INSIGHTS GAINED THROUGH DEVELOPMENT OF PALEONTOLOGY OUTREACH KITS FOR RAPID CITY MIDDLE SCHOOL STUDENTS

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ABSTRACT

Paleontology is a highly effective gateway to science education, making it ideal for outreach. With this in mind, the authors, in collaboration with the South Dakota School of Mines and Technology Paleontology Club, developed teaching kits designed to educate middle-school students about dinosaurs and paleontology.

The self-contained kits, designed to be mobile and easily implemented, include all materials necessary for delivering a lesson illustrating which dinosaurs lived during particular geologic time periods. Scale models of exemplar dinosaur from all Mesozoic time periods are accompanied by fact sheets. The fact sheets, presented in "comic book" style, present aspects of each Mesozoic period, including age, paleogeography, local geology, flora and fauna. Dinosaurs from each period are given a general description and students are prompted to identify example taxa from each time period.

The kits were implemented with 124 eighth-grade students from South Middle School in Rapid City. Cognition of material was measured through concept inventories administered before and after lesson implementation. Student responses to ten questions gauged knowledge of and confidence with the material pre- and post-lesson.

Students showed cognitive improvement in understanding of several paleontologic concepts presented in the kits. Students were initially aware of some paleontologic concepts, such as continent movement, but were generally unaware of changes in dinosaur associations throughout the Mesozoic or showed reduced familiarity with less "charismatic" dinosaur taxa.

Keywords

paleontology, education, outreach, middle-school, dinosaur

INTRODUCTION

Paleontology as a cross-disciplinary endeavor offers many opportunities to introduce students to science. Earth's history offers dynamic and engaging examples from which to draw, and the broad disciplinary nature of paleontology permits application across many scientific disciplines, including geology, biology, chemistry, physics, anatomy, and ecology (Gunckel 1994; Trend 2001; Allmon 2010). Additionally, comprehension of paleontology and Earth history require some fundamental basis in scientific thought, particularly with regard to the vastness of geologic time and understanding of evolutionary change (Smith and Smith 2001; Dodick and Orion 2003a; Dodick and Orion 2006; Dodick 2007). As such, paleontology is filled with opportunities for developing comprehension of scientific knowledge and concepts.

In conjunction with the South Dakota School of Mines and Technology (SDSMT) Paleontology Club, the authors developed a series of teaching kits designed to deliver a lesson on geologic time and evolutionary change among dinosaurs during the Mesozoic Era. The Tech Paleontology Club, established in 1997, has a long and award-winning history of education and outreach involving undergraduate earth science majors and the general public. The club works in cooperation with both the Department of Geology and Geological Engineering and the Museum of Geology at SDSMT to participate in public outreach events.

The kits were targeted at a middle school audience (grades six to eight). This age group was chosen in response to high outreach demand experienced by the club. Additionally, studies suggest that seventh and eighth grade students are at a key developmental point in their ability to comprehend the logical principles of geology and reconstruction of geologic events (Dodick and Orion 2003b; Kozman 2004).

Current South Dakota middle school science standards do not directly address paleontology, even though eighth grade physical science standards place considerable emphasis on the theory of plate tectonics. In addition, life science standards do not emphasize paleontology, changes in diversity through time, or the notion of faunal change. Thus, the teaching kits targeted concepts students were not immediately exposed to.

METHODS

The teaching kits were self-contained, and included all the materials necessary to deliver a lesson on dinosaur paleontology. Materials included scale models of several dinosaur taxa, "fact sheets" with pertinent lesson information, instructional materials, and background information for instructors in both hard copy and on CD ROM. All materials were enclosed in heavy-duty rubberized totes with the intention of quick and easy deployment for outreach events by club participants.

A key component to the kits was the "fact sheets". These sheets provided the necessary information to familiarize each student with specific geologic ages and their associated dinosaur fauna. The sheets were presented in "comic book" style making the material readily accessible in a short amount of time. Each sheet provided a brief description of one of the three periods within the Mesozoic Era. Sections included descriptions of the age, continent position, flora, fauna, and prominent sedimentary rock units in western South Dakota associated with each age. A cursory description of the types of dinosaurs found in each time period helped students find examples among the scale models provided.

Lesson goals were fourfold. Primary goals included instilling knowledge of the names of and temporal order of the three geologic time periods in the Mesozoic Era, and an associated recognition of the types of dinosaurs present during each period. Secondary goals included familiarizing the students with local sedimentary formations from each geologic period, and developing familiarity with paleogeography, flora, and fauna throughout the Mesozoic Era.

The kits and associated lesson were implemented in several eighth-grade classes at South Middle School in Rapid City in October of 2012. A total of 124 students in five classes participated in the initial delivery. Class size ranged from 20-25 students with an approximately 54/46% male/female distribution. Students were divided into groups of four or five individuals. Each group followed the provided directions guiding them through the lesson. Paleontology Club members were on hand to provide assistance when needed. Each class period lasted approximately thirty-five minutes providing ample time for completion of lesson activities.

Approximately one week prior to the lesson, the students were given a concept inventory (CI) to assess their pre-existing knowledge of lesson material. Students assessed ten Likert items (Likert 1932) indicating their level of confidence in each statement's validity. Each item contained five possible responses equating to the following statements: 1) I know this statement is false; 2) I think this statement is false; 3) I am unsure whether this statement is true or false; 4) I think this statement is true; 5) I know this statement is true. For example, the first CI statement was, "The scientific name of the Age of Dinosaurs is the Mesozoic Era." In response, the students could indicate, "No way", "I don't think so", "I don't know", "I think so", or "Absolutely". The number of true versus false statements was randomized to prevent students from recognizing trends. The same concept inventory was administered the day after the lesson was delivered, in order to assess cognition and retention of the material. Each Likert item was coded on a one to five scale to facilitate statistical comparison of students' assessments, the "correct" response for a given question coded as "5" regardless of the true or false nature of each statement.

The pre- and post-lesson inventory results were compared using standard descriptive statistical techniques. Comparisons of total scores and individual item scores were compared using mean, median, mode, and t-tests. The distribution of the scores was assessed using measures of skewness or assessed visually using histograms.

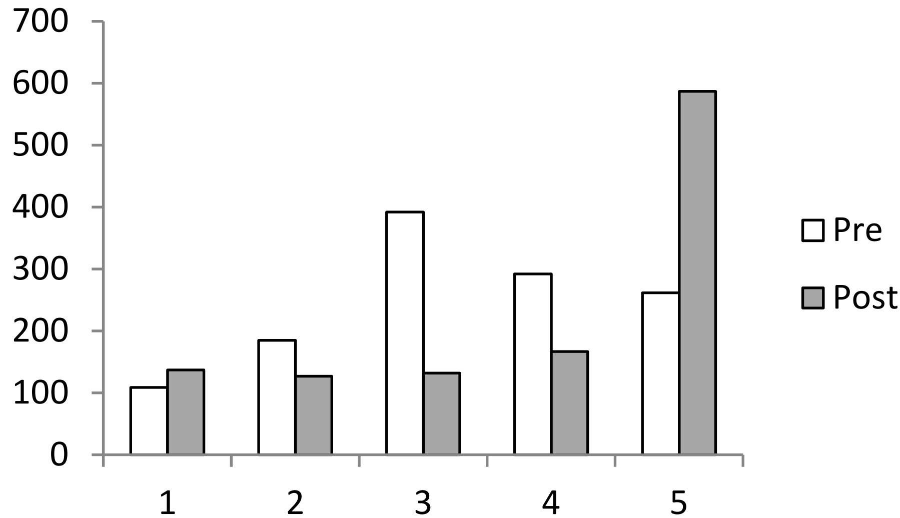

Figure 1. Histogram showing the total Likert scale distribution of scores pre- and post-lesson. The bins, numbered 1 through 5, are as follows: 1= I know this statement is false; 2 = I think this statement is false; 3 = I do not know if this statement is true or false; 4 = I think this statement is true; 5 = I know this statement is true. Responses for individual statements are coded so that the "correct" response is always "5". For false statements, the ordering is reversed, with the statement, "I know this statement is false", coded as "5".

RESULTS

Students showed demonstrable improvement in cognition of the material provided in the lesson. Table 1 illustrates a comparison of the total score on the pre- and post-lesson CI out of a possible score of 50, indicating perfect statement assessment. Male and female students showed no significant difference in pre- and post-lesson scores and equal levels of improvement in cognition. All descriptive statistics indicate an improvement in CI performance and t-test results indicate significant improvement in overall score.

Figure 1 illustrates the distribution of responses based on the modified Likert scale. The apparent normal distribution of the pre-lesson histogram indicates the majority of values on the Likert scale fall within the central bins, suggesting lower confidence in the material (skewness = -0.26632). Figure 1 also shows the distribution of answers following the lesson. Not only do many more values fall in bin "5" indicating correct assessment of each CI statement, it also reveals that students show a much higher level of confidence in their assessment of each statement (skewness = -0.85045).

Table 2 illustrates descriptive statistics for each question in the discussion section, including mean, median, and mode. The results of t-tests are also provided based on individual question differences before and after the lesson.

Answers to Question 3 (Q3), "The same types of dinosaurs lived together throughout the Mesozoic Era" indicated effective cognition of the core concept presented in the lesson. The mean score increased from 3.1 to 4.2 with significance (Table 2). Median and mode values suggest increased confidence in responses as well. The distribution of responses also reveals much greater accuracy and confidence in statement assessment, with many more "correct" responses post lesson (Figure 2). Although both distributions show negative skewness, comparison of pre-lesson (skewness = -0.05467) and post-lesson (skewness = -1.5989) shows a shift toward "correct" responses as well.

Responses to Question 7 (Q7), "Dinosaurs were large and abundant during the Triassic Period" indicated little change. Mean values increased only slightly, but the results were significant (Table 2). Median and mode showed little change. The distribution of responses changed only slightly before and after the lesson (Figure 3a). Dinosaurs were neither large nor abundant in the Triassic; however, most students appeared to be unaware of this fact before the lesson (skewness = 0.548228). Students showed little cognitive improvement in this concept. Most students still delivered an incorrect assessment of this statement after the lesson, and with little confidence, although the number of correct responses did improve slightly (Figure 3a) (skewness = 0.22736).

Conversely, students fared much better with Cretaceous dinosaurs. Responses to Question 9 (Q9), "The largest carnivorous dinosaurs lived during the Cretaceous Period", reveals a great deal of uncertainty before the lesson, with a mean of 3.08 (Table 2). The most well-known carnivorous dinosaur, *Tyrannosaurus*

Table 1. Pre- and Post-Lesson statistics for concept inventory scores out of a total of 50 with t-test results.

	N	Mean	Median	Mode
Pre-Lesson	124	33.306	33	32
Post-Lesson	115	38.139	38	38
	t = 8.2774	P = 9.2034E-15		

Table 2. Descriptive statistics and t-test results for concept inventory questions discussed in the results section. Q3: The same types of dinosaurs lived together during the Mesozoic Era; Q7: Dinosaurs were large and abundant during the Triassic Period; Q9: The largest carnivorous dinosaurs lived during the Cretaceous Period; Q10: Earth's continents have always been in the same location.

	Mean	Median	Mode	t	P
Q3	3.1209	3	2	-	-
Q3 Post	4.2782	5	5	-7.1134	1.33E-11
Q7	2.3387	2	2	-	-
Q7 Post	2.9043	3	2	-3.3898	6.49E-05
Q9	3.0887	3	3	-	-
Q9 Post	3.5565	4	5	-3.0063	1.15E-07
Q10	4.4032	5	5	-	-
Q10 Post	4.7043	5	5	-2.4614	0.0145

rex, is derived from Cretaceous deposits. While the post lesson mean score for this statement was 3.55, both medial and mode values indicate improvement. Response distribution also revealed little prior knowledge of large Cretaceous carnivores (skewness = -0.24592) (Fig 2b), but showed considerable improvement afterward (skewness = -2.834817) (Figure 3b).

Finally, students showed excellent pre- and post-lesson comprehension of the concepts of continent movement throughout time. Responses to Question 10 (Q10), "The continents have always been in the same location" were correct with confidence during both assessments. Mean, median and mode values (Table 2) were all high or showed slight improvement, and the distribution of responses (Figure 4) changed little.

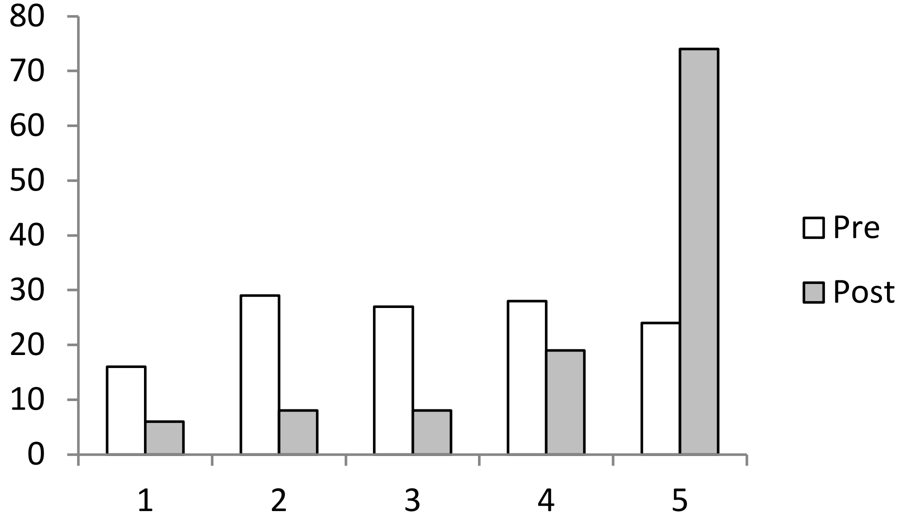

Figure 2. Histogram showing the pre- and post- lesson distribution of responses to the statement, "The same types of dinosaurs lived together throughout the Mesozoic Era." See Figure 1 for explanation of bins.

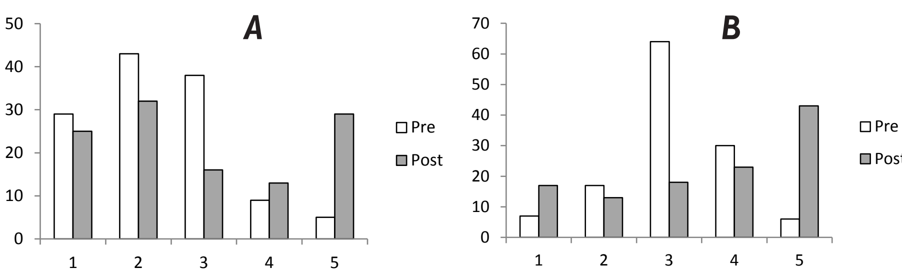

Figure 3. a) Histogram showing the pre- and post- lesson distribution of responses to the statement, "Dinosaurs were large and abundant during the Triassic Period." b) Histogram showing the pre- and post- lesson distribution of responses to the statement, "The largest carnivorous dinosaurs lived during the Cretaceous Period." See Figure 1 for explanation of bins.

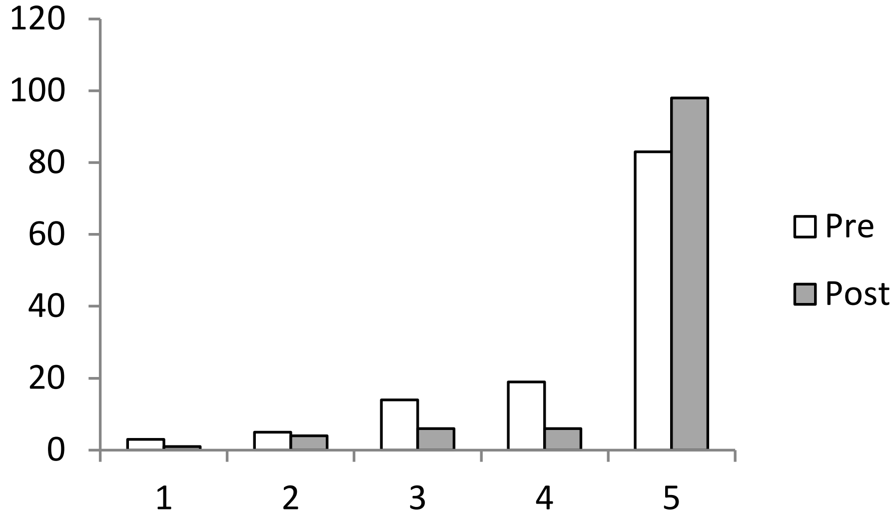

Figure 4: Histogram showing the pre- and post- lesson distribution of responses to the statement, "Earth's continents have always been in the same position." See Figure 1 for explanation of bins.

DISCUSSION

The evaluation results show that, although brief, the lesson appears to have improved students' cognition of some of the key concepts presented through the teaching kits. Students showed demonstrable improvement in both knowledge of and confidence with the material at hand, suggesting that this delivery method is an effective educational tool. Teaching kits can effectively illustrate the concepts of geologic time, changes in biological diversity throughout Earth's past, and plate tectonics.

The responses to specific statements were insightful. The notable increase in "correct" answers to Q3 suggests that students were able to understand, with confidence, the concept of faunal change during the Mesozoic, as presented by the lesson.

Students appeared unable to recognize that dinosaurs were still small and relatively rare during the Triassic Period. The result of this uncertainty may be due to the scale models themselves. The Jurassic and Cretaceous dinosaur models are produced at slightly less than 1:55 scale. The Triassic dinosaur models are produced at 1:10 scale. This likely proved misleading, as all models were similar in size despite the notable differences in size among the actual taxa.

Additionally, Triassic dinosaurs are not morphologically distinctive. As such, they lack some of the "charisma" that dinosaurs from the other time periods exhibit. During the lesson, Triassic dinosaurs may have been overshadowed by more "interesting" dinosaurs from other time periods. Therefore, it would seem more effective to utilize the more recognizable dinosaur taxa to illustrate important concepts as distinct dinosaurs appear to more easily capture students' attention.

Finally, comparatively little attention is paid to Triassic taxa as far less information is readily available. A World Wide Web search for "Triassic dinosaurs" produced 943,000 results, whereas a search for "Cretaceous dinosaurs" produced 2,020,000 results, and one for "Jurassic dinosaurs" produced 15,200,000 results. If less information is available on Triassic dinosaurs, students have less pre-existing knowledge.

It was encouraging to note that our sample of students appears to be familiar with the concept that continents have changed position throughout Earth's past. One of the earth science standards in sixth grade at South Middle School requires a comprehension of basic plate tectonics. These concepts are repeated in eighth grade earth science. By middle school, students are equipped with a rudimentary knowledge of a changing and evolving Earth throughout geologic time. Further education could involve outlining events in greater detail.

The impact of these kits and the associated lesson complements some concepts proposed by the Next Generation Science Standards (NGSS). Paleontology can effectively act as a study in scientific synthesis, and many broad scientific concepts can be illustrated through paleontological examples. The need to directly address the cross-disciplinary nature of science was a key factor in development of the NGSS (NGSS Lead States 2013).

Paleontology is specifically utilized in several of the disciplinary core concepts outlined in the NGSS. For example, Middle School-Earth Systems Science practice History of Earth 1-4 (MS-ESS1-4) requires students to "Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6 billion year old history." (NGSS Lead States 2013). One of the primary goals of the teaching kits was to illustrate the differing dinosaur associations from different time periods in the Mesozoic Era, thus allowing students to organize a series of events in Earth history. This study has shown these concepts to be readily accessible to most middle-school students given the proper framework and presentation.

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