A Comparison of Student Understanding of Seasons Using Inquiry and Didactic Teaching Methods

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Abstract. Student performance on open-ended questions concerning seasons in a university physical science content course was examined to note differences between classes that experienced inquiry using a 5-E lesson planning model and those that experienced the same content with a traditional, didactic lesson. The class examined is a required content course for elementary education majors and understanding the seasons is part of the university's state's elementary science standards. The two self-selected groups of students showed no statistically significant differences in pre-test scores, while there were statistically significant differences between the groups' post-test scores with those who participated in inquiry-based activities scoring higher. There were no statistically significant differences between the pre-test and the post-test for the students who experienced didactic teaching, while there were statistically significant improvements for the students who experienced the 5-E lesson.

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INTRODUCTION

Since publication of the National Science Education Standards [1] and the Benchmarks for Science Education [2], there has been an increasing call for reforms in science education, not just K-12 but also in higher education. Separate physics classes for elementary education majors have been called for [3,4] while reformers suggest constructivist teaching methods as both a model of inquiry and an effective means for the non-science major to develop the conceptual knowledge needed to lead the elementary classroom [5]. Teachers generally seem to teach as they have been taught [6,7,8]. In particular, faculty who teach the physics and astronomy physical science classes have graduate school experiences of lecture-based classes with many theoretical derivations of concepts where one concept is based upon another. These professors are comfortable with using variables or constants instead of numbers, using higher mathematical skills, and theoretical applications in place of real-life applications. The students in non-science major physical science classes have chosen fields different from science, either by having other interests or by poor performance in science classes. They may be more qualitative than quantitative. They may construct their scientific understandings on life experiences rather than theoretical concepts. Should physics professors teach these students and elementary education majors in particular, using the same methods by which they themselves learned the content? Since the historically, heavy emphasis on quantification in science is at odds with quantitative research methods education and the social sciences often employ [9], there is a call for quantitative evidence that constructivist teaching methods produce statistically significant improvements in student performance when compared to comparable students taught didactically.

OBJECTIVES

The purpose of this study is to compare knowledge of scientific concepts gained by non-science major university students taught by two different professors using two different methods of teaching. Research question: Are there any differences in the conceptual understanding of undergraduate non-science majors after participating in constructivist versus didactic forms of instruction? We will consider a null hypothesis that no differences in conceptual learning will be found with different methods of instruction.

Theoretical Underpinnings

Bybee [10] contends that science lessons must actively involve students, both mentally and physically, in order for learning to occur. When science professors teach non-science majors using the methods that were successful for the professors, i.e. using similar didactic methods emphasizing theoretical and mathematical derivations, students often struggle [3]. Uno suggests, “the key then is not to teach the course as if you are talking to yourself or your colleagues” [11].

Constructivism has been defined as the notion that people build their own knowledge and their own representations of knowledge from their experiences and thoughts [12, 13]. A constructivist mode of teaching incorporates either students’ prior knowledge and experiences or a class’ shared experience allowing the student to build scientific concepts upon that foundation. The 5-E lesson-planning model [14] encourages the instructor to identify misconceptions held by students and allows the instructor to modify the instruction to address these strongly held misconceptions using conceptual change teaching strategies [15, 16]. Activities that manipulate data, either collected or found from reference, at the student’s mathematical level, can help cement the scientifically accepted concepts in the student’s understandings [5, 17, 18, 19]. The 5-E lesson planning model helps pre-service teachers understand the scientific concepts they will teach while modeling lessons that can be adapted for the elementary student’s content level.

Design and Procedure

This study took place within the context of a general education physical science course at a medium sized, rural, four-year Midwestern university. About two-thirds of the 224 students enrolled in the seven sections (32 students each) of the course were elementary education majors, predominantly women, predominantly juniors, the other third being non-science majors fulfilling general education requirements. One group (“Didactic Group”) consisted of three sections taught in a traditional didactic lecture style. Their professor assumed the students understood seasons at the high school level and lectured at a university content level. Additional assignments applied the lecture’s content to two-dimensional models of the Earth and Sun. Another professor taught the “Constructivist Group,” the remaining four sections, with the treatment being the constructivist, 5-E lesson design described in Ashcraft & Courson [20].

In this two-group, pretest-posttest (OXO) design, n=148, a pre-test questionnaire was given to students to measure their initial understandings of the reasons for the seasons:

<u>Pretest – Posttest Question 1</u>

Q. What causes seasons? Why is [university’s location] warmer in our summer and colder in our winter?

A. The Earth's axis having a 23 1/2° tilt with respect to the Earth/Sun plane causes a greater amount of daylight with the Sun having a higher elevation angle in the summer, and a smaller amount of daylight with the Sun being lower in the sky. (The Earth/Sun distance does not affect seasons.) [from rubric]

<u>Pretest – Posttest Question 2</u>

Q2a. Assume the tilt of the earth changed from what it is presently to 35°. How would this affect [university’s location’s] summers and winters?

A. Both the summer and winters would be more severe. [from rubric]

Q2b. How would this affect the lengths of hours of daylight and hours of darkness?

A. The daylight would be longer in the summer (nighttime shorter) and the nighttime would be longer in the winter (daytime shorter). [from rubric]

The students were given 5-10 minutes to complete the questions. The pre-test was administered at the beginning of the astronomy unit, about two weeks before the seasons lesson. The post-test questions were integrated into the unit exam of the Constructivist Group and offered as an optional, non-graded part of the Didactic Group’s final exam. Both the pre-tests and the post-tests were given in similar settings in each classroom, although the Constructivist Group had their post-test graded in their exam score. A single rater graded the pre-test at the same time as the post-test using the same rubric. The Constructivist Group’s tests were given and graded a week before the Didactic Group’s. While it can be argued that the Didactic Group did not take the survey as seriously as their counterparts since their surveys were not graded as part of their exam, participation in the study was voluntary for both groups.

A single grader using a rubric that assigned a score from zero points (no understanding or a non-scientifically supported conception) to four points (a scientifically accepted conception, example shown in the results section) graded all questionnaires. The questions were either identified by code or were embedded in an exam. The grader did not know the subject’s identity unless the subject used a known and significantly different penmanship style. Only students who gave permission and who answered both the pre- and post-test were included in the study.

TABLE 1. Means (and standard deviations) of scores on a 0-4 point scale (four being an ideal score) on pre- and post-tests for the two groups.

		Question 1	**Question 2**
Didactic Group	Pre-test	1.67 (1.73)	1.54 (1.52)
(n = 46)	Post-test	1.89 (1.83)	1.13 (1.46)
Constructivist Group	Pre-test	1.79 (1.67)	1.08 (1.39)
(n = 102)	Post-test	3.28 (1.32)	2.96 (1.30)

TABLE 2. Statistical significances between two different sets of responses to questions.

Set 1	Set 2	For	Level of significance
Didactic Group Pre-test	Constructivist Group Pre-test	Question 1	None
Didactic Group Pre-test	Constructivist Group Pre-test	Question 2	None
Constructivist Group Pre-test	Constructivist Group Post-test	Question 1	$p < .05$
Constructivist Group Pre-test	Constructivist Group Post-test	Question 2	$p < .05$
Didactic Group Pre-test	Didactic Group Post-test	Question 1	None
Didactic Group Pre-test	Didactic Group Post-test	Question 2	Decrease, $p < .05$
Didactic Group Post-test	Constructivist Group Post-test	Question 1	$p < .05$
Didactic Group Post-test	Constructivist Group Post-test	Question 2	$p < .05$

Weaknesses of the Study

While both groups were self-selected, class attendance was necessary to participate in the pre-test. Over 90 percent of the Constructivist Group attended that particular class and participated in the survey, while less than two thirds of the Didactic Group attended and participated. The Didactic Group answered the post- test after they had completed a 12-page, two-hour final exam while the Constructivist Group's post-test was included in their exam. The Constructivist Group needed to notify the instructor if they did not want their post-test included in the study, while the Didactic Group only had to not participate. The Constructivist Group had the added incentive of answering correctly since the question was on the exam; the Didactic Group did not have this incentive, since the post-test did not count toward their grade.

The two instructors were markedly different. The Didactic Group's instructor was very formal in style, using an instructor-centered teaching style that (self-admittedly) had changed little through the decades utilizing infrequent laboratory activities and two exams for assessment. The Constructivist Group's instructor held classes that were less formal, with more student/instructor dialog and more student involvement including weekly quizzes and activities and four exams for assessment. Did these differences in instructors or their teaching styles cause students to self-select themselves into one section with a certain instructor instead of the other instructor? Only one student out of 105 said the Constructivist Group's instructor was the "main reason for taking [the] course" in their student course-evaluation, while there is no student evaluation data on the Didactic Group's instructor (because of tenure). Available data do not support that self-selection explanation.

RESULTS

Table 1 shows the mean and standard deviations of student pre-test and post-test scores on both questions and Table 2 lists the statistical significances of differences between the means for the different-sized groups. While both the Didactic Group and the Constructivist Group seem to come from the same population of students, they appear to be different populations after instruction. Likewise, there were statistically significant improvements in student response for those students with the constructivist teaching methods. While the didactic group's improvement on Question 1 is not statistically significant, they do have a statistically significant decrease in their response for Question 2.

Finally, normalized gains were calculated. A normalized gain is a statistic used to compare two samples where they are thought to be from the same population, but may not be [21]. It is a score used to measure improvement, taking into account that there is a ceiling for improvement, i.e. students scoring high in a pre-test can not improve as much as a student scoring lower in a pre-test. Hake [21] defines the normalized gain as a ratio of the differences between class means in pre-test and post-test with the difference between the maximum score achievable and the pre-test mean.

TABLE 3. Normalized gains between the experimental group and the control group.

	Didactic Group	Constructivist Group
Question 1	0.093	0.675
Question 2	-0.168	0.644

From Table 3, the Constructivist Group showed more improvement on both questions than the Didactic Group and when answering the second question, the Didactic Group showed even less understanding after their lectures than before their class studied astronomy.

Considering the above data, this study rejects the null hypothesis that no differences in conceptual learning will be found with different methods of instruction.

DISCUSSION

The results of this study indicate greater knowledge gains by non-science major undergraduate students as a result of instruction integrating constructivist teaching strategies as opposed to traditional didactic instruction. Statistically significant improvements were made in the non-science major classes that used a constructivist, 5-E lesson plan when compared with a similar class using a traditional lecture style of teaching. This study can also support an argument that courses for science majors should be taught with constructivist methods to improve student understanding.

Were differences in teaching methods the only differences between the two classes? Attendance was markedly different between the classes with student attendance consistently above 90 percent in the Constructivist Group and consistently lower in the Didactic Group. Perhaps the frequent assessment using weekly quizzes and activities cause the students to attend more and keep up with the course's content or the constructivist class was more interesting to the students. Yet, McDermott et al [4] contend that personality of the instructor does not account for significant improvements in students' conceptual understandings.

This study could provide evidence to university content professors that constructivist pedagogies can result in better student understanding. A better performance by students in the classroom may lead to higher student evaluations, higher job satisfaction by the professor, and higher retention rate among students. These in turn may lead to long-term goals of a better institution reputation and more successful graduates.

Since science departments often teach more non-majors than majors, this research supports the argument that university professors should understand teaching as well as their content area. The implementation of this understanding of teaching would be an effective model for pre-service teachers.

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