Digging into earth science: alternative conceptions held by K-12 teachers
Excavando las ciencias de la tierra: ideas alternativas de profesores de K-12

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Abstract

Perceptions of 139 in-service teachers in South Dakota were examined to determine their level of understanding in a number of geoscience topics. Data were collected through surveys, questionnaires, individual interviews and a geoscience concept inventory. The findings revealed that teachers in the sample do hold alternative conceptions about the geosciences, particularly in reference to the composition and interior of the Earth. As a result, it supports the assertion that many teachers lack adequate subject matter knowledge for teaching geoscience concepts.

Key words: *teacher's alternative conceptions, teacher knowledge, science education, geoscience.*

Resumen

Las opiniones de 139 profesores en Dakota del Sur fueron examinadas para determinar su nivel de comprensión en varios temas de la geociencia. Los datos fueron recogidos con los exámenes individuales, los cuestionarios, las entrevistas y un inventario de los conceptos de la geociencia. Los resultados revelaron que los profesores en la muestra tienen concepciones alternativas, particularmente en referencia a la composición y el interior de la tierra. Por lo tanto, apoya la afirmación que, muchos profesores carecen del conocimiento necesario para enseñar asuntos de la geociencia.

Palabras clave: *conceptos alternativos, conocimientos de profesores, educación en ciencias, geociencia.*

INTRODUCTION

In the past few years there has been significant interest in the alternative conceptions held by teachers: in particular, teachers of science. Currently, work in this area is predominately conducted in the United States (e.g., Atwood & Atwood, 1996; Bendall, Goldberg & Galili, 1993; Groves & Pugh, 1999; Pomeroy, 1993; Schoon, 1995; Schoon & Boone, 1998) and the United Kingdom (e.g., Boyes, Chambers & Stanisstreet, 1995; Dove, 1996; Kruger, 1990; Preece, 1997; Trend, 2000 & 2001). However, the alternative conceptions of pre- and in-service teachers are also being studied in other countries, such as Australia (Murcia & Schibeci, 1999), Canada (Berg & Brouwer, 1991), Greece (Kallery & Psillos, 2001), Hong Kong (Mak, Yip & Chung, 1999), India (Banerjee, 1991), Israel (Trumper, 2001), Pakistan (Pardhan & Bano, 2001), South Africa (Sanders, 1993) and Spain (Mellado, 1997).

This extensive research shows that teachers generally have a range of perspectives along the non-scientific to scientific continuum of conceptual understanding. Most commonly, teachers mix scientific and non-scientific ideas to create their own world-view and models of natural phenomena. These alternative conceptions and mixed mental models have been identified among a range of topics in biology, chemistry and physics. Although there has been extensive investigation into children's ideas in Earth science (for examples see, Driver, Guesne & Tiberghien 1985; Driver, Squires & Wood-Robinson 1994), those of teachers have remained relatively unexplored. Some exceptions are Barba and Rubba (1992 & 1993), Schoon (1995), Stofflet (1993) and Trend (2000 & 2001).

This leads to the question, "What do teachers really know about the geosciences?" This study attempted to provide some answers to this question for one sample of South Dakota teachers.

METHODOLOGY

Data were collected through questionnaires and surveys, individual interviews and administration of a geoscience Concept Inventory (Libarkin and Anderson, in preparation). The administration of questionnaires and surveys served a dual purpose. First, the personal interests of teachers and the frequency of occurrence of certain geoscience topics in classrooms, as well as teachers' own views about common geoscience topics, provided insight into the importance teachers place on the teaching of specific concepts. Second, questionnaires and surveys helped reveal alternative conceptions and assisted in the preparation of an interview protocol for further discovery of alternative conceptions in the geosciences. Finally, a geoscience Concept Inventory (Libarkin and Anderson, in preparation), was used to provide a comprehensive and quantitative picture of teachers' understandings about these concepts.

Biases and Limitations. This study relied solely on volunteers, and as a result biases may exist. It is possible that those electing to participate in the study were a) more confident about their scientific knowledge or b) more interested in science education than non-participants. However, if teachers who are willing to participate in a research study, and thus are less inhibited about discussing their ideas, are found to have alternative conceptions, it is likely that those choosing not to participate hold alternative conceptions as well. An additional limitation is the relatively small geographic region from which participants were sampled. Study conclusions cannot necessarily be generalized from this small sample to all South Dakota teachers, or teachers in other states. However, this study, with some corroboration from other similar studies, can offer an indicator of conceptions held by a wider population of teachers.

Population and Sample. The subjects in the sample were K-12 educators from across South Dakota who volunteered to participate in the study. To reduce the time and financial cost associated with a more direct approach to recruitment, two established electronic mailing lists of approximately 110 and 3300 K-12 South Dakota educators were used to distribute surveys, questionnaires, and appeals for interview volunteers.

DATA COLLECTION AND INSTRUMENTATION:

Data collection was divided into several phases. The first phase sought to elicit teachers' ideas about the geosciences by using a survey based on a similar instrument created by Trend (2000 & 2001). This survey was sent to an electronic mailing list of approximately 110 South Dakota K-12 science educators asking them to consider their interest in and classroom encounter with twelve common geoscience topics and then rate them on a four-point scale. Trend's (2000 & 2001) five-point scale was modified in an attempt to prevent the respondents from returning all three's, which is a "neutral" response, to the topics presented. The response rate to this survey was 41%, much higher than expected based upon similar studies. Of the forty-five returned surveys, seven were dropped from the analysis because they were either incomplete or reached someone other than a science educator (e.g., a band instructor), leaving 38 surveys for analysis.

Next, a brief conceptual questionnaire was sent to an electronic mailing list of approximately 3,300 South Dakota K-12 educators. This questionnaire was designed to elicit teachers' understandings about such topics as volcanoes, mountains, ice age/s, and the interior of the Earth. Teachers with a variety of classroom experience, subject expertise, and grade level experience returned questionnaires. The response to this mailing was ~1.5%, significantly lower than the previously mentioned survey, although forty-nine surveys were returned. Possible reasons for the low return rate will be explored in the Discussion section.

During phase two, a 30- question multiple-choice Geoscience Concept Inventory (Libarkin, and Anderson, in preparation) was administered to in-service teachers participating in two summer geology workshops, with 24 and 20 participants respectively. This same inventory was later given to two sections of pre-service teachers (N = 38) at Black Hills State University in the semester before their student teaching experience. Overall scores for the inventory, as well as question-by-question breakdowns were analyzed and compared.

In phase three, the data collected from the surveys, questionnaires, and the Geoscience Concept Inventory, as well as the South Dakota and national science content standards and research literature were used to develop an interview protocol and probing questions. Interviews consisted of justified true and false statements, geosequencing cards, (modeled after TREND 2000 & 2001), and open-ended questions. Individual interviews were conducted with in-service teachers (N=8) based on a structured protocol, modeled in part by similar interviews conducted by TREND (2000 & 2001) to determine their understanding of a variety of geoscience topics.

Five of the eight interviewees held master's degrees in education. All but one of the teachers interviewed indicated that they had taken an Earth science/geology course during their college preparation. All eight of the interviewees also indicated that their last science course was completed after 1996. (Six of the teachers completed their last science course after 2001.) All teachers interviewed, with the exception of one, indicated they were responsible for teaching science in their classrooms. The teacher not responsible for teaching science interacted with science classrooms and indicated the possibility of teaching science in the near future.

Interviews were scheduled and conducted at the convenience of the volunteering teacher. Individual interviews lasted approximately 30 minutes and were audio taped for full transcription and analysis. Teachers were given the opportunity to respond to questions and to further explain their responses before the next question was asked. If answers were incomplete or unclear, probing questions were used to give respondents a chance to clarify answers and to generate more accurate representations of their views. Teachers were also encouraged to sketch objects to help give details that might otherwise be difficult to explain.

RESULTS AND DISCUSSION:

Phase 1: Survey Results. Interest and classroom occurrence rates for selected topics were generally correlated, although personal interest tended to be much greater than reflected in the classroom. Table 1 lists topics in order of high interest and high occurrence respectively. Although mean scores for personal interest lie between 3.18 (earthquakes) and 2.74 (plate tectonics), those for classroom occurrence are much lower (2.71 Fossils and 2.08 Ice Ages).

As in the TREND (2000 & 2001) studies, the study of volcanoes generated both high interest and high classroom occurrence ratings. In contrast, the study of plate tectonics generated low ratings for both interest and occurrence. Taking into consideration the important relationship between these two topics, it may suggest that plate tectonics is a subject that teachers do not feel adequately prepared to teach. In fact, looking ahead to the data generated on the Geoscience Concept Inventory, only 30% of teachers were able to correctly identify the location of the Earth's tectonic plates!

Table 1
Rank Ordered Mean Ratings for Personal Interest and Classroom Occurrence

Geoscience Topic	**Interest**			**Occurrence**	
	Mean	*StDev*		*Mean*	*StDev*
Earthquakes	3.18	0.56	Fossils	2.71	1.06
Volcanoes	3.11	0.73	Volcanoes	2.71	0.87
Dinosaurs and their extinction	3.00	0.57	Mountains	2.71	0.84
The formation or composition of planet Earth	2.95	0.87	Rocks	2.66	1.07
The first humans	2.92	0.91	Earthquakes	2.61	0.92
Mountains	2.89	0.76	Ideas about time	2.58	1.06
Rocks	2.89	0.92	Glaciers	2.55	0.80
The Ice age/s	2.84	0.75	Dinosaurs and their extinction	2.50	0.89
Fossils	2.84	0.95	The formation or composition of planet Earth	2.50	0.92
Glaciers	2.84	0.75	The first humans	2.34	1.02
Ideas about time	2.82	0.87	Plate tectonics	2.26	1.06
Plate tectonics	2.74	0.92	The Ice age/s	2.08	0.88

Personal Interest=teachers own personal likes or dislikes for the topics listed.
Classroom Occurrence= frequency with which each of the topics listed occur in that teachers classroom.

Phase 1: Questionnaire Results. Though an entire spectrum of alternative ideas was embodied in the responses to the questionnaire, perhaps the most interesting discovery was the surprising number of teachers who attributed the source of magma to the core of the Earth. "…it [volcano] has an opening in the Earth's crust that allows the inner core of the Earth to flow out". This seems to be related to the large number of teachers (61%) who, according to their written descriptions of the Earth's interior, believe that the core of the Earth is "liquid" or "molten".

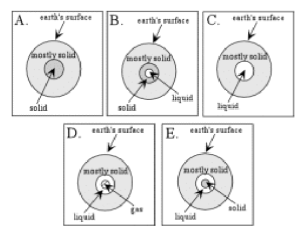
Table 2
Common Responses to Geoscience Questionnaire

Topic	**Common Responses**
Volcanoes	Erupts, magma, lava, gasses, steam, ashes, heat, pressure, opening in Earth, cone shaped with opening at top, hollow
Mountains	Does not erupt, solid, no openings, higher than volcnoes
Ice Age/s	Most of Earth covered with glaciers, change or creation of landforms, extinction or adaption of plant or animal species
Interior of Earth	layers, heat, liquid or molten core

Phase 2: Geoscience Concept Inventory Results. The Geoscience Concept Inventory (GCI; Libarkin and Anderson, in preparation) was administered to identify possible alternative conceptions in a sample of pre-service (N=38) as well as in-service teachers (N=44). Overall, in-service teachers scored 8% higher than pre-service teachers (47.7% and 39.8%, respectively). However, scores for neither group would have indicated passing marks had this inventory been graded. As it happens, data indicate that teachers have a range of ideas about geological phenomena that are not necessarily in line with scientific thought.

GCI Sample Question:
Which of the following figures do you believe is most closely related to what you might see if you could cut the Earth in half?

Circle one: A B C D E



27% of in-service teachers and 31% of pre-service teachers were able to identify the correct figure [E].

However, 36% of in-service and 46% of pre-service teachers chose D, suggesting a belief that the Earth's center is gaseous.

Earth at Formation. The GCI shows that 66% of in-service teachers and 64% of pre-service teachers believe that simple-one celled organisms were present when the Earth first formed as a planet! Only 13% of pre-service teachers held the scientific view that there would be no life on Earth at its formation, compared to 27% of in-service teachers.

Calculating Age of Earth. The GCI asked teachers to choose techniques for calculating the age of the Earth. 48% of in-service teachers and 38% of pre-service teachers chose analysis of carbon in rock as the most accurate method. Following closely was the comparison of different layers of rock (in-service 27%/ pre-service 33%). Only 18% of pre-service teachers and 14% of in-service teachers selected the correct response, "Analysis of uranium and lead in rocks".

When asked to choose all techniques that scientists use to calculate the Earth's age, pre-service teachers most often chose comparison of fossils found in rocks and comparison of different layers of rock (92% and 90% respectively). In-service teachers most often selected comparison of different layers of rocks (77%), analysis of carbon in rock (70%), and comparison of fossils found in rocks (68%). "Analysis of uranium and lead in rocks", the most common and accurate method, was chosen by only 33% of pre-service teachers, compared to 41% of in-service teachers. Interestingly, the same number of pre-service teachers (33%) also believed that the measurement of the height of mountains could be used to calculate the age of the Earth.

Volcanoes. Both in-service and pre-service teachers believed that volcanoes occur mostly along the margins of both the Atlantic and Pacific Oceans (43% and 33%), although volcanoes do not occur along the passive western margin of the Atlantic Ocean. Interestingly, 26% of pre-service teachers believed that volcanoes are typically observed on continents or islands in warm climates, compared to 9% of in-service teachers.

Earth's magnetic field. While both pre-and in-service teachers marked a variety of responses on the inventory to explain why the Earth had a magnetic field, gravity was most often attributed to the existence of the Earth's magnetic field (34% in-service and 33% pre-service). However, the Earth's revolution around the sun came in a close second. The correct response, "Liquid metal moving inside the Earth" was chosen by only 1/3 of each pre-service and in-service teachers. Interestingly, 3% of pre-service teachers indicated that the Earth does not have a magnetic field!

Interview Results. A variety of techniques were used to gather information during face-to-face interviews with in-service teachers. Sequence cards were used with five of the teachers to uncover their conceptions of geologic time, both relative and absolute. Teachers were given a set of ten cards, each representing a specific event in the Earth's history. They were then asked to arrange the cards and put them in chronological order. After an order was established, teachers were asked how long ago each event took place. During the interview, teachers appeared comfortable with relative time, but many teachers expressed discomfort over assigning a specific date or time to the events. In fact, one of the teachers was so unsure that she refused to put a date or time on any of the events.

Formation of the Earth generated the most specific quantitative responses (4 of 5 participated) ranging between 2 million and 4.6 billion years ago. Answers about the appearance of the first dinosaurs on Earth were put into eras "later Triassic/early Jurassic" or given a time relative to today, "200 million years ago" and "220,000 years ago". The extinction of dinosaurs ranged from "late Jurassic" to "200 million years ago" to "200,000 years ago". Responses for the appearance of the first humans ranged from "10,000 years ago" to "2003 years ago".

Date and order were used to analyze teachers' ideas, following Trend (2001), with mean order used to rank responses (Table 3). Events with the largest standard deviation in order, suggesting the most uncertainty in the interview population, were: Dinosaurs become extinct, Wooly mammoths become extinct, first humans appear on Earth and Atlantic Ocean begins to form.

Table 3
Sequence of Geo-events

	Teacher		*Scientific Consensus*
Event	Mean Rank	StDev	Rank
Today	10	0	10
First humans appear on Earth	7.4	2.07	8
Wooly mammoths become extinct	7.2	2.05	9
Dinosaurs become extinct	7	2	6
Last ice age begins	6.6	0.89	7
First dinosaurs appear on Earth	5.2	1.48	4
Trilobites become extinct	4.8	1.30	3
Atlantic Ocean begins to form	3.2	2.17	5
First life appears on Earth	2.6	0.55	2
Earth Forms	1	0	1

Rank 1 = first event

DISCUSSION

It is unclear exactly why the return rate for the questionnaire (1.5%) was so different than that of the survey (41%). It seems unlikely that time of year is responsible since both items were distributed during the same time frame. Some probable reasons include, but are not limited to: differences in the teacher's personal experiences, the content being studied, the type of responses required, or the time necessary to complete the request.

Another possibility is that the teachers belonging to the "K-12 educators" list do not consider themselves "science teachers". In fact, during the search for volunteers to participate in the interview phase several teachers indicated that although they teach science in their classrooms, they are not science teachers or do not teach Earth science. Many others suggested that the middle school or the high school science teacher should be approached. This may further indicate the possibility of content as a factor. It is also important to note that during this study the importance of subject matter knowledge was lost to some of the teachers. In fact, one stated, "I just don't see what difference it makes what I know about the Earth. It is my instructional practices that count in the classroom".

In contrast to this teacher's perspective, research shows that teachers' knowledge on the content they teach influences the way they represent that content to students. Hashweh (1987) found that in planning instruction, teachers tended to delete details that they themselves do not understand, and by doing so, teachers may embed their own alternative conceptions into their lessons and directly pass their ideas on to students.

An unexpected finding during the current study was the reluctance of teachers to participate in the interview phase. An appeal for volunteers was sent to the K-12 electronic mailing list, garnering only one reply. Teachers were then approached in person about participation in interviews. Sixty-two teachers declined to participate, with only eight teachers agreeing to face-to-face interviews.

The low number of teachers willing to participate in interviews suggests that teachers were uncomfortable with the subject matter. Throughout the process of searching for face-to-face interview participants, many teachers, especially at the primary levels, were likely to state they perceived themselves as lacking the necessary knowledge to answer any questions related to Earth science. Although several cited uneasiness with the No Child Left Behind Act (United States Department of Education No Child Left Behind Act of 2001), Dakota STEP testing (state testing program) and increased pressure to cover content as reasons for not participating in the face-to-face interviews, most simply declined to participate stating that they would like to help, but didn't feel comfortable doing so.

Several indicated they did not feel they knew enough about Earth science to provide any answers, while others cited being afraid of not knowing the right answers. Some simply stated, "that is not in the standards this year" and saw no reason to participate. Finally, several teachers expressed concern over providing "ammunition" to those who are looking closely at teachers' knowledge and performance, and were worried about personal anonymity.

The general impression given by those choosing not to participate in the interview phase of the study seemed to be, "We don't want anyone to know what we don't know".

CONCLUSIONS

While NCLB (No Child Left Behind) has emphasized the need for the increased content knowledge of teachers, the picture painted by this study suggests that many teachers who volunteered to participate are lacking the necessary knowledge to be effective teachers of Earth science.

It is important to note that research shows that weaknesses in science programs often stem from teachers' lack of scientific knowledge, rather than difficulties using a variety of methods for teaching science (Kruger and Summers, 1990). In many cases, simply improving the subject-matter knowledge of teachers will also improve their ability to teach the Earth science curriculum in their classrooms. However, research also acknowledges that alternative conceptions in science cannot be eradicated by simply presenting new information. Conceptual change (allowing learners to examine their own experiences, and confront inconsistencies in their theories) is facilitated when people examine their own conceptions and find that they are "less intelligible, less plausible and less fruitful" than the scientific concepts (Hewson and Hewson, 1983).

This means that during both teacher preparation and training teachers (and their students) must be confronted with an expert view and be helped to appreciate why such a view is generally more powerful and useful than their own. This will require that teachers take a closer look at their own knowledge about the earth, as well as participate in activities and learning opportunities that address alternative conceptions and present a more plausible scientific description of the earth and its systems.

While research indicates the existence of alternative conceptions in the sciences is a widespread phenomenon recent research is now taking a closer look at conceptions of teachers. Despite the fact that there has not been a large-scale effort to remedy the alternative conceptions among this group, the fact remains that the majority of teachers are responsible for teaching science content in their own classrooms and it is important that they do not, unwittingly, perpetuate their alternative conceptions in the classroom.

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Tablas de Young como herramienta docente en matemáticas
Teaching mathematics with Young tableaux

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Resumen

Las tablas de Young presentan características y propiedades que las hacen herramientas adecuadas tanto para introducir conceptos matemáticos elementales, como para realizar investigación en diversas ramas de la matemática, ciencias de la computación y la física. En este trabajo se presentan algunas ideas y ejemplos para usar las tablas como herramientas en docencia de la matemática, para introducir los conceptos de función, relación y operación desde la escuela secundaria.

Palabras clave: Tabla de Young, función, relación, operación.

Abstract

Young tableaux present properties and characteristic allowing them to be adequate tools to introduce mathematical simple concepts and also providing powerful research ideas in mathematics, physics and computer science. In this work we present some examples in order to illustrate how Young tableaux can be used to present the concept of function, relation and operation in high school.

Key words: Young tableaux, function, relation, operation.

INTRODUCCIÓN

Las tablas de Young nos permitirán introducir desde los primeros cursos de secundaria las nociones de función, relación, relación de orden, relación de equivalencia, operación y polinomios, por medio de preguntas y construcciones naturales, las cuales estimulan en el estudiante la necesidad de preguntarse sobre la validez de sus razonamientos con base en el conteo de dichas construcciones. Algunos números como los factoriales y las combinatorias, lo mismo que las permutaciones, tienen en este contexto un lugar muy especial. Es de recordar que productos notables y el teorema del binomio de Newton, requieren de factoriales y combinatorias para representar algunos de sus coeficientes con la dificultad de encontrar ejemplos para motivar estos números y se tienen que presentar a través de las definiciones usuales. Por lo tanto, las siguientes construcciones pretenden ofrecer algunos ejemplos de los usos de estos diagramas a nivel de educación media.

Un diagrama de Young o de Ferreλ es un arreglo de cajas alineadas a la izquierda. El número de cajas en la fila *i* se denota como λ_i y la secuencia de longitudes de las filas de la tabla de Young satisface $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_k > 0$. Los λ_i se llaman las partes de λ y se identifica cada diagrama con la secuencia $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_k)$. Así por ejemplo, (3,3,2,1) se representa como

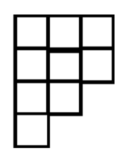

Figura 1

Los diagramas de Young están muy relacionados con las particiones enteras de un número.

Una partición de *n* es una sucesión $(\lambda_1, \lambda_2, \ldots, \lambda_k)$ tal que $\sum_{i=1}^{k} \lambda_i = n$ y $\lambda_1 \geq \lambda_1 \geq \lambda_2 \geq, \ldots \geq \lambda_k$). Para $n = 5$ tenemos 7 particiones que podemos identificar por su tabla de Young correspondiente:

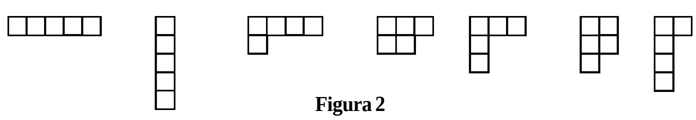

Figura 2

las cuales representan a las particiones (5), (1,1,1,1,1), (4,1), (3,2), (3,1,1), (2,2,1), (2,1,1,1).

Al remplazar cada entrada por un número (usualmente un número natural) en un diagrama de Young obtenemos una tabla de Young. Hay muchas clases de tablas de Young y afortunadamente, cada cual podrá definir una clase de tablas para que satisfagan las condiciones que desee o necesite. Entre las tablas más usadas están las estándar y las semiestándar. Una tabla se dice estándar si no se permiten repeticiones y toda fila y toda columna es