Introductory Biology for Elementary Education Majors: 
Inquiry vs. Traditional Approach - A Five year study

By

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Abstract

Biology 110 is an undergraduate survey course for Elementary / Middle Level Education majors covering similar course content as the traditional lecture and laboratory format class, Biology 100, but is taught in a hands-on inquiry based format. Using a quasi-experimental pretest – posttest design, a modified version of the NABT (National Association of Biology Teachers) Biology Exam was administered to students in both courses to determine if the instructional format would influence the students’ understanding of the content covered in each class. The Biology 110 students showed a statically significant difference on the post test scores over the Biology 100 students as determined by an ANOVA statistical analyses (F= 7.6, p =<.001) and a Neuman-Kuels Multiple Comparison test. The results held true for each semester the course was taught over a 5 year period. The instructional method used (inquiry based versus traditional lecture and lab) seemed to make a significant difference in the amount of content learned for education majors consistently over time.

For the entire paper in PDF format, please visit Dr. Crowther’s web site:

http://equinox.unr.edu/homepage/crowther/

Click on lesson plans from workshops for the sub-directory.

The paper is labeled with the title above.
Introduction

The discrepancy between how the National Science Education Standards (NSES) recommend most students experience science and how most students experience introductory science courses at the university level seems vast (National Research Council, 1996). Halls are filled with a hundred or more students listening to lectures. Smaller groups participate in prescriptive labs that seldom promote thinking, problem solving or learning that relates the daily life of the student in creating personal meaning from what they have been presented. The experience that the majority of students have after such a course is that of listening to many hours of lecture, reading, and memorizing concepts and terms from a text. These courses are generally designed for the non-biology major who will be future writers, social workers, artists and politicians. These courses are also where the future elementary / middle level educators in this country learn the science content they will be expected to teach to future generations in their classrooms.

The NSES (1996) recommend that prospective educators experience science in situations that include problem solving, inquiry, and the use of hands-on experiences in order to develop a “broad base of knowledge” that will allow them to understand the role, processes, and nature of scientific inquiry (p. 59). They must also understand the basic facts and principles of the sciences and be able to make connections between and within them (NRC, 1996). Considering their recommendations, it is difficult to believe that Elementary / Middle Level Education majors are receiving the education suggested in the NSES.

Participation in most universities’ traditional lecture and laboratory format classes are often the sole science requirements and, therefore, the only content-based science
experiences they, as students, will have before entering their own classrooms. The call has been made clear that undergraduate science courses, especially for those who will become teachers, be restructured. (NRC, 1990; Tobias, 1992; NRC, 1996).

In 1990 the National Research Council (NRC) published *Fulfilling the Promise: Biology Education in the Nation's Schools*. The report indicated that:

Teachers of science in elementary school must be far better prepared than are most at present. To disguise their anxieties about science, most elementary school science teachers have hidden behind textbook-centered lessons that stress vocabulary and memorization of fact (p16). In order to remedy this deficit, the NRC suggested science training that surpassed the conventional college level courses. Such training in science would require the addition of approaches to teaching science in the elementary school and approaches that engage children in the excitement of the subject. This result should fulfill the desired outcome that

Students should leave elementary school with a strong love for and appreciation of nature and for their own world around them and with the recognition that science is an important way to learn about the world. In elementary school, every student should feel successful in learning science and should look forward to additional instruction. Emphasis should therefore be placed on active participation in science activities, and not on highly competitive grading procedures. These objectives are far more important than either acquisition of the kind of knowledge that is measured by traditional examinations or attempts to identify and reward future scientists’ (p16).

Since the publication of the National Science Education Standards (NRC, 1996), a second call for reform resulted in the report *Science Teacher Preparation in an Era of Standards Reform* (National Research Council, 1997). This document recommends that universities and their faculty develop courses for elementary education students that reflect the best practices recommended by the NSES. Such courses should include
pedagogy and assessment practices, as well as the content knowledge that will be needed in their future profession. Classes should be designed so that the subject matter being taught in the college classroom reflects the subjects that the students will eventually teach in their own classrooms. Recent literature exists which demonstrates that the establishment of science courses for Elementary Education majors can have positive effects, though few colleges and universities have implemented such courses. Although dated, one study done found that only 32 colleges or universities had specialized science courses for Education majors (Crowther, 1999).

There is controversy regarding these “specialized” sections or courses. Courses such as these tend to cover fewer concepts more deeply, rather than survey the mass of knowledge in a given field. It is important to acknowledge that most of the recent literature related to these courses has considered the students’ attitude toward or comfort levels with the science subject taught. The question remains whether students who take courses such as these learn the content that is necessary to become educators who can create experiences in their classrooms that conform to the recommendations of the NSES (1996). If colleges and universities are going to be convinced that designing such courses, which require more money and faculty resources to develop and teach, rather than keeping what is currently being taught, evidence must be shown that the students who participate in them are developing more than just a positive attitude, but that they are learning and retaining content at an equivalent or better than their counterparts who participate in a more traditional course.
Purpose

The purpose of this study was to determine if there existed any statistically significant differences in the pretest and posttest examination scores between students in two undergraduate biology classes taught in two fundamentally different praxes at the University of Nevada, Reno (UNR). Biology 100, *Principles and Applications of Biology*, an introductory biology course for non-majors, was taught in a traditional large lecture hall with a prescriptive laboratory format. Biology 110, *Biology for Education Majors*, was a newly created course beginning in the Spring term 2001, designed for Elementary Education majors using an approach recommended by the NSES (1996). This approach included inquiry, collaborative work, and hands-on investigations.

Background

The University of Nevada, Reno (UNR) offers two lecture sections of Biology 100 each semester, which is taken by between 150 - 200 students per section, and meets for lecture two times per week. Biology 100 also has a requirement of four three-hour labs taught by Graduate Teaching Assistants (GTA’s) that must be attended during the semester. Labs are generally limited to around 20 students per lab section. Biology 100 is a survey course offered in general content biology for all non-biology majors. It is a "Core A" science requirement. This means that it is a core science choice with a minimum number of lab hours as a requirement and also includes a prerequisite in college algebra and includes a writing requirement. The professors who teach Biology 100 are given a certain amount of latitude as to the depth and breadth of content focus during the semester as long as the syllabus meets the standards of the Biology
Department. UNR also offers Biology 190 for Biology majors, which is not considered in this study.

Biology 110 was originally developed and taught in the spring semester of 2001. A Howard Hughes Medical Institute (HHMI) Grant to the University of Nevada, Reno, initially funded the course. The portion of the grant that funded this initiative was part of the undergraduate / graduate portion designated for content enhancement for teachers and pre-service teachers. Biology 110 is offered as a general Biology course for Elementary / Middle Level (K-8) Education majors. The course consists of a weekly four-hour lab and an additional one-hour recitation, which meets two days after the lab. The course was, and still is, taught as a collaboration between the College of Arts and Science (Biology Department) and the College of Education (Curriculum and Instruction Department), and was co-taught by professors from the Biology Department and the College of Education.

The labs were designed utilizing a hands-on inquiry approach to teaching content biology within the framework of the 5-E model of Engage, Explore, Explain, Elaborate, and Evaluate as described by Bybee and Landes (1990). Biology concepts covered in the lab were comparable to the topics and concepts in Biology 100 and included a range of environmental concepts, biogeochemical cycles, classification, adaptation, evolution, the cell, cell division including mitosis and meiosis, human reproduction including STDs, Mendelian genetics, molecular genetics, protein synthesis, cellular respiration, photosynthesis, and body systems and health. The lab topics were taught modeling current education methodology and pedagogy, and utilized a constructivist philosophy and a guided inquiry mode of presentation. The one-hour recitation offered two days after the lab allowed for the students to make sense of the content explored in the hands-
on setting and encouraged discussion of the reading from the text, which was generally assigned after the lab experience.

Biology 110 is open to 25 - 30 Elementary / Middle Level (K-8) Education or pre-education majors, although enrollments in the first two offerings were low, subsequent enrollment has reached the maximum capacity. This small number is comparable to a lab section in Biology 100 rather than the large lecture section. Biology 110 is currently under institutional review for UNR’s General Education "Core A" science status.

Hypotheses

There will be no statistically significant differences between the post test mean scores of those who participated in Biology 110, Biology for Education Majors, and the students who participated in Biology 100, Principles and Applications of Biology, during the five years that Biology 110 has been taught.

Delimitations and Limitations of the Study

All efforts were made to insure that both Biology 100 and Biology 110 covered the same topics through aligning the syllabus of Biology 110 to that recommended by the department of Biology. Each professor of Biology 100, however, is given some freedom to adjust the course based upon personal interest or experience. Therefore, the topics covered in the different courses, even the different sections of Biology 100, may not have been covered in equal depth or breadth.

The questions taken from The National Association of Biology Teachers (NABT) Biology Content Exam, the instrument chosen to assess the learning of the students, were previewed by all professors teaching courses in this study prior to the study’s onset. The
questions used on the instrument were considered by the professors to be both valid and to cover topics that should be included in Biology 100, regardless of the professor focus. The Biology 110 course attempted to align content with the Biology 100 course by following the recommendations of the Department of Biology. With the differences in teaching style and preference of topics, there were no guarantees that all the questions would ask precisely what students had studied in their courses.

Class size is also an issue, which must be considered. Those who participated in the Biology 110 course had a considerably smaller class size than those who were in Biology 100 due to the fact that the Biology 110 course was initially offered as a pilot course and then later had a class size cap. However, the class size cap is similar in size to a lab section of Biology 100. All efforts were made during the analysis to compensate for the differences by performing non-parametric statistical analyses on the data.

Finally, due to the incredible amount of data generated from the large sections of Biology 100 along with the resources involved, the professor in Biology elected to discontinue the collection of data from the Biology 100 sections. Data from 2001 and 2002 were used as the baseline of comparison for each year of the Biology 110 students and it should be noted that there was no statistically significant difference between post test scores of the 2001 and 2002 Biology 100 test scores.

Review of the Literature

The publication of the Third International Mathematics and Science Survey (TIMSS) (1999) reported that the trend in science achievement in the United States was slightly below that of the international average, though there was an insignificant gain in
scores between 1995 and 1999 (p. 36). Results from the United States Department of Education show that the average science scores between 1996 and 2000 remained the same for students in grades four and eight, but dropped significantly in grade twelve (United States Department of Education, 2001). When considering the ultimate goal of a scientifically literate society, and comparing that goal to the results of these recent studies and publications such as “Before It’s Too Late,” (National Commission on Mathematics and Science Teaching for the 21st Century, 2000) it appears that whatever is being done, it is not enough to show positive results as measured by an increase in students’ standardized scores in science.

*The National Science Education Standards* (NSES) (NRC, 1996) call for a “reform effort in science education [that] requires a substantive change in how science is taught” is not surprising (p. 56). The NSES recommend that students at all levels, as well as “prospective and practicing teachers of science, must take science courses in which they learn science through inquiry, having the same opportunities as their students will to develop understanding” (p. 61).

There is a relationship between the experiences pre-service teachers have during their elementary and secondary education and how comfortable they feel learning the subject later. Research has shown that pre-service teachers who learned science during elementary and secondary schools in an atmosphere that encouraged questions and provided hands-on experiences were more likely to feel positively toward the subject and were more comfortable while learning science as college students (Moore & Watson 1999; Mulholland & Wallace, 1996). A positive correlation has been shown to exist between an Elementary Education major’s previous experience in school and with
informal science activities and his or her confidence while teaching science. Indeed, Jarrett (1999) found that “the best predictor for interest in science was a positive experience in elementary school” (p. 53). Watters and Ginns (1997) found that when Elementary Education majors were in the position to learn subject content, but were not comfortable with the subject, “high levels of anxiety are generated leading to an expressed desire to avoid the teaching of these subjects in their future career” (p.13). Spector and Strong (2001) indicate that learning science through inquiry goes against the culture of most current pre-service elementary teachers’ science education.

Tingle (2000) found that many practicing teachers who did not have the opportunity to learn science in a manner recommended by the NSES were “intimidated by activities in the classroom...because activities made students ask questions, and the teachers often did not have the answers” (p. 42). As students of all ages learn science, they need to experience it in a hands-on, inquiry manner, thus increasing their comfort with the subject and the likelihood that they will take more science courses through their education. A number of these students will go on to become the teachers who will be able to create such an atmosphere in their own classrooms. In order to raise scores in elementary and secondary classrooms, colleges and universities need to have courses that provide experiences for preservice teachers where they can become comfortable with the subject and from that comfort gain the content so that they can, in turn, create positive learning experiences for their students. Therefore, the courses where future teachers of science and of all subjects learn the concepts they will later teach must be critically evaluated.
With the number of Elementary Education students who come to universities with low levels of comfort and interest in science, changes must be made in how they experience the subjects. Schools of higher education must look to creating courses that will increase learning and comfort levels while they teach the content. In an attempt to create experiences that conform to the NSES, many universities have created special lab sections or science courses that teach science content in a hands-on, inquiry manner, many of which are designed specifically for Elementary Education majors.

Creating specialized lab sections that incorporate, through hands-on or inquiry based activities, the information given in traditional prescriptive labs has shown to increase student attitude and learning. Leonard (1983) reported that modification of the lab portion of the University of Nebraska, Lincoln’s introductory Biology course to a more problem based, inquiry oriented program resulted in a significant increase in the amount of content and concepts learned when compared to those who attended labs based on more prescriptive methods. Stallheim-Smith and Scharmann (1994) found that by creating an atmosphere where the “personal needs, learning styles, and interest orientations of Elementary Education majors” were met in a special recitation section of their general “Principles of Biology” course there were significant results in achievement (p. 170). Students in this section scored higher in average grade distribution when compared to other sections taught by the same instructor, sections taught by other instructors during the same semester, and even when compared to the cumulative data for the previous ten years (pp. 175, 176).

Modifying college level courses from the traditional lecture based, teacher centered format to one that is constructivist and learner centered has also shown positive
results. In a comparison of an Environmental Sciences course where two control sections participated in a teacher centered traditional format and two experimental sections participated in learning the same content in a more student centered constructivist format, Lord (1999) reported that the students in the constructivist based class “performed significantly better on exams, rated the course higher, and participated in more campus and regional environmental efforts than students in traditional classes” (p. 22). Christianson and Fisher (1999) found that Biological concepts were understood better by students who participated in a discussion group and laboratory class based on constructivist philosophy than those who learned the same concepts in a large traditionally designed lab/lecture course. They maintain that understanding regarding the concepts of biology “may be forfeited in large lecture biology courses, even with skilled and educated teachers” teaching the courses (p. 687) and that small groups who participated in inquiry based instruction “developed deeper understanding” of the concepts compared to those who learned then in larger lecture based classrooms (p. 695). Developing good attitudes is important, but exploring the attitudes with intention to teach science takes this research to yet another level. Weld and Funk (2005) explored the intentions of pre-service elementary majors to teach science in their future classrooms based upon a content Biology course that added the National Science Education Standards expectations and standards into an inquiry course. They found significant growth in the four domains of teacher expectations that they explored.

In order to encourage preservice teachers toward science, colleges and universities around the country have been creating specialized science classes designed specifically to meet the needs of Elementary Education majors. Professors of physics or
biology would not be expected to be experts on the newest and most effective teaching practices in elementary education (K-8), nor would one who specializes in education be expected to be expert at all of the disciplines of science. Therefore, education and science professors need to work together to create experiences that integrate content and pedagogy (Stevens & Wenner, 1996; NRC, 1997).

At Clemson University, a physical sciences course for Elementary Education majors has shown significant results. Instead of the traditional design of a lecture followed by a lab situation, science concepts were taught in a format where content was integrated with application. It was found that reducing the amount of time students had between when the discovery phase (the lecture) and the concept development and application phases (the lab) took place student attitudes toward the subject and the teaching of it were more positive than if there was a period of hours or days between them. Students who took this course were three times more likely to agree to the statement “I look forward to teaching physical science,” and the students’ attitudes toward science were more positive after the experience (Fones et al., 1999).

At St. Cloud’s University, Hall (1992), describes “Biology for Elementary Teachers,” a three credit undergraduate course. Teaching methods used include “inquiry and problem solving using a variety of hands-on/minds-on, process oriented activities,” that were shown to be "influential in promoting positive attitudes toward science and science teaching." (pp. 239, 240).

Pennsylvania State University created an integrated science course whose central focus was the microbial world. The course was created by a collaborative team including professors of chemistry, physics, molecular biology, and science education (McLoughlin
Qualitative research gathered resulted in two assertions. The first is that “learning science was most meaningful...when it was framed within a context of pedagogy,” and the second was “activity based experiences, pedagogically-oriented assignments and the development of classroom community” were the factors that led to an increase in student confidence and learning in their classroom (pp. 78, 80).

In a multiple case study of students in a hands-on Biology course designed for preservice teachers at the University of Nebraska, Lincoln, a substantive theory was generated regarding the five stages preservice teachers went through during the course of the semester. The first stage is hesitation and reservations where the students feel anxiety, usually based upon prior negative experiences with science. This is followed by awareness and enjoyment. At this point the students have overcome their initial hesitation and have come to enjoy the act of “doing” science. Next comes an intrinsic shift in understanding where the learner begins to relate classroom exercises to not only themselves as learners, but to themselves as future teachers. After this personal shift, there is a rapid growth in self-confidence and efficacy, which is followed by empowerment (Crowther & Bonstetter, 1997). When students finally reach the stage of empowerment they “have full confidence in themselves and their abilities to actually teach science in their future classrooms”(p. 15). This class also showed through a pretest / posttest examination given to the group that a significant amount of learning took place during the semester (p.5).
All of the courses found that were designed to teach science content in an inquiry manner, and especially those that integrated the pedagogy of teaching, showed positive results. The vast majority of the research shows positive affective results. Students were found to be more interested, more likely to take other science courses, and more comfortable with science and science teaching. Two of the courses that incorporated constructivist learning methods and showed positive results in content learning did not look specifically at education majors (Lord 1999; Christianson & Fisher, 1999).

Stallheim-Smith and Scharmann (1994) presented results that measured the content learned by preservice teachers in a specialized section compared to students in a more traditional situation; however, the course on which they reported was a specialized recitation section of a science program that had been in place for some time. Crowther and Bonstetter (1997) showed that there was an increase in student learning over the course of a semester, but did not compare that learning to a more traditional situation. More research needs to be done to determine if students in general and Elementary Education majors specifically, learn the content of the subject in such specialized courses, and how the content learning compares to that of traditionally taught courses.

Methods

Design

A quasi-experimental pretest-posttest design was used for this study. Students enrolled in Biology 100 during the spring semesters of 2001 and 2002 and the students enrolled in Biology 110 from 2001 – 2005 were the basis for the groups involved. Those
in Biology 100 were introduced to biological concepts through a traditional teacher
centered lecture and laboratory format consisting primarily of didactic teaching coupled
with teacher demonstrations. The large lecture format made student / professor
interaction difficult. Students were expected to have read the information in their
textbook regarding the topic prior to the lecture. Biology 100 students participated in a
lab section four times during the semester, which were taught by Graduate Teaching
Assistants (GTAs) from the department of Biology. During these labs, they participated
in experiments related to the topics covered in the lectures and related to their readings.

Biology 110 was designed to teach the same topics as Biology 100. However,
students participated in constructivist-based investigations that integrated scientific
methodology with educational pedagogy. The class met twice a week, once for a four-
hour lab experience and again later in the week for a one-hour recitation. During the lab
meetings small groups of students (n = 4) worked together on investigations presented in
a 5-E inquiry method as proposed by Bybee and Landes (1990). The recitation met later
in the week to discuss problems students were having understanding concepts, to
elaborate on the concepts presented in the lab, and to provide time for student reflection
and discussion. Students were expected to read from their textbook after being
introduced to the topic during the lab experience but before the recitation meeting.
Biology 110 students were also required to keep track of their learning through journals,
in which they described the lessons they were presented, ask questions, relate concepts to
personal situations, and engage in personal written dialogue with the instructors regarding
biological concepts, learning, pedagogy, and concerns.
While Biology 100 and 110 were both designed to teach the same biological concepts, Biology 110 embedded them in the learning experience by involving learning through hands-on investigations and inquiry and coupled the content of the course with pedagogy that related to the teaching of science. Through a pretest and posttest given to both classes on the first and last day of the semester, this study was designed to determine if the instructional format used to present the content information would result in a difference in learning of the biological concepts between the two classes.

In order to determine if there was a significant difference in learning, the pretest and posttest mean scores of the Biology 110 and Biology 100 students were compared using an Analysis of Variance (ANOVA) statistical analysis and a Neuman-Kuels Multiple Comparison test.

Subjects

All subjects who participated in this study were undergraduate students at the University of Nevada, Reno during the Spring semesters of 2001 through Spring 2005. The majority of the students were freshmen or sophomores, and all were enrolled in Biology 100 or Biology 110. All students enrolled in Biology 110 had declared themselves as Elementary Education majors or were in the process of being accepted into the program. The subjects in Biology 100 represented non-biology majors from departments and colleges throughout the university, including some Elementary Education majors. The number of subjects in Biology 110 were 194 pre and 193 post in 2001 and 179 pre with 149 post in 2002. Note that the number of students changed over the course of the semester due to absences, declaring their major during the course of the
semester, and attrition. The number of Biology 110 students was low, but reflected a small to average lab section in Biology 100 and were greater than or equal to the number of Elementary Education majors in Biology 100 (2001 = 15, 2002 = 12, 2003 = 17, 2004 = 24, and 2005 = 28).

Instrument

The National Association of Biology Teachers (NABT) Biology Content Exam was developed in conjunction with the National Science Teachers Association (NSTA) as a high school exit exam for Honors placement in college level biology courses. In this study, the students’ understanding of biology content was measured by administering a modification of the NABT Biology Content Exam using a pretest-posttest design. In a previous study, thirty questions had been selected from the NABT test and administered to general Biology courses at the University of Nebraska, Lincoln (Bruning & Glider; unpublished). Test questions were selected that covered a broad range of content and several evaluative (process skills) questions. The validity and reliability were not changed from the Bruning and Glider study, but were within acceptable ranges. This instrument was reviewed by instructors of both the Biology 100 and Biology 110 courses prior to the beginning of the study and approved it for content validity.

Variables

The dependent variable in this study were the scores on a modification of the National Association of Biology Teachers (NABT) Biology Content Exam given to the students in the Biology 100 and Biology 110 courses. The independent variable in this study was the difference in the teaching strategies that were used between Biology 100
and Biology 110, specifically, the constructivist approach to teaching Biology 110. Intervening variables in this study included gender, number of subjects, and that the number and make up of subjects in the study included all available and willing participants.

*Procedure*

On the first day of class for both Biology 100 and Biology 110 copies of the NABT Biology Content Exam were given to students who were asked to answer the questions to the best of their ability. The participants were made aware that their answers on this test were going to be used for research purposes and would not be looked at until after the course was over. They were reminded that participation would not negatively affect the grade they received in the course. Any student who did not want to be part of the study was given the option to not take the test. However, 5 points of extra credit (a non significant number) was offered for participation in the study. Participants were asked to write their declared major or pre-major on the test. As students finished, tests were collected and stored for the duration of the semester.

On the final day of classes, students were again given copies of the NABT Biology Content Exam, identical to those that had been taken on the first day of the course and were asked to answer to the best of their ability. Again, they were asked to write their declared major or pre-major on the test. Participants were told that the tests were given for research purposes, and that their participation would not negatively affect their grade in the course. As students finished the test they were collected and stored until the end of the semester for analysis.
Data Analysis

Data was collected in the form of pretest and posttest scores from the NABT Biology Content Exam as taken by those who participated in Biology 100 (for years 2001 and 2002) and Biology 110 (2001 – 2005). Analyses were performed on the pretest scores of those in Biology 110, Elementary Education majors in Biology 100, and students of all majors, including Elementary Education, in Biology 100 to determine if they could be considered homogeneous groups at a .05 alpha level (p-value). Additional t Tests were run on each group separately to determine any significant pretest / posttest difference. An analysis of variance test (ANOVA) was then performed to establish the existence of any significance between the pretest / posttest means between the groups, and a Newman-Keuls multiple comparisons test was used to show where the significant differences found in the ANOVA, if any, occurred.

Results

For data analysis purposes, the Biology 100 and 110 students were put into groups according to the year they took the course, pre and post test designation, academic major, number of subjects, standard deviations, and mean scores. (see Table 1). The Analysis of Variance (ANOVA) and multiple comparisons of groups are included in Table 2.
### Table 1

**Group designations of Biology 100 and Biology 110**

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Biology 100 or 110</th>
<th>Major</th>
<th>Year</th>
<th>Test Designation</th>
<th>Subjects</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>1</td>
<td>Bio 110</td>
<td>Education Majors</td>
<td>2001</td>
<td>Pre-test</td>
<td>15</td>
<td>15.1333</td>
<td>3.8705</td>
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<td>Bio 110</td>
<td>Education Majors</td>
<td>2001</td>
<td>Post-test</td>
<td>15</td>
<td>20.0</td>
<td>4.9857</td>
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<td>Ed Majors in 100</td>
<td>2001</td>
<td>Pre-test</td>
<td>13</td>
<td>11.3077</td>
<td>5.266</td>
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<td>Ed Majors in 100</td>
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<td>Post-test</td>
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<td>11.0714</td>
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<td>2001</td>
<td>Pre-test</td>
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<td>Pre-test</td>
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<td>Post-test</td>
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<td>11.4</td>
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<td>General (all students)</td>
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<td>Pre-test</td>
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<td>4.0147</td>
</tr>
<tr>
<td>15</td>
<td>Bio 110</td>
<td>Education Majors</td>
<td>2004</td>
<td>Pre-test</td>
<td>24</td>
<td>12.125</td>
<td>3.8029</td>
</tr>
<tr>
<td>16</td>
<td>Bio 110</td>
<td>Education Majors</td>
<td>2004</td>
<td>Post-test</td>
<td>24</td>
<td>15.8333</td>
<td>4.4786</td>
</tr>
<tr>
<td>17</td>
<td>Bio 110</td>
<td>Education Majors</td>
<td>2005</td>
<td>Pre-test</td>
<td>26</td>
<td>13.5385</td>
<td>2.9696</td>
</tr>
<tr>
<td>18</td>
<td>Bio 110</td>
<td>Education Majors</td>
<td>2005</td>
<td>Post-test</td>
<td>28</td>
<td>18.5714</td>
<td>4.1937</td>
</tr>
</tbody>
</table>
Table 2

Analysis of Variance and multiple comparisons of Biology 100 and Biology 110

<table>
<thead>
<tr>
<th>Source</th>
<th>S.S.</th>
<th>d.f.</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>3071.79</td>
<td>17</td>
<td>180.69</td>
<td>7.6</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22362.78</td>
<td>940</td>
<td>23.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25434.56</td>
<td>957</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Newman-Keuls Multiple Comparison*

| Gp  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 4   | 3 | 10| 15| 6 | 5 | 12| 13| 9 | 11| 17| 1 | 16| 8 | 18| 14| 2 |

* This is a graphical representation of the Newman-Keuls multiple comparisons test. At the 0.05 significance level, the means of any two groups underscored by the same line are not significantly different.

** Denotes Biology 110 post test scores for each year of the study

Conclusion

The hypothesis of this study stated that there would be no statistically significant difference between the post test mean scores of those who participated in Biology 110 and the post test mean scores of students who participated in Biology 100. Data was collected over the 5 year span of the study. The pre / post test data was analyzed with an Analysis of Variance (ANOVA) \((F=7.6, p \leq .001)\) to show that there was a significant difference between groups. A Newman-Keuls multiple comparison test was then used to show where the differences were made. The data clearly demonstrate that the Biology 110 post test (groups 2, 8, 14, 16, and 18) were significantly different than the post test
scores of the Biology 100 students (groups 6 and 12) and the Education Majors in Biology 100 (groups 4 and 10).

Therefore, the hands-on inquiry based instructional format used in the Biology 110 course for Elementary / Middle Level Education majors did appear to make a difference in biological content learned in the undergraduate course for each year of the study.

Discussion

As can be seen by the results of this study, the delivery and use of hands-on investigative labs and the use of inquiry seemed to make a difference in the content learned and retained over the period of an academic semester. That difference held each semester that Biology 110 was taught as compared to students taking the regular Biology 100 course. The data is impressive, but does have some limitations. The fact that we were only able to collect data from Biology 100 for two years of the study is a limitation, however, the results of the post test scores from Biology 100 for those two years was not significant, thus suggesting that there is a beginning of a trend in the Biology 100 post test data.

The second concern that may arise from this study is the number of students involved in Biology 110. For the first few years, the student enrollment was low due to the new course offering. However, as the course grew in both availability and popularity the enrollment rose. Again, the enrollment in Biology 110 was similar to the lab sizes that Biology 100 uses and was similar in size to the number of Elementary / middle level Education majors that were enrolled in the Biology 100 course. With that said, many
people would speculate that with fewer students a greater difference could be made. However, lecturing to 15 – 30 students is still the same as lecturing to a larger group. This would suggest that we look to alternative ways of teaching to both populations.

With those concerns noted, the significance of this study is considerable. Several previous studies have found that Elementary Education majors show a marked increase in attitude toward science and confidence with the subject when the learning of science content is combined with pedagogy (Weld & Funk, 2005; Watters & Ginns, 2000; Crowther, 1996; Shroyer et al., 1996); however, these studies are generally qualitative in nature and deal with the affective results gained through similar courses. Other studies have been found on the subject, however, few (to this date) demonstrate, empirically, whether or not Elementary Education majors show an increase in content learning in such an environment as Biology 110 (Willden, 2002; Crowther & Bonnstetter, 1997).

Additionally, constructivist based, inquiry approaches to teaching are significantly more expensive in both resources and faculty time. Though reform in education at all levels has been called for in order to increase the science literacy of the population at large (NRC, 1996), courses that conform to such recommendations require that a college or university invest greater amounts of money and faculty resources in the design and teaching of introductory science courses. Demonstrating, with this study, that more content knowledge is learned and retained over a semester and that positive affective results are eminent when compared to traditional teaching methods, may help to justify the expense of separate core science classes for prospective teachers. Though expensive for the institution to implement, the change in attitude and learning of the teachers who
graduate from such programs could be profound. Future generations of students at all levels of education would have teachers who were more comfortable and knowledgeable with science and would be better able to create positive learning environments.

Implications for Further Research

To extend this research other experimental core science courses (physics, chemistry, and earth science) for Elementary Education majors using a similar design, should be constructed and empirically analyzed. Such courses could create a hands on, inquiry based science program designed to elevate content understanding and a broad familiarity of the sciences for a population, for both prospective and practicing teachers in addition to elementary students, where such a demand exists.

A long-term study of students who participate in this course, or courses such as Biology 110, could also be followed over the course of their education and into their teaching to determine how taking hands-on inquiry based classes affect their classroom teaching.
References

Bruning R. & Glider, W. (Unpublished). Study performed on both content knowledge and attitudes of undergraduate students at the University of Nebraska, Lincoln. Unpublished study and modification of the National Association of Biology Teachers instrument. Study completed in 1996.


