessingthinking.html | |

# APPENDIX N

## STUDENT SURVEY

Student Survey Questions

The purpose of this survey is to gather your opinions on the Bridge to Science Program. There are no “right” or “wrong” answers. Please answer all questions completely and honestly. This survey will not impact your grade in any way.

Please circle the number that most closely represents how you feel about each statement.

| **I. Attitude and Motivation** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. I enjoy science class. | 5 | 4 | 3 | 2 | 1 |
| 2. Science lab activities are interesting. | 5 | 4 | 3 | 2 | 1 |
| 3. Doing lab activities increases my motivation to learn science. | 5 | 4 | 3 | 2 | 1 |
| 4. Explain what motivates you specifically about the lab activities? | | | | | |
| 5. I found the lab activity instruction engaging. | 5 | 4 | 3 | 2 | 1 |
| 6. Explain what engaged you specifically about the instruction? | | | | | |
| 6. The lab instructor increased my motivation to learn science. | 5 | 4 | 3 | 2 | 1 |
| 7. Explain what motivated you about the lab instructor? | | | | | |

| **II. Career Options** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. A career involving science would be interesting. | 5 | 4 | 3 | 2 | 1 |
| 2. The lab activity increased my awareness of science-related careers. | 5 | 4 | 3 | 2 | 1 |
| 3. Explain how the activity impacted your awareness of science careers. | | | | | |
| 4. The lab activity increased my | | 4 | 3 | 2 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| interest in pursuing a science-related career. | 5 | | | | |
| 5. Explain how the activity increased you interest in pursuing science careers. | | | | | |
| 6. The lab instructor is a positive role model for science careers. | 5 | 4 | 3 | 2 | 1 |
| 7. I am interested in learning more about the lab instructor's career or career plans. | 5 | 4 | 3 | 2 | 1 |
| 8. What interested you specifically about the lab instructor's career or career plans? | | | | | |

9. Is there anything else you would like to mention that was not asked in the survey? Please explain.

# APPENDIX O

## CLASSROOM TEACHER INTERVIEW QUESTIONS

Teacher Professionalism
Interview Questions

1. Do you feel a sense of professionalism as a science teacher? Explain.

2. Do you feel you have any control or can influence your sense of professionalism? Why or why not.

3. Do you think your sense of professionalism affects your teaching? Explain.

4. Do you think your sense of professionalism impacts student learning? Explain.

5. Has implementing this lab activity influenced your sense of professionalism? Why or why not.

6. Would changing any aspect of the lab activity increase your sense of professionalism? Explain.

7. What other activities or relationships would influence your sense of professionalism? Explain.

8. Is there anything else you would like to mention that I have not asked in this interview? Explain.

# APPENDIX P

## CLASSROOM TEACHER SURVEY

Teacher Survey Questions

The purpose of this survey is to gather your opinions on the Bridge to Science Program.
Please answer all questions completely and honestly.
Please circle the number that most closely represents how you feel about each statement.

| **Teacher Professionalism** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. I have a strong sense of professionalism as a science teacher. | 5 | 4 | 3 | 2 | 1 |
| Explain. | | | | | |
| 2. Involvement in lab activities increases my sense of professionalism. | 5 | 4 | 3 | 2 | 1 |
| Explain. | | | | | |
| 3. Using guest speakers in the classroom increases my sense of professionalism. | 5 | 4 | 3 | 2 | 1 |
| Explain. | | | | | |
| 4. Forming professional relationships with scientists in the community increases my sense of professionalism. | 5 | 4 | 3 | 2 | 1 |
| Explain. | | | | | |
| 5. Explain how your sense of professionalism is impacted by your involvement in lab activities. | | | | | |

6. Is there anything else you would like to mention that was not in the survey? Please explain.

# APPENDIX Q

## PERSONAL OBSERVATION PROMPTS

Personal Observation Prompts

1. Classroom teachers' professionalism

    a. Nontreatment unit prompts:
    - What teaching strategies are they implementing?
    - Do they appear to enjoy the lab activity?
    - Are they engaged in the lesson?
    - Are they learning new concepts or teaching strategies?

    <u>Observations and comments:</u>

    b. Treatment unit prompts:
    - What teaching strategies are they implementing?
    - Do they appear to enjoy the lab activity?
    - Are they engaged in the lesson?
    - Are they learning new concepts or teaching strategies?

    <u>Observations and comments:</u>

2. Program staffs' pedagogy

    a. Treatment unit prompts:
    - Are they implementing effective teaching strategies?
    - Are they implementing new strategies if other strategies are ineffective?
    - Are they showing skills for teaching science?
    - Do they communicate science effectively with high school students?

    <u>Observations and comments:</u>

3. Additional observations or comments.

# APPENDIX R

## PROGRAM STAFF INTERVIEW QUESTIONS

Program Staffs' Pedagogy
Interview Questions

1. Do you feel you can communicate science concepts effectively? Explain.

2. Do you feel you have the ability to effectively teach science to high school students? Why or why not.

3. How would you describe your skills for teaching science? Explain in general terms and also provide specific teaching strategies you use.

4. What ideas do you have regarding science education? Explain.

5. What ideas do you have about science teaching? Explain.

6. Regarding the teaching aspect of the BTS program, would you suggest any changes? Explain.

7. Is there anything else you would like to mention that I did not ask during the interview?
   Explain.

APPENDIX S

PROGRAM STAFF SURVEY

Program Staffs' Pedagogy Survey

The purpose of this survey is to gather your opinions on the Bridge to Science Program. Please answer all questions completely and honestly.

Please circle the number that most closely represents how you feel about each statement.

| **Program Staffs' Pedagogy** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. I am able to communicate science concepts effectively.<br>Explain. | 5 | 4 | 3 | 2 | 1 |
| 2. I have effective science teaching skills.<br>Explain. | 5 | 4 | 3 | 2 | 1 |
| 3. I have effective teaching strategies for high school students.<br>Explain. | 5 | 4 | 3 | 2 | 1 |
| 4. Teaching strategies impact student learning.<br>Explain. | 5 | 4 | 3 | 2 | 1 |
| 5. Explain how teaching strategies impact student learning. | | | | | |

6. Is there anything else you would like to mention that was not in the survey? Please explain.

# APPENDIX T

PERSONAL JOURNAL PROMPTS

Personal Journal Prompts
Nontreatment and Treatment Units

1. Describe your professional relationship with the classroom teachers.
   a. Nontreatment lab-

   b. Treatment lab-

2. Describe your professional relationship with the BTS program staff.
   a. Nontreatment lab-

   b. Treatment lab-

3. Describe your sense of professionalism.
   a. Nontreatment lab-

   b. Treatment lab-

4. Describe your level of involvement with the BTS program.
   a. Nontreatment lab-

   b. Treatment lab-

5. What is the impact of my capstone project on my educational philosophy regarding science teaching?

6. Describe any additional observations or comments.

# APPENDIX U

PERSONAL SURVEY

Pre and Postunit Personal Survey Questions

| **I. Professional Relationships** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. My relationships with the classroom teacher have positively grown. | 5 | 4 | 3 | 2 | 1 |
| 2. Explain how your relationships have been impacted. | | | | | |
| 3. My relationships with the BTS staff have positively grown. | 5 | 4 | 3 | 2 | 1 |
| 4. Explain how your relationships have been impacted. | | | | | |
| **II. Professionalism** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
| 1. My sense of professionalism has increased. | 5 | 4 | 3 | 2 | 1 |
| 2. Provide a description of how your sense of professionalism was impacted. | | | | | |
| **III. Involvement** | **Strongly Agree** | **Slightly Agree** | **Undecided** | **Slightly Disagree** | **Strongly Disagree** |
| 1. My involvement with the BTS program has increased. | 5 | 4 | 3 | 2 | 1 |
| 2. Provide specific details regarding your involvement. | | | | | |
| 3. My future involvement with the BTS program will increase. | 5 | 4 | 3 | 2 | 1 |
| 4. Provide examples of your future involvement with the program. | | | | | |

5. Additional observations or comments.