Effects of Different Teaching Methods on University Students' Understandings

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Abstract

This study examined the effects of different teaching methods on university student understanding of a particular astronomical concept. The reasons a mid-latitude location would experience seasons were taught in a didactic, lecture-based method by one professor and with an active learning, constructivist lesson plan by a second professor. Pre- and post-test open ended questions asked students to explain the seasons and to apply their understanding to another situation. Statistically significant improvements were seen in student groups with a constructivist instruction, but not in the didactic class.

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Since publication of the National Science Education Standards (National Research Council [NRC], 1996) and the Benchmarks for Science Education (American Association for the Advancement of Science, 1993), there has been an increasing call for reforms in science education, not just K-12 but also in higher education. Teachers generally seem to teach as they have been taught (Lortie, 1975; Richardson, 1996; Weinstein, 1989), and this is especially true at the university level. University science professors were successful enough in their undergraduate classes that they were admitted to graduate school where they attained an advanced degree emphasizing research and scholarship, but not education. When hired by a university, a major aspect of their job description is teaching for which they have had little or no training, only modeling by virtue of 18+ years as a student. In particular, the physics and astronomy physical science classes are typically taught by physicists or astronomers who were taught in a lecture-based class 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. Similarly many introductory college biology courses are designed by content-matter experts and are understandable to “an already knowledgeable instructor’s perspective, but not necessarily from an inquiring learner’s perspective” (Lawson, 2001, p. 11). 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 they learned the content?
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

If a university physics instructor teaches mimicking their undergraduate experiences, this often means using similar didactic methods emphasizing theoretical and mathematical derivations. Bybee (1993) 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, students often struggle “the key then is not to teach the course as if you are talking to yourself or your colleagues.” (Uno, 1999, p. 2).

The notion that people build their own knowledge and their own representations of knowledge from their experiences and thoughts is known as constructivism (von Glaserfeld, 1989; Driver, Asoko, Leach, Mortimer, & Scott, 1994). 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 (Trowbridge, Bybee, & Powell, 2000) 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 (Hewson, Beeth,
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 (NRC, 2000; Ebert-May, 2001; Ashcraft & Courson, 2003b). 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 (2003a).

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. The pre-post test consisted of two open-ended paper and pencil questions, and 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. Still, the concept of the reasons for seasons was curricula for both sections, and both groups were expected to understand the concepts.

The pre-test was graded by a single rater at the same time as the post-test using the same rubric. The Constructivist Group’s tests were graded a week before the Didactic Group’s. The Constructivist Group’s post-test was reviewed before their final exam while the Didactic Group took their post-test during the final exam. Only students who gave permission and who answered both the pre- and post-test were included in the study.

A single grader using a rubric that assigned a scored 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 on embedded in an exam. The grader did not know the subject’s identity unless the subject used a known and significantly different penmanship style.

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, teaching his last year before retirement, was very formal in style. The Constructivist Group’s instructor held classes that were less formal, with more student/instructor dialog and more student involvement. Student attendance was consistently above 90 percent in the Constructivist Group and was consistently lower in the Didactic Group. 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 tenured, Didactic Group’s instructor. Available data does not support that self-selection explanation.

Results

Pretest – Posttest Question 1
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]

Pretest – Posttest Question 2
Q2a. Assume the tilt of the earth changed from what it 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]

From Table 1, the two groups did not show statistical significance when comparing pre-test scores for Question 1 using a “Student’s” t test of hypothesis and significance using
differences of means (t= 0.397, n = 148, p < 30%). This would support an argument that the two samples came from the same population before instruction. There was a statistically significant difference between the mean post-test scores (t = 5.198, n = 148, p < 0.5%), suggesting that the Constructivist Group answered the post-test significantly better than the Didactic Group. In fact, while the Constructivist Group showed statistically significant improvement between pre-and post-test (t = 7.023, n = 204, p < 0.5%), the Didactic Group did not show any statistically significant improvement (t = 0.579, n = 92, p < 30%). These results indicate that students gain statistically significant improvement in conceptual understanding if they participated in the constructivist class.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Question 1</th>
<th>Question 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didactic Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>1.67 (1.73)</td>
<td>1.54 (1.52)</td>
</tr>
<tr>
<td>(n = 46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test</td>
<td>1.89 (1.83)</td>
<td>1.13 (1.46)</td>
</tr>
<tr>
<td>Constructivist Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>1.79 (1.67)</td>
<td>1.08 (1.39)</td>
</tr>
<tr>
<td>(n = 102)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post test</td>
<td>3.28 (1.32)</td>
<td>2.96 (1.30)</td>
</tr>
</tbody>
</table>

Similar results were found in the second question, with one exception. When comparing the pre-test scores between the two groups, the Didactic Group had statistically significant higher scores than the Constructivist Group (t = 1.818, n = 148, p < 5%). This signifies that the Didactic Group understood the relationship between the Earth’s tilt and the severity of seasons better than Constructivist Group before any teaching occurred. After instruction, the Constructivist Group showed statistically significant better scores than the Didactic Group (t = 7.569, n = 148, p < 0.5%). Constructivist Group also experienced statistically significant improvement between pre-test and post-test (t = 9.924, n = 204, p < 0.5%), while the Didactic
Group showed a decrease, but not a statistically significant decrease, in scores with their mean dropping from 1.54 to 1.13 ($t = 1.319$, $n = 92$, $p < 10\%$).

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 (Hake, 1988). 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 (1998) 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.

\[
N = \frac{(\text{mean post-test} - \text{mean pre-test})}{\text{Maximum score} - \text{mean pre-test}}
\]

Table 2

<table>
<thead>
<tr>
<th>Question 1</th>
<th>Didactic Group</th>
<th>Constructivist Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>0.093</td>
<td>0.675</td>
</tr>
<tr>
<td>Question 2</td>
<td>-0.168</td>
<td>0.644</td>
</tr>
</tbody>
</table>

From Table 2, 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. Was one class more interesting or was the other class taught in a manner where the other students felt attendance was not important? Did the Constructivist Group’s more frequent assessment using weekly quizzes and activities cause the students to attend more and keep up with the course’s content?

When teaching upper-level science courses, instructor mastery of content has been assumed to be more important than teaching strategies. 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 can lead to higher student evaluations, higher job satisfaction by the professor, and higher retention rate among students. These in turn could 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.
References


