DOCUMENT RESUME

ED 465 607	SE 066 329
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TITLE	A Quantitative Comparison of Instruction Format of Undergraduate Introductory Level Content Biology Courses: Traditional Lecture Approach vs. Inquiry Based for Education Majors.
PUB DATE	2002-01-00
NOTE	23p.; In: Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science (Charlotte, NC, January 10-13, 2002); see SE 066 324.
AVAILABLE FROM	For full text: http://aets.chem.pitt.edu.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Biology; *Elementary School Teachers; Hands on Science; Higher Education; Inquiry; Introductory Courses; Lecture Method; Nontraditional Education; *Preservice Teacher Education; Science Instruction; *Teaching Styles; Undergraduate Study

ABSTRACT

The purpose of this study was to determine if there were 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. Biology 100, an introductory biology course for non-majors, was taught in a traditional lecture and laboratory format. Biology 110 was a newly created course designed for elementary education majors using an approach recommended by the National Science Education Standards. This approach includes inquiry, collaborative work, and investigations. Data analyses should reflect any difference in students' understanding of the biological content presented in each course based upon final examination scores. The instructional format (inquiry and hands-on) used in the Biology 110 course for elementary education majors did prove to make a significant difference in biological content learned in the undergraduate course. (Contains 14 references.) (MVL)

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A QUANTITATIVE COMPARISON OF INSTRUCTION FORMAT OF UNDERGRADUATE INTRODUCTORY LEVEL CONTENT BIOLOGY COURSES: TRADITIONAL LECTURE APPROACH VS. INQUIRY BASED FOR EDUCATION MAJORS

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The discrepancy between how most students experience introductory science courses at the university level and how the National Science Education Standards (NSES) recommend they should be experienced 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 relate learning to the daily life of the student. The experience that the majority of students have after such a course is that of listening to many hours of lecture, reading, and memorizing material from a text. These courses are generally designed for the non-science major; those who will be future writers, social workers, and artists. However, these courses are also where most of the future elementary educators in this country will learn the science concepts they will be expected to teach in their own 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). Looking at just these few guidelines among those recommended, it is difficult to believe that elementary education majors are receiving the education

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suggested in the standards through participation in the traditional lecture and laboratory format classes. The recent publication of the report *Science Teacher Preparation in an Era of Standards Reform* recommends that universities and their faculty develop courses for elementary education students that reflect the best practices recommended by the NSES (National Research Council, 1997). 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.

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). Several science courses for education majors have been created around the country through collaborative efforts between departments and colleges with positive results. Specialized chemistry classes have been created at Colorado State University and at the University of Maryland (O'Haver, 1997; Jones et al, 1997). Research gathered from a physics class for education majors at Pennsylvania State University found by integrating content taught in a hands on manner with pedagogical practices in a comfortable classroom setting that students confidence and learning were enhanced (McLoughlin & Dana, 1999). Biology courses for education majors at the University of Nebraska and St. Clouds have promoted positive changes in attitude toward science and in the confidence the students in seeing themselves as science teachers (Hall, 1992; Friedrichsen, 2001).

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In situations where it was impossible to create courses specifically for education majors changing the manner in which students participate in the traditional lecture and lab have also shown positive results. At Clemson University, a program had been previously introduced that provided education majors with experiences that followed NSES recommendations embedded in a format of lecture and lab. Recent research by Fones et al. (1999) found that by 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, through integration in an experimental course, student attitudes toward the subject and the teaching of it were more positive. Stallheim-Smith and Scharmann (1994) found that by creating a recitation section specifically for education majors where their "learning styles and interest orientations" were considered significant differences were found in the achievement when compared to other sections during that semester and when compared to the cumulative data from the previous ten years (p. 170).

Recent literature exists that demonstrates that the establishment of science courses for elementary education majors proves to have positive effects, however, the controversy of "specialized" sections or courses still exists. It is important to acknowledge that the most of the recent literature research has been on the students' attitudes or comfort levels with the subject. 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 learning more than a positive attitude.

Purpose

The purpose of this study is to determine if there were 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, an introductory biology course for non-majors, is taught in a traditional lecture and laboratory format. Biology 110 was a newly created course designed for elementary education majors using an approach recommended by the NSES (1996). This approach includes inquiry, collaborative work, and investigations. Data analyses should reflect any differences in students understanding of biological content presented in each course, based upon final examination scores.

From this research, new information regarding the relationship between how a course is taught and the understanding of course content by the students may be gained. This may effect how college-level science courses are designed, independent of students' academic majors. If it can be demonstrated that students who participated in the Biology 110 course, *Biology for Education Majors*, outscored their peers in the traditional Biology 100 course, *Principles and Applications of Biology*, than the methods of teaching used in the Biology 110 course could be advocated for other science content courses at the college-level.

Background

The University of Nevada, Reno (UNR) offers two lecture sections of Biology 100, which are composed of between 150 - 200 students per section and 15 lab sections where the students are divided evenly, usually about 20 students per lab section. Biology 100 is a survey course offered in general content biology for all non science majors. It is a Core A science requirement (Core A meaning that it is a core science with a minimum lab hour requirement in addition to a pre-requisite in college algebra and a writing requirement). Biology 100 meets for lecture two times per week and has a requirement of a three hour lab that must be attended four times during the semester. UNR also offers Biology 190 for science majors (which was not considered in this study).

Biology 110 was originally developed and taught in the spring semester of 2001. The course was initially funded by a Howard Hughes Medical Institute (HHMI) Grant to the University of Nevada, Reno. The portion of the grant funding this initiative is part of the undergraduate / graduate portion of the grant for content enhancement for teachers and pre-service teachers. Biology 110 was offered as a general biology course for elementary (K-8) education majors. The course consisted of a weekly four hour lab and an additional 1 hour recitation, which meet two days after the lab. The course was taught as a collaboration between the College of Arts and Science (Biology Department) and the College of Education (Curriculum and Instruction Department) Dr. Alan Gubanich co-taught the course from the Biology Department and Dr. David Crowther co-taught the course from the College of Education. The lab was designed using a hands-on inquiry approach to teaching content biology. 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 and Cell Division (Mitosis), Meiosis, Human Reproduction (including STD's), 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, utilizing a constructivist philosophy and an inquiry mode of presentation. The one hour recitation, which was offered two days after the lab, allowed for the students to make sense of the content explored in the hands-on setting and allowed for discussion of the text which was assigned to be read (most often) after the lab experience.

Biology 110 was open to 25 - 30 elementary (K-8) education / pre-education majors, although only 15 enrolled in the course. This small number was to be more comparative to a lab section rather than a lecture section. Biology 110 is currently under institutional review as a Core A science.

Hypotheses

Hypothesis 1: There will not be a statistically significant difference between the pretest and posttest mean scores of those who participated in Biology 110, *Biology for Education Majors*, during the spring semester of 2001.

Hypothesis 2: There will not be a statistically significant difference between the pretest and posttest mean scores of elementary education majors who participated in Biology 100, Principles and Applications, during the spring semester of 2001.

Hypothesis 3: There will not be a statistically significant difference between the pretest and posttest mean scores of all students who participated in Biology 100, Principles and Applications, during the spring semester of 2001.

Hypotheses 4: There will not be a statistically significant difference between the post test mean scores of those who participated in Biology 110, *Biology for Education*

Majors, and the elementary education majors who participated in Biology 100, Principles and Applications, during the spring semester of 2001.

Hypothesis 5: There will not be a statistically significant difference between the post test mean scores of those who participated in Biology 110, *Biology for Education Majors*, and all students who Participated in Biology 100, Principles and Applications, during the spring semester of 2001.

Review of the Literature

The recent 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 between the scores from 1995 to 1999 (p. 36). Results from the United States Department of Education showed 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 outcome 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 not enough is being done to change the experiences students have while learning 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" (p. 56) is not surprising. 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). The learning that takes place in a classroom is dependent upon the effectiveness and attitude of the teacher in that classroom toward the subject being taught.

There is a relationship between the experiences preservice teachers have during their elementary and secondary education and how comfortable they feel learning the subject later. Research has shown that preservice 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 (Mulholland & Wallace, 1996; Moore & Watson 1999). 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). 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

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number of these students will go on to become the teachers who will be able to create such an atmosphere in their own classrooms.

Many elementary education students, however, come to universities with low levels of comfort and interest in science. In an attempt to create experiences that conform to the NSES many universities have created science courses that teach science content in a hands-on, inquiry manner, some specifically designed for elementary education majors. The following does not attempt to relate all courses created with a similar design, but to show the diversity of classes that have been created recently around the country. At the University of Portland a course designed for education majors but open to all non-science majors was created. According to Tolman (1999) the sophomore level "Natural Science Course" they have developed covers a variety of science topics, all of which were taught in a manner designed to keep the students active in their learning. Results of this course include a "marked decrease in [the students'] fear of math and science courses" (pg. 45). Western Washington University developed a course that was designed to be a "capstone" that would integrate the content learned during core science courses by providing investigative situations for elementary education majors to apply what they have learned. After taking this class, students had a greater confidence with and understanding of inquiry science (Morse, 1999). 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. 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 towards science was more positive after the experience (Fones et al., 1999).

Research on three different courses around the country that were designed for education majors and based on teaching the content of Biology using the inquiry methods recommended by the NSES have been found. 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 &Dana, 1999). 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," (p. 78) and the second was "activities based experiences, pedagogically-oriented assignments and the development of classroom community" were the factors that lead to an increase of student confidence and learning in their classroom (p. 80). 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," (p.239) that were shown to be "influential in promoting positive attitudes toward science and science teaching…" (p.240). Stallheim-Smith and Scharmann (1994) found that by creating an atmosphere where the "personal needs, learning styles, and interest orientations of elementary education majors" (p. 170) were met in a special recitation section of their "Principles of Biology" course there were significant results in achievement. 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 (p.175), and when compared to the cumulative data for the previous ten years (p. 176).

All of the courses designed to science content in an inquiry manner, and especially those that integrated the pedagogy of teaching, showed positive results. The vast majority

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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. Only Stallheim-Smith and Scharmann (1994) presented results that measured the content learned by the students, and the course on which they reported was a specialized recitation section. Positive affective results have been shown to be the result of courses designed to teach science content, but more research needs to be done to determine if the students learn the content of the subject in such courses.

Methods

Design

A quasi-experimental pretest/posttest design was used for this study. Students who were enrolled in Biology 100 and Biology 110 were the basis for the groups who were involved. Those in Biology 100 were introduced to biological concepts through a traditional lecture and laboratory format consisting primarily of didactic teaching coupled with teacher demonstrations. Students were expected to have read the information in their textbook regarding the topic prior to the lecture. Students participated in a once a week lab section taught by graduate teaching assistants from the department of Biology where they experienced experiments related to the topics covered in the lectures and their reading.

Biology 110 was designed to teach the same topics as Biology 100. However, students would participate in hands-on investigations that integrated scientific methodology with educational pedagogy. The class met twice a week, once for a four-hour lab experience and once for a one hour recitation. During the lab meetings small groups of students worked together on investigations presented in a 5-E inquiry method as proposed by Bybee and Landes (1990). The recitation met to discuss problems

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students were having understanding concepts, elaborate on the concepts presented in the lab, and provide time for student reflection and discussion. Students were expected to read their textbook after being introduced to the topic from the lab experience.

Biology 100 and 110 both have the aim of teaching the same biological concepts. Biology 110 embeds them in the learning experiences involving hands on investigations and inquiry and couples the content of the course with science teaching pedagogy. Through a pretest/posttest given on the first and last day of classes to both groups this study is designed to determine if how the information was presented would result in a difference in the learning of the biological concepts between the two classes.

In order to determine if there is a significant difference in learning, the pretest and posttest mean scores of the Biology 100 and Biology 110 students were compared using an Analysis of Variance (ANOVA) statistical analysis. Hypotheses, mentioned above, were answered according to the six groups of data

Subjects

All subjects participating in this study were undergraduate students at the University of Nevada, Reno (UNR). The majority of students were freshmen or sophomores, and all were enrolled in Biology 100, *Principles and Applications of Biology*, or Biology 110, *Biology for Education Majors*. All students participating in Biology 110 ($n = 15$) were students who had been accepted as students in the College of Education or were planning on entering. The subjects in Biology 100 ($n = 194$) represented non science majors from departments and colleges throughout the university, including elementary education majors ($n = 14$). Biology 110 majors were few in numbers due to the fact that this was the first time that the course was taught, but reflect a small to average lab section in Biology 100.

Instrument

The National Association of Biology Teachers (NABT) Content Biology Test was developed in conjunction with the National Science Teachers Association (NSTA) as an exit exam for Honors placement in college level biology courses. Content biology was measured by using a pre / post test design on a modification of the (NABT) Biology Content Test. 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 using 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. Content validity was reviewed by Dr. Alan Gubanich, UNR and was approved for this study.

Variables

The dependent variable in this study was the score on the NABT exam of 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 hands-on inquiry approach to teaching Biology 110. Intervening variables in this study included gender, number of subjects and the fact that the number of subjects included all available and willing participants in the study.

Procedure

On the first day of class for both Biology 100 and Biology 110 copies of the NABT Biology Test 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, and that participation would in no way effect 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 on the test their declared major or pre-major. As students finished, tests were collected and stored for the duration of the semester.

On the final day of classes, students were given copies of the NABT Biology Test identical to those, which 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. Participants were told that the tests were given for research purposes, and that their participation would in no way effect their grade in the course. As students finished the test they were collected and stored for analysis.

Data Analysis

Data was collected in the form of pre and posttest scores from the NABT Content Biology Test from those who participated in Biology 100 and 110. Analyses were run on the pretest scores of those in Biology 110, elementary education majors in Biology 100, and all students in Biology 100 to determine if they were homogeneous groups at a .05 alpha level (p-value). Additional t Tests were run on each group separately to determine if they had a pre-post test difference. An ANOVA was run to find if there was any significance between the pretest / posttest means of the groups, and a Newman-Keuls multiple comparisons test was used to determine where the significance differences occurred.

Results

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Initial ANOVA testing concluded that there was no significant difference (Alpha .05) between the three groups on pre-test mean scores. Thus the groups could be considered homogeneous groups at the onset of the study.

Hypotheses one through three were initially explored with t Tests, with significance to be determined at the .05 level. These hypotheses addressed whether there were differences within each individual group. The only group that showed a statistically significant difference from pretest to posttest was the experimental Biology 110 group, with a p-value equal to .006. (See Table 1)

Table 1

Group Mean Score Comparison between Biology 100 and Biology 110 students

Group	N	NABT pretest	NABT posttest	Mean difference	p-value
Biology 100 (All students)	194	12.39	12.33	-0.055	0.91
Biology 100 (Education Majors)	14	11.30	11.07	-0.24	0.92
Biology 110	15	15.13	20	4.8	0.006

In order to determine the existence of significance between the groupings an ANOVA was run. The ANOVA showed significant difference ($p < .001$) between the groups using all scores (both pre and post). A Newman-Keuls multiple comparison test determined that at the .05 alpha level there were statistically significant differences between the posttest mean scores of those in Biology 110 (the Elementary Education majors experimental section) and the posttest mean scores of both the elementary education majors in Biology 100 and the group of all students in Biology 100 (both traditionally taught). (See Tables 2 - 5)

Table 2

Independent Group Analysis between Biology 100 and Biology 100 students

Group Name and Number	Mean	SD	N
Biology 110 Pre-test (1)	15.13	3.87	15
Biology 110 Posttest (2)	20.00	4.98	15
Biology 100 Ed. Majors			
Pretest (3)	11.30	5.26	13
Biology 100 Ed. Majors			
Posttest (4)	11.07	6.46	14
Biology 100 All Students			
Pretest (5)	12.39	4.39	194
Biology 100 All Students			
Posttest (6)	12.33	5.49	193

Table 3

Analysis of Variance Table (ANOVA) between Biology 100 and Biology 110 students

Source	S.S.	DF	MS	F	Approx. P
Total	11965.77	443			
Between Groups	993.01	5	198.6	7.93	<.001
Within Groups	10972.77	438	25.05		

Table 4

Newman-Keuls Multiple Comparison Test Between Groups

Newman-Keuls Mult. Comp.	Diff.	P	Q	Critical q (.05)
Mean(2)-Mean(4) =	8.9286	6	6.789	4.041 *
Mean(2)-Mean(3) =	8.6923	5	6.481	3.869 *
Mean(2)-Mean(6) =	7.6632	4	8.078	3.639 *
Mean(2)-Mean(5) =	7.6082	3	8.021	3.318 *
Mean(2)-Mean(1) =	4.8667	2	3.766	2.775 *
Mean(1)-Mean(4) =	4.0619	5	3.088	3.869
Mean(1)-Mean(3) =	3.8256	(Does not test)		
Mean(1)-Mean(6) =	2.7965	(Does not test)		
Mean(1)-Mean(5) =	2.7416	(Does not test)		
Mean(5)-Mean(4) =	1.3203	(Does not test)		
Mean(5)-Mean(3) =	1.0841	(Does not test)		
Mean(5)-Mean(6) =	0.055	(Does not test)		
Mean(6)-Mean(4) =	1.2654	(Does not test)		
Mean(6)-Mean(3) =	1.0291	(Does not test)		
Mean(3)-Mean(4) =	0.2363	(Does not test)		

*shows significant differences.

Table 5

Homogeneous Populations, groups ranked

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**Gp Gp Gp Gp Gp Gp

  4  3  6  5  1  2
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**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.

Conclusions

Findings indicate that the within groups hypotheses one through three there existed a significant difference only between the pretest and posttest mean scores of those who participated in Biology 110. Therefore, hypothesis one is rejected, as significant differences were found. Hypotheses two and three were accepted by the results. There were no significant differences between the pretest and posttest scores of elementary education majors taking Biology 100 or in the scores for all students in Biology 100.

Hypothesis four stated that there would be no statistical difference between the posttest mean scores of the elementary education majors who took Biology 110 and those who took Biology 100. This hypothesis is rejected. A significant difference ($p = .05$) between the posttest mean scores was found. Hypothesis five is also rejected as the ANOVA showed that there was also a difference in the posttest mean scores at the .05 level between elementary education majors in Biology 110 and the students of all majors who participated in Biology 100.

Therefore, the instructional format (inquiry and hands-on) used in the Biology 110 course for Elementary Education majors did prove to make a significant difference in biological content learned in the undergraduate course.

Discussion

Although this study concluded that the instructional style of inquiry and hands-on labs proved to be significantly superior to traditional means of instruction, there were some points of discussion that should be made. 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, however, each professor in Biology 100 is given some freedom to adjust the course. Therefore, the topics covered in the different courses may not have been covered in equal depth or breadth.

The questions taken from The National Association of Biology Teachers (NABT) Biology Exam, the instrument chosen to assess the learning of the students, were previewed by a professor from the department of Biology. The questions used on the instrument were considered by the professor to be both valid and cover topics that should be included in Biology 100, regardless of the professor. However, with the differences in teaching style and preference of topic, there were no guarantees that all the questions would ask precisely what students had studied in their courses.

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 (Watters & Ginns, 2000; Shroyer et al., 1996), however, these studies are qualitative in nature and deal with the affective nature of science. Only two other empirical studies have been found on the subject and none (to this date) demonstrate, empirically, whether or not students show an increase in content learning in such an environment as Biology 110.

Additionally, hands on 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 their 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.

Affective data was collected in this study for both populations, Biology 110 and Biology 100, regarding student attitudes toward science and science teaching. Although the quantitative data has not yet been examined, anecdotal conversations with both populations show that the education majors in Biology 100 did not have such a positive experience and thus their attitude towards teaching and learning content biology seemed to be lower than those who took Biology 110. The quantitative data needs to be explored to verify the anecdotal conversations and subsequent courses should be analyzed to confirm that positive changes in attitude occurred in this setting.

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, both prospective and practicing teachers in addition to elementary students, where such a demand exists.

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Editors: Peter A. Rubba, James A. Rye, Warren J. DiBiase, & Barbara A. Crawford

Organization: Association for the Education of Teachers in Science

Publication Date: June 2002

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