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AUTHOR Ross, Katharyn E. K.; Shuell, Thomas J.
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ABSTRACT

Some pre-instructional misconceptions held by children can persist through scientific instruction and resist changes. Identifying these misconceptions would be beneficial for science instruction. In this preliminary study, scores on a 60-item true-false test of knowledge and misconceptions about earthquakes were compared with previous interview results to determine whether or not both methods yield the same conclusions. An Earthquake Information Test (EIT), was administered to 194 students in grades 4 through 6 in Salt Lake City (Utah) and Buffalo (New York). Subjects included: 19 fourth graders from an urban public school in Buffalo; and 175 fourth, fifth, and sixth graders from an urban public school in Salt Lake City. The EIT contained scientifically correct statements interspersed with misconceptions previously expressed by students in individual interviews. The EIT was administered after most students had received some instruction about earthquakes. Students from Buffalo and a random sample from Salt Lake City were also individually interviewed. Internal consistency was calculated, and an item analysis was performed. Students could correctly choose scientifically acceptable answers while simultaneously choosing answers not compatible with science. The EIT was least reliable for grade 4 students. While a refined version of the EIT could provide useful information about student misconceptions, individual interviews should continue as a source of test questions and information about children's misconceptions. Five tables provide study data. A 25-item list of references is included. (SLD)

THE EARTHQUAKE INFORMATION TEST: VALIDATING AN INSTRUMENT FOR DETERMINING STUDENT MISCONCEPTIONS

Katharyn E. K. Ross & Thomas J. Shuell
State University of New York at Buffalo

The Earthquake Information Test: Validating an Instrument for Determining Student Misconceptions[1]

Katharyn E. K. Ross and Thomas J. Shuell[2]

State University of New York at Buffalo

There is growing evidence that children have a great deal of knowledge about the natural and technological world prior to formal science instruction; they do not come as "blank slates" as previously believed (Boyes, 1988; Champagne, Gunstone, & Klopfer, 1983; Johsua & Dupin, 1987; Osborne, Bell, & Gilbert, 1983; Solomon, 1983). However, some of their beliefs and understandings contain ideas scientists would consider misconceptions (Boyes, 1988; Champagne, Gunstone, & Klopfer, 1983; Johsua & Dupin, 1987; Osborne, Bell, & Gilbert, 1983; Solomon, 1983).

These pre-instructional beliefs are often not only persistent but resistant to change as well (Champagne, Gunstone, & Klopfer, 1983; Osborne, Bell, & Gilbert, 1983). For example, recent studies have shown that many adults, interviewed about their understanding of fundamental science concepts, give responses similar to those of elementary school children (Stepans & Kuehn, 1985).

Various researchers have offered explanations for the persistence of naive conceptions. Osborne, Bell, and Gilbert (1983) stressed that the current scientific viewpoint has emerged in just the last 250 years and has involved the introduction of concepts for which there are not observable instances (e.g., atoms, electric fields) and no physical reality, (e.g., potential energy). Gilbert, Osborne, and Fensham (1982) noted that one pattern in "children's science" is that nonobservables do not

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exist;[3] therefore students may view their naive beliefs as more logical than the scientific concepts taught in school. Another explanation is that the multiple meanings of scientific language used outside the school environment (e.g., energy, food, and force) can be quite different from tight, scientific explanations (Eaton, Anderson, & Smith, 1983). Still another is that teachers themselves may come to instruction poorly prepared, teaching a mixture of textbook science and their own views (Osborne, Bell, & Gilbert, 1983).

Teachers need to know student beliefs and areas of possible misconception prior to instruction (Eaton, Anderson, & Smith, 1984). This information could help them initiate instruction at the students' level of understanding, highlight words with multiple meanings, provide a base for deciding what to stress and detail in a unit, and give insight into student failure to learn a particular scientific concept.

One topic covered in science education is the occurrence of natural phenomena, such as earthquakes, and the appropriate precautions that should be taken should one occur. Whereas a survey of the published literature failed to provide references specifically related to children's beliefs about earthquakes, it did reveal that children can confuse earthquakes and volcanoes (Bezzi, 1989) and that they can hold beliefs about other geologic phenomena that contain misconceptions (Ault, 1984). It also revealed that some adults hold beliefs about earthquakes that scientists would consider misconceptions. Turner, Nigg, and Paz (1986), for example, interviewed a representative sample of 1,450 adults in southern California and found that many believed in such predictors as "earthquake weather."

In a preliminary study, Ross and Shuell (1989) individually interviewed 35

[3]Gilbert, Osborne, & Fensham (1982) referred to the strong and persistent views that students bring to science instruction and their accompanying conceptual structures as "children's science."

students in kindergarten through sixth grade. These students held a variety of misconceptions about earthquakes, what occurs during an earthquake, what causes an earthquake, and what one should do during an earthquake. Subsequent interviews, by these authors, of students in fourth to sixth grades have continued to support this observation.

A survey of the research revealed that several assessment methods have been used to determine student beliefs about a particular scientific concept. In addition to various types of interview formats, researchers have used multiple choice pre-post tests (Eaton, Anderson, & Smith, 1984; Stead & Osborne, 1980) and small group discussion with cards illustrating examples of a concept (e.g., work) in such a way that various interpretations of the concept were revealed (Gilbert & Osborne, 1980).

Whereas interviews are a beneficial investigative tool when beginning research in a new topical area, there are limitations. Osborne and Gilbert (1980) noted the limitations of the Interview-About-Instances method:[4] difficulty selecting a limited but adequate set of instances, ordering of instances so student response is not influenced, length of time to transcribe interviews, difficulty in analysis of the information, and problem reporting results succinctly. Stead and Osborne (1980) also noted the heavy responsibility on the interviewer.

Hoz (1983) stressed that the reliability of clinical interviews can be jeopardized by student differences, while Schuster (1983) emphasized the role and effect of the investigator. The investigator's theoretical leanings, expectations, unconscious cues,

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[4]The interview-about-instances approach explores children's meanings for words through taped individual interviews that use cards with line drawings depicting instances and noninstances of a concept. For a particular concept, i.e. work, up to 20 familiar situations are depicted by these drawings. The child is asked whether each drawing is an instance or not. This method has been used for concepts such as work, electric current, force, light, living, friction, gravity, and animal.

expertise, and approach could compromise the reliability of the interview.

Good (1977) noted that reviewing children's responses from individual interviews does not allow for an evaluation of the conviction with which the child answered a question and usually does not include nonverbal cues.

Finally, a limited number of questions are usually included in individual interviews which results in lower test reliability. In a preliminary study of children's beliefs about earthquakes (Ross & Shuell, 1989) the interview consisted of five major questions.

An objective test designed to detect misconceptions would enable the researchers to ask more questions as well as facilitate a statistical analysis of the results. This could provide a more concise identification of common patterns in error responses and reveal the significance of sex, age, geographic area, experiencing an earthquake, instructional method, and curriculum. A survey of the literature revealed there was no test in the area of earthquake education for students in kindergarten through sixth grade.

Before relying totally on the information provided by another assessment tool, it is important to determine if the information from that tool will be comparable with that obtained from individual interviews. Individual interviews provide a great deal of information and allow students to clarify and expand their responses. This evaluative technique should not be quickly replaced until it is determined if an objective test would pinpoint some of the same misconceptions.

The purpose of this preliminary study was to determine if a 60-item true-false test developed to detect both earthquake knowledge and earthquake misconceptions could identify misconceptions in grades four, five and six. Test results from the two evaluative methods were compared in addition to determining the reliability of this true-false test.

METHOD

Subjects

One hundred and ninety-four students in fourth, fifth, and sixth grades in Salt Lake City, Utah and Buffalo, New York were given the Earthquake Information Test, devised by the present authors. There were 19 fourth graders from an urban public school in Buffalo and 175 fourth, fifth, and sixth graders from an urban public school in Salt Lake City. All of the classrooms were described by teachers as having a heterogeneous mix of students which meant there were some students classified as learning disabled included in this sample.

Grades 4-6 were the focus of this study because of results from a preliminary study of 35 students in grades K-6 (Ross & Shuell, 1989) which revealed that students in K-3 had not studied about earthquakes in school while students in fourth grade all noted that they had learned about earthquakes that academic year. This absence of formal instruction seemed to be a factor in the responses given by the K-3 students. More students in this group indicated they did not know the answers to the questions than did those in grades four to six. A survey of science texts (Ross, 1989) showed that information about earthquakes and volcanoes is usually introduced between grades four and six in the regular science curriculum. In those states where earth science is not a required subject, this may be the only time when students are exposed to this information.

Therefore, because scientific content is usually introduced in grades 4-6, and because student responses are necessary to discern whether misconceptions exist, it seemed that grades 4-6 were a better focus for this instrument than the entire range of grades K-6.

All of the representative classes in Utah learned about earthquakes from the Utah Geologic Hazards curriculum written and taught by a representative of the Utah

Museum of Natural History. A random sample of 23 students, selected from a group with returned parental permission slips, was interviewed prior to instruction in November, 1989. The students in the Buffalo, New York group learned about earthquakes from Earthquakes: A Teacher's Package for K-6, written jointly by the National Science Teachers Association and the Federal Emergency Management Agency. They were taught by the classroom teacher. Seventeen of these fourth graders (one class), as well as a random sample of 16 students in fifth and sixth grade, were interviewed prior to instruction in October and November, 1989. The fourth graders were also interviewed after instruction in March, 1990. The Earthquake Information Test was administered in May, 1990.

Materials

The Earthquake Information Test, a 60-item true-false instrument, was developed by the authors. Scientifically accurate phrases, generated from a nationally recognized curriculum on earthquakes for students in grades K-6 (Callister, Coplestone, Consuegra, Stroud, & Yasso, 1988) and a geologist at the National Center for Earthquake Engineering Research, were interspersed with misconceptions expressed by students in individual interviews (Ross & Shuell, 1989). All test items were initially evaluated for scientific accuracy by a geologist and reviewed by a person knowledgeable about misconceptions in science. Suggestions from both individuals were incorporated into the version of the test used in this study.

A true-false format was used so that all items would have a response. Hoz (1983) noted that the conventional measure of correctness of responses is not the only measure to be considered when identifying misconceptions. The nature and type of errors is also important. This test provided a measure of correctness and a measure of misconceptions.

The test consisted of two parts. Part I was used to gather information about the respondent: sex, grade, age, and whether earthquakes had been studied in school that year. Part II was divided into four sections: the definition of an earthquake, the cause of an earthquake, what occurs during an earthquake, and appropriate action that should be taken in the event of an earthquake. There were 11 items in the first section, 15 in the second, 16 in the third, and 18 in the fourth. True and false items were included in each of these four sections. There were 21 true and 39 false items in the test.

The following are some sample test questions from the first section of the test:

An earthquake is:

T **F** A shaking of the earth.

T **F** A release of energy stored in rocks.

T **F** A volcano.

T **F** An explosion.

The individual interview format used in this study was also developed by the authors. The interview focused on six basic questions: (a) What is an earthquake? (b) What causes an earthquake? (c) What happens on the ground when there is an earthquake? (d) What happens below the surface when there is an earthquake? (e) Have you ever been in an earthquake? If so, what happened? (f) What should a person do if he or she is in an earthquake?

Supplemental questions were available for probing responses which needed further clarification. Probe questions involved similarities and differences between earthquakes and volcanoes, student understanding of energy, student beliefs about ground movement, and further information about earthquakes such as how one would know if an earthquake was occurring.

Procedure

The true-false tests were administered by the classroom teacher. Written instructions informed teachers that Part I should be done as a class so that if students were confused by any of the questions they could be answered before the test commenced. The teacher was instructed to emphasize the following points prior to the start of the test: no names should be put anywhere on the test paper; each question should be answered, even if the student was not sure of the response; if unsure of a word, the student should raise his or her hand and ask the teacher; and that in Part II, **T** should be circled if the student felt the answer was true and **F** should be circled if the student felt the answer was false. Teachers were informed that because this was not a reading test, it could be administered orally to those students with a lower reading level. This was only done in the fourth grade class in the New York sample.

Teachers were also given written notification that the results of the test would not be used as an evaluation of the school's science program or of their curriculum. They were told that the administration of this test was to determine test reliability.

A total score was determined for each student, internal consistency was calculated using the K.R. 20 and an item analysis was done. Questions where students had indicated both true and false as the correct response were eliminated from the analysis.

Interviews were done individually with students in a room separate from the classroom. Interviews ranged from several minutes to approximately fifteen or twenty minutes, including time at the end of the interview for the student to ask questions. Extensive field notes were made by the interviewer, who was experienced in taking field notes. The interviews were tape recorded to permit later review and analysis of student responses. Information from the field notes and tapes were analyzed in a search for consistent similarities and differences among answers to the questions. In addition, the frequency of various responses was recorded. The information obtained from the interviews was compared with that obtained from the Earthquake Information Test.

RESULTS

Total Group Results

The internal consistency of the Earthquake Information Test, as measured by the K.R. 20, was .66 and the standard error was 2.54. There was a mean of 50.9 (s.d. 4.38). Student scores ranged from 25 to 60 (the maximum score), with the mode being 51. The highest and lowest scores were each achieved by one student. One fifth grade student achieved a score of 60 and one sixth grade student achieved a score of 25. The next lowest score on the test was 35.

The most difficult question on the test (difficulty of .43) concerned liquefaction or the fact that during an earthquake, soil with high liquid content can become like quicksand. This particular question was also a good discriminator between high and low groups (discrimination index was .32), as was the definition of an earthquake being an eruption.

The definition of an earthquake as a release of energy stored in rocks (#2) was marked false by 50% of the group while the cause of an earthquake being the release of energy at zones of weakness in the Earth (#26) was marked false by 29% of the students.

Association of the word "eruption" with an earthquake was found both in the interviews and in the test responses. In the New York interviews seven percent of the students, who were asked the probe questions related to the differences between earthquakes and volcanoes, used the word erupt in their comparative descriptions of an earthquake and a volcano, even though the word was not used in any of the questions. Thirty-four percent of the total group (more students in the lower than higher group) marked as true, "An earthquake is an eruption." However, only nine percent marked as true that an earthquake is a volcano.

In the New York interviews, prior to instruction, over half of the students answered that they did not know what caused an earthquake; about 22% of the Utah group answered in this way. Some of the other causal answers provided by the New York group were faults, plates or layers of the earth moving, general movement in the earth, heat, the Earth turning the wrong way, the earth letting out air like when we cough or sneeze, thunder, rain, wind, and rocks in water. On the Earthquake Information Test, the majority of students correctly marked as true that earthquakes are caused by built up pressure, movement of the earth's crustal plates, tectonic plate movement, and release of energy at zones of weakness in the Earth. However, some students also marked as true that an earthquake is caused by the earth's core moving to the surface, the layers of the earth fighting, and atmospheric conditions.

Insert Table 1 about here

In addition to the movement of the earth's core being noted as cause of earthquakes, 26% of the entire group marked as true that in an earthquake, the core moves toward the crust and hits it and the core releases air.

Question #47 ("Take a plane out of the area,) had a difficulty of .90 with the discrimination index calculated to be +.02. Approximately 10% of the students answered this question "true." This was higher than what was found in the previous interviews. In the New York group, prior to instruction, 3% of the students gave this response. No student interviewed in the Utah group said he would take a plane out of the area.

Question #45 ("Hold on to something metallic,") had a difficulty of .67. Thirty-three percent of the group marked this as true. In the New York interviews, forty percent of those fourth graders answering "stand in a doorway" specifically mentioned metal. Further probing of this response resulted in one fourth grader stating, "An earthquake doesn't do metal. It does concrete."

Comparison of Fourth, Fifth, Sixth Grades

The mean age of the total fourth grade group was 9.8 years. The mean age for the fifth grade group was approximately 10.8 years, and for the sixth grade group, 11.7 years. The K.R. 20 was highest for the sixth graders (.75) however, the standard error for all three grades was similar.

Insert Table 2 about here

The most difficult question for both fourth and fifth graders was one concerning the phenomenon of liquefaction. The difficulty level for fourth graders was .33 and for fifth graders was .35. The question was:

During an earthquake:

33. **T** **F** Soil with high liquid content can become like quicksand.

No question had a difficulty below .50 for the sixth graders. The most difficult question, with a difficulty of .53, identified as a cause of earthquakes the layers of the earth fighting.

Comparison of Two Geographic Areas

The mean age of the fourth graders in New York was approximately 9.6 years and for the fourth graders in Utah, approximately 10.0 years. The K. R. 20 for the New York sample was .52 and for the Utah group, .66.

Insert Table 3 about here

The most difficult question for the New York group (difficulty level of .47) was the definition of an earthquake as a release of energy stored in rocks. This question had a similar difficulty level for the Utah group (.44). However, the most difficult question for the Utah group (difficulty level of .19) concerned liquefaction.

In both fourth grade groups, more students in the higher than the lower group marked as true the response that in an earthquake, a person should take a plane out of the area.

Gender Comparison

There were 100 females and 93 males in the study; one student did not mark sex. There were some differences between males and females.

Insert Table 4 about here

The most difficult question for both males (difficulty of .49) and females (difficulty of .37) concerned liquefaction. Another question that was difficult for females (difficulty of .46) concerned the definition of an earthquake as the release of energy stored in rocks. This particular question was a good discriminator (+.30 on the discrimination index) between high and low females.

The results of the analysis also indicate that there were some differences between males and females in the different grades.

Insert Table 5 about here

In the sixth grade group of males, the low score was 25 and the high was 59. The most difficult question (with a difficulty level of .59) was the definition of an earthquake as the release of energy stored in rocks. The questions that best discriminated between the high and low groups (both +.38 on the discrimination index) were the cause of an earthquake being the layers of the earth fighting and the response of going to the first floor in a tall building in an earthquake. Both questions were keyed false.

In the group of sixth grade females, the low score was 42 and the high score was 58. The most difficult question (with a difficulty of .44) was that the cause of an earthquake was the layers of the earth fighting. In this particular question, more students in the high group selected the incorrect response. The additional questions for which more female students in the lower than high group selected the correct response were that the causes of an earthquake were the earth turning the wrong way and drilling in the sidewalk and a correct action in an earthquake was to stand under a tree.

The questions that best discriminated between the high and low group of sixth grade females (both +.35 on the discrimination index) were the definition of an earthquake as a tremor and the observation that during an earthquake the ground can move in a wave-like motion.

Discussion

The most difficult question for the entire group, especially for the fourth and fifth graders and females, as a group, was one concerning liquefaction. However, when geographic areas are viewed separately, it is seen that this question was not as difficult for the fourth graders in New York. The difficulty of this question could be a reflection of the accessibility of information about liquefaction to the public, the curriculum used, how the concept of liquefaction was taught, and/or the wording of the test question. In interviews with students in New York and Utah, no student mentioned liquefaction of the soil or ground failure when asked, "What happens below the surface when there is an earthquake?"

The New York group was taught earthquake information from a curriculum written jointly by the National Science Teachers Association and the Federal Emergency Management Agency. This curriculum was used to generate scientifically accurate phrases for the current version of the test. Earthquakes: A Teacher's Package for K-6 (Callister, Coplestone, Consuegra, Stroud, & Yasso, 1988) defined liquefaction as, "The process in which soil/sand suddenly loses the properties of solid material and instead behaves like a liquid" (p. 73).

The Utah sample was taught earthquake information from a curriculum written by the Utah Museum of Natural History. As part of the Utah Geologic Hazards curriculum, students were taught that when liquefaction occurs, the soil becomes like a thick milk shake. As part of an earthquake presentation, students were instructed to imagine a thick milk shake from a fast food restaurant being overturned to illustrate the concept of lateral spreading. The curriculum developer and instructor explained that she used the milk shake metaphor because it is something familiar which could not support a building and it flows. She felt the word "quicksand," also an analogy, might be associated with a common misconception that in an earthquake things are swallowed.

Even though all grades in the Utah sample were taught this concept with the same analogy, this test question was most difficult for fourth and fifth graders. Difficulty bridging the gap from analogy to scientific definition could therefore be related to the developmental level of the students. Piaget, with Montangero and Billeter (1977), as cited in Wagner and Sternberg (1984), suggested three steps in the development of analogical reasoning. The sample in this particular study ranged from 9 to 12 years of age. In the Piaget model this age range would encompass stages two and three. The second stage describes the performance of children from approximately 8 to 11 years old. During this stage, students can form analogies but will readily rescind them when challenged with countersuggestions. Piaget interpreted this to suggest only a weak or tentative level of analogical reasoning ability. The third stage characterizes the performance of children 11 years and older. During this stage, students can form analogies, clearly state the conceptual bases of these analogies, and resist countersuggestions.

The milk shake analogy may have been more developmentally appropriate for the older students in the Utah sample; it may also have been seen as unconnected to the ground/soil. The use of the word "quicksand" on the test may have confused the younger students, especially since it presented a visual image quite different from a milk shake. To distinguish whether there is a general lack of knowledge about liquefaction or difficulties with the metaphors used to describe this phenomenon, more questions, using different descriptors, should be added to updated versions of this test.

One question (#24) used an analogy verbalized by New York fourth graders in interviews done after instruction. This analogy was not present in interviews done prior to instruction. This question was about earthquakes being caused by the layers of the earth fighting. One student, when interviewed, described it in the following way: "The crust gets mad at the mantle and they start fighting and they go against each other, and then they start moving a lot."

Question #24 was the most difficult one for the entire sixth grade group (.53) but was the best discriminator of high and low students. When the results from sixth grade males and females were examined separately, it was revealed that more females in the lower group selected the correct response. In the fifth grade group, the difficulty level was .49, and in the fourth grade group the difficulty level was .65. However, in the fourth grade group, more students in the lower group gave the correct answer than did students in the higher group. Again, these results could be indicative of developmental level and understanding of analogies. In addition these results indicate ambiguity in the question. Even though it was keyed false, it does contain elements of truth. There is a need to look at how analogies should be keyed on tests designed to detect misconceptions.

To simplify complex earthquake education concepts for younger students, it may be necessary to rely more on analogies. Therefore, it is important to know to what extent analogies can be a useful instructional tool and whether students in certain age groups correctly infer the relationship between the analogy and the concept. Will certain analogies inadvertently reinforce misconceptions?

Gilbert, Osborne, and Fensham (1982) have noted that the use of metaphors in common language can reinforce misconceptions. For example, the teacher who says, "The electric current chooses the path of least resistance," (p. 627) can support the belief that objects have characteristics of humans or animals. Johnson and Wellman (1982) hypothesized that metaphors about mental acts such as "use your head" or "she's brainy" (p. 233) support the belief that the brain functions in cognitive acts but not in involuntary responses. Any metaphor needs to be carefully examined to ensure that a misconception is not inadvertently being strengthened. Subsequent versions of this test may incorporate more analogies as well as their definitional counterparts to better explore this relationship.

Some of the terminology used both on this test and in classroom instruction may need to be carefully examined. Certain words may need clearer definition. An example of such a word is "eruption." In a preliminary study of students in kindergarten to sixth grade (Ross & Shuell, 1989), 21% of the fourth to sixth graders expressed confusion between earthquakes and volcanoes. Ten percent of the students in this study who were asked the probe questions related to the differences between earthquakes and volcanoes, used the word erupt in their comparative descriptions of an earthquake and a volcano. In the current set of interviews, seven percent of the New York sample who were asked the related probe questions used the word "erupt" to describe both an earthquake and a volcano. On the Earthquake Information Test, 34% of the total sample marked as true, "An earthquake is an eruption." However, only about nine percent marked as true, "An earthquake is a volcano." It may be that the difficulty not only lies in the conceptual difference between earthquakes and volcanoes but also in the terminology used to describe both. Future studies should probe this connection further and continue to ask students about the differences/similarities between earthquakes and volcanoes. More volcano related statements and terminology should be added to future versions of the test.

Another word whose use should be carefully examined is "earth." One reason why more female sixth graders in the high group may have incorrectly marked as true that an earthquake was caused by the earth turning the wrong way could have been confusion about how the word "earth" was used. This particular question was included in the test because some students had talked about the earth turning the wrong way in interviews. Probing of these responses revealed that "earth" was being defined as the planet. However, in the test, the sixth grade females could have interpreted "earth" to mean ground. Unfortunately, the objective test format does not permit probing of reasons why a particular response was given. Careful attention will be paid to the use of the words "ground" and "earth" on subsequent versions of the test.

The placement of and relationship of the core to the tectonic process appears to be elusive to some students. The core as a cause of earthquakes was seen in the responses of students in fourth to sixth grade in a preliminary study (Ross & Shuell, 1989). On this test, approximately one fourth of the total group of students marked as true that in an earthquake the core moves toward the crust and hits it and the core releases air. These responses seem to be indicative of a lack of understanding of the composition of the earth and the spatial relationships that are involved. Marking as true, questions involving movement of the core to the crust or surface, could also be indicative of confusion with convection currents. There is a need to incorporate questions related to convection currents on the test and to add probe questions related to the core in the individual interview format.

Another question that was difficult for some of the students was the definition of an earthquake as the release of energy stored in rocks. The relationship of energy in tectonic processes can be difficult to understand. Understanding the concept of energy has been shown to be difficult for students much older than this age group. Viennot (1979) noted, when speaking of Belgium physics undergraduates, that the concept of energy was "inextricably mixed with the concept of force" (p. 164). Prior to and following a unit on energy, Solomon (1983) asked 128 fourth year students to give examples of energy. Although the post test showed an overall trend toward the use of newly learned physics terms, less able students needed more guidance and the right cue to give the correct answers. There is a need to examine how the relationship of energy to earthquake generating mechanisms is being taught to fourth, fifth, and sixth graders. Subsequent versions of this test may incorporate more questions that test the understanding of energy.

When considering student difficulty understanding the role of energy and convection currents in tectonic processes, there may also be a need to evaluate the appropriateness of teaching certain concepts at younger ages. Does the necessity for oversimplification of concepts lead to misconceptions?

Fifty-eight percent of the New York sample, interviewed prior to instruction, answered they did not know the cause of an earthquake; after instruction, 12% answered in this way. In the Utah sample, approximately 22% gave this answer. It is difficult to discern student beliefs when they answer "don't know." The second section of this test provided a great deal of information about students' causal beliefs. The test responses showed that holding a correct belief did not preclude holding scientifically incompatible views about the causes of an earthquake. This is consistent with the findings of Turner, Nigg, and Paz (1986) who found after interviewing adults that acceptance of a scientific explanation of earthquakes did not necessarily mean rejecting all explanations that were incompatible with current scientific viewpoints. This test may be a helpful tool with students prior to instruction or with those who frequently respond, "don't know," in the interview situation. Subsequent versions should be administered to a group of students prior to instruction.

The fourth section of the test related to what one should do in an earthquake. Some of the questions in this section need to be reexamined. The overall phrasing of the questions ("In an earthquake a **person should**," followed by the responses to be marked true-false) may have caused some difficulties for students. For example, more fourth graders in the higher than the lower group marked as true that a person should take a plane out of the area. Ten percent of the total group marked this question as correct. A lesser percentage of students verbalized this alternative in individual interviews. However, the comparable interview question was, "What should a person do if he/she is in an earthquake?"

The Utah curriculum developer mentioned that after a discussion about earthquake prediction, a brainstorming activity was held and some students noted that if you knew an earthquake was going to occur tomorrow, you could take a plane out of the area. Discussions such as this may explain why some students marked the airplane alternative "true." Perhaps some students in this age group are not at a developmental level where they can distinguish between what is possible and what is speculative. Ambiguous phrasing of this section may have added to their confusion. Subsequent revisions of this test will rephrase this section to state one of the following: "during an earthquake a person should" or "while an earthquake is happening a person should" or "if a person is in an earthquake, he/she should." In addition, questions related to prediction may be included on other versions of the test.

One question (#59) elicited a response from teachers in Utah. This question stated that in an earthquake a person should "sway with the motion." Whereas this would not be considered a protective technique, it was felt that one would do this regardless. As a result, those questioning it felt there was not a clearly true or false response. Again, the phrasing of the entire fourth section may not have clarified whether the action to be taken in an earthquake was volitional or an involuntary response. Revisions of the test will attempt to clarify this.

Question #45 ("Hold on to something metallic,") was added to the test after interview results showed that some fourth graders in New York specifically mentioned metal when stating that one would be safe in an inside doorway. Probing of this response indicated that some children felt it was the metal that was protecting them rather than the structure of the building. On the Earthquake Information Test, 33% of the total group marked this as true. The belief that metal has a protective power could lead to an incorrect response in an earthquake. For example, one fifth grader said that if you were in the bathroom you should hold on to the sink pipes; the metal would protect you. There is a need to further examine whether children believe that it is metal that protects them in an earthquake rather than building structure. Additional questions will be added to subsequent versions of the test.

The Earthquake Information Test revealed that fourth, fifth, and sixth grade students could correctly mark scientifically acceptable viewpoints while simultaneously marking as true viewpoints that would be considered incompatible. It also revealed areas that need further exploration: the use of analogies with certain age groups, the scoring of analogies on objective tests, conceptual understanding of liquefaction, and the understanding of the role of energy and convection currents in tectonic processes.

However, there is a need to re-look at the test format and questions. Subsequent versions will have a more equitable distribution of true and false items. Poor questions will be revised or discarded. Scientifically accurate statements will be re-evaluated to ensure that they do not cue test-wise students to select appropriate responses because they appear "scientific" in comparison to the misconception statements, (i.e. use of the word "tectonic" may have cued students that this was a scientifically correct response). The use of words such as "earth," "ground," and "eruption" will be closely scrutinized. The fourth section, concerning appropriate action in an earthquake, will be rephrased so that it is clearer to students that it refers to action while an earthquake is occurring. In addition, because the K.R. 20 was highest for the sixth grade group, the test will be reexamined to discern whether reading level was a factor in the reduced reliability with younger grades. The Earthquake Information Test might be more appropriately used with older students. Finally, the test will be readministered to a group of students prior to instruction.

As this test is further refined, so that it becomes a more reliable indicator of earthquake knowledge and misconceptions, there is a need to continue individual interviews. Information from these interviews could provide additional items for the test as well as continue to reveal children's beliefs about earthquakes.

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Table 1

Causes of an Earthquake

An earthquake is **caused by:**

	% Answering True
12. The release of built up pressure	81%
13. Hot weather	4%
14. The earth turning the wrong way	11%
15. The movement of the earth's crustal plates	95%
16. Drilling in the sidewalk	4%
17. Strong winds	6%
18. Thunder	2%
19. Tectonic plate movement	90%
20. The earth's core moving to the surface	30%
21. Toxic waste	2%
22. Nuclear testing	5%
23. Construction workers taking down a building	2%
24. The layers of the earth fighting	45%
25. Atmospheric conditions	21%
26. The release of energy at zones of weakness in the Earth	71%

Table 2

Differences Between Fourth, Fifth, Sixth Grades

	K.R. 20	Standard Error	Mean	(s.d.)
4th (n=46)	.59	2.61	50.3	4.08
5th (n=76)	.57	2.46	51.2	3.75
6th (n=72)	.75	2.53	51.1	5.09

Table 3

Differences Between Fourth Graders in New York and Utah

	K.R. 20	Mean	(s.d.)
NY (n=19)	.52	50.1	3.86
UT (n=27)	.66	50.4	4.22

Table 4

Differences Between Males and Females

	K.R. 20	Standard Error	Mean	(s.d.)
Males n=93	.74	2.46	51.5	4.78
Females n=100	.55	2.58	50.4	3.86

Tab.e 5

Differences Between Males and Females in Fourth, Fifth, and Sixth Grades

	K.R. 20	Standard Error	Mean	(s.d.)
4th Males n=22	.49	2.38	51.7	3.35
4th Females n=24	.58	2.72	48.9	4.22
5th Males n=34	.55	2.42	51.4	3.60
5th Females n=42	.59	2.46	51.0	3.86
6th Males n=37	.85	2.45	51.6	6.23
6th Females n=34	.40	2.53	50.7	3.27