Pre-Service Primary Teachers' Constructed Knowledge of Physical Science Concepts in Singapore, Taiwan and the U.S.

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Abstract

Science education researchers have shown considerable interest in student interpretations of science phenomena. Results of their research make it evident that many students hold shared views of science quite different from those generally accepted by the scientific community and that these personal constructed views are often retained into adulthood. This paper reports on the assessment of pre-service primary teachers' constructed views on selected physical science concepts. Data were gathered from Singapore, Taiwan and the U.S. using a two- tier test. Comparisons are drawn between countries and in the case of US data, over time.

Introduction

Science education researchers have shown considerable interest, over the past decade, in children's interpretations of science phenomena. Results of this research make it evident that children hold shared views of science quite different from those generally accepted by the scientific community and that these alternative views are often retained into adulthood.

Alternative views have been labeled "children's science" (Gibert, Osborne, & Fensham, 1982; Osborne, Bell, & Gilbert, 1983), "alternative frameworks" (Driver & Easley, 1978), "preconceptions" and "misconceptions" (Stepans et al. 1986; O'Sullivan, 1988). The term of choice often depends on one's epistemological or philosophical view of education. The term "alternative framework" is frequently associated with a constructivist view and suggests that while the student response may be incompatible with the science community, it is not necessary an "incorrect" idea. No matter what term is used by researchers to describe students' nonscientific ideas, it is widely recognized that these ideas often act as barriers to learning.

Research indicates that primary teachers' conceptual development in selected areas of physical science does not progress much beyond "children's science". (Jin-Yi Chang 1999; Toh, Chew, Low, Ho & Wan 2002) Toh et al. (2002) ask a crucial question…"Can conceptual science be taught by teachers who themselves do not fully understand science concepts?" (p. 99).

Purpose of the study:

This study reports the results of pre-service primary teachers' responses to a two-tier test of physical science designed to identify physical science alternative conceptions. Responses of pre-service primary teachers enrolled in the National Institute of Education in Singapore, were compared with responses on the same instrument by pre-service primary teachers in the University of Georgia United States and Taipei Teachers College, Taiwan. Beyond group comparisons, the study examines how two tier tests can be used as an intervention strategy in helping students examine, abandon or defend their ideas in a co-operative learning setting.

Identifying Misconceptions

Several methods are described in the literature for identifying misconceptions. The most widely used is the clinical interview (Gilbert, Osborn, & Fensham, 1982; Treagust et al, 1986). The clinical interview has the advantage of providing excellent in-depth information about students' conceptions. It also has some drawbacks. Tamir (1989) states the method is difficult to apply to large numbers of samples and cannot be applied in regular instruction.

A number of paper and pencil tests have been developed as alternatives to interviewing (Helm, 1980; Trembath, 1984; Halloun & Hestenes, 1985; Lawrenz, 1986; Treagust and Haslam, 1986; Brown & Clement, 1987; Clement & Brown, 1989). According to Tamir (1989) these tests fall into two categories: open-ended short essays and multiple choice. Although essay tests provide information about students' conceptions, they are time-consuming. Examiners need to generalize students' answers and classify the type of student misconceptions. It is hard to be consistent when evaluating students' responses, thus the validity of essay format test is low.

Staver (1986) designed two combinations, one completion, multiple choice and justification, and the other completion and essay. He found that achievement is affected by the item format on unfamiliar or complicated tasks.

The Physical Science Test (PST), (Lawrenz 1989) was constructed from the National Assessment of Educational Progress (NAEP, 1978) released items for seventeen years old. This multiple choice test provides information on student performance but requires one to infer the respondents reasoning. To overcome this problem, Treagust and Haslam (1986) developed a two-tier multiple choice item. The two-tier test uses a correct response and two or three distracters in the first level. The second level contains four possible reasons for the answer selected in the first part. The advantage of this test is that it not only identifies students' performance in a selected science field, but also provides information about the students' reasoning in that field.

Two-tier tests:

Two-tier tests were developed as a means of efficiently assessing students' alternative conceptions. Treagust (1988); Hsiung and Riley (1989). They have been used in the U.S. by Odom, and Barrow (1995) as well as in Asia by Tan, Goh, Chia and Treagust (2002), and Chang, Chen, and Chen (2004). Possible weaknesses in the form of two tier testing have been identified by Griffard and Wandarsee (2001). They point out some inconsistencies between alternative conceptions diagnosed by two tier instruments and the student's authentic thinking as measured in interviews. While these findings might draw cautionary interpretations in studies measuring specific concepts, this study measured a varied sample of physical science concepts and the test was considered robust enough to capture student authentic thinking.

Prior Research on Selected Physical Science Concepts

Over the years, a number of research studies have identified a wide range of assumptions about physical science phenomena which students have apparently formed on their own. These studies provided the rationale for selecting the first tier of the two tier test. (Novak, 1977; Trowbridge & McDermott, 1980; Brown, & Clement, 1987). Stepans et al. (1986) investigated students' misconceptions about density. They found students believe that density determines weight. That is to say that a crumpled piece of aluminum foil weighs more than the same sheet of foil not crumpled.

Lawrenz (1986) reported that students tend to believe that an empty container doesn't necessarily weigh less than the same container filled with hydrogen. Mas et al. (1987) found students tend to equate weight with a tendency to fall. This leads them to believe that gases, which are the ideal model of something that rises, have no weight and no mass.

Research in conservation of mass indicates that students think that once a material goes into solution it no longer exists because it disappears. Even when students accept that a substance is conserved, they believe that weight and mass are not. For example, if one pound of salt is dissolved in twenty pounds of water, the result will be twenty pounds because the salt disappears (Novak, 1977; Lawrenz, 1986; Mas et al, 1987).

In studying acceleration, Hewson (1981) found students usually have an Aristotelian view of motion. Students, instead of believing that a constant force produces a constant acceleration, and therefore, an increasing velocity, believe the increase in velocity is due to the application of a large force. Trowbridge and McDermott (1980) state that students think equal position means equal speed. Many students think that speed, velocity and acceleration mean that constant motion requires constant force.

Students have a variety of ideas of what a force is and what it accomplishes. Champagne, Klopfer, and Anderson (1980) list the ideas of force commonly mentioned by students. They state that students think the force is to push an object and keep the object moving. If the forces are absent then objects are either at rest or, if moving, they are slowing down. An absence of forces results in immobility. Marshall (1983) points out that students think that a moving object is moving only because the initial motive force "remains" with the object, until it is "used up," or "worn out" by friction.

Stead & Osborne (1981) studied students' misconception about friction. Among their findings were that students think friction is associated only with the movement of solid objects, and that it doesn't affect liquids or gases. Students believe that if there is no visible movement there is no friction.

In identifying students' misconception about gravity, Minstrell found that students believe that the effect of gravity has on an object is proportional to the object's weight. Some students believe that the effect of gravity increases with height and weight. So the higher and heavier an object is, the stronger the effect of gravity. (Gilbert & Watts, 1983). Champagene & Klopfer (1982) reported that students think that acceleration is dependent on gravity and time. For example, students think that an object falling a short distance is significantly affected by the increase in the force of gravity as it nears the Earth's surface.

Gilbert and Watts (1983) identified students' misconceptions about Newton's second law. They indicated that students often believe that when an object doesn't receive constant force, then the force that causes its motion is "used up" during movement until other force takes over.

Brown and Clement (1987) state that the Newton's third law is important for developing the students' qualitative concept of force. They found that many students adopt a concept of force as an innate or acquired property of objects rather than as arising from an interaction between two objects. For example, when a sixteen pound bowling ball hits a four pound pin, students think the bowling ball to be clearly more "force-full" because it is moving, it is heavier, and it is more able to cause damage than the pin.

Test Construction

The above findings helped determine the selection of first tier problems included in the Physical Science Misconceptions Test (PSMT). The second tier of reasoning options were identified though interviews conducted with 20 pre-service teachers at the University of Georgia
(Hsiung & Riley,1989). The first phase emphasized item construction and modification. A sample of 20 preservice elementary teachers was administered a first draft of the test. This first draft consisted of 30 items of which eighteen were from released items of the National Assessment of Educational Progress (NAEP 1978), four from Brown and Clement (1987), and eight designed by the investigators. After the item presentation, preservice teachers were required to choose a response and then write an explanation for their choice. They were also encouraged to evaluate and write suggestions about each item. All items included illustrations and diagrams to help subjects more readily visualize each problem.

The open response data from theses subjects were collected, reviewed and organized into the second tier of the two tier format. In some cases, original distracters in the first tier were altered based on respondents comments. The second tier provided plausible, contingent reasons for selecting one of the distracters in the first tier. Figure I provides a representative item from the test.

A sample of 59 preservice teachers enrolled in the same course one quarter later (10 weeks) was administered the test. Data from this sample was used to determine the internal consistency of test items, item difficulty, and item discrimination. The final PSMT consisted of twenty-two items with two items measuring equilibrium of torque, two items measuring density, five items measuring conservation of mass, six items measuring Newton's second law, and seven Newton's third law.

Content Validity

The content validity of a test is the degree to which samples of items, tasks, or questions on a test are representative of some defined universe or domain of content. Face validity was assessed by a panel of three judges, who were considered experts in science and science education. The panel agreed that the test items appeared to meet the criteria provided on a table of specifications for physical science content.

Construct Validity

Factor analysis, was employed to assess construct validity. The analysis extracted only components with eigenvalues greater than one and used the promaix method of axis rotation. The factor structure matrix contains respective correlation coefficients between the factors and observed variables. Four factors were retained in this matrix. Five items (items 7, 10, 13, 21, and 22) were loaded on factor 1, five items (items 8, 9, 12, 15, and 19) were loaded on factor 2, three items (items 2, 5, and 18) were loaded on factor 3, and four items (items 3, 4, 11, and 14) were loaded on factor 4. Although the instrument was designed with five subtests one for each different concept, results of this analysis of student response suggests that the PSMT measures less than five variables.

Reliability

Based on the data from three different administrations of the PSMT to three different samples reliability coefficients ranged from .50 to .66 for the total test. Subtest reliabilities ranged from 0.06 to 0.67.

Item Analysis

An item was considered correct if the student selected both the correct content choice and the correct reason. Item difficulties ranged from 0.01 to 0.84, averaging 0.32. For most tests, items in the difficulty range from 0.30 to 0.70 tend to maximize the information about the differences between individuals. However, unlike achievement tests, the purpose of this instrument is not to compare individuals with one another but to assess misconceptions. An item difficulty of .00, indicating that every respondent selected a distracter rather than the correct response, would be judged a poor item on most achievement tests. According to Anastasi (1988) these items are considered excess baggage because they don't provide differential information about test takers. On an instrument examining student misconceptions, an item difficulty level of .00 might indicate a widely held misconception. Criteria for item selection on misconception instruments need to be rethought. Discrimination indices for each item ranged from -0.04 to 0.74, averaging 0.24. An indices between 0.30 and .39 is a reasonably good item anything over 0.40 is considered very good.

Test Administration

The test was administered on August 27, 2004 to Singapore teacher trainees enrolled in the preservice primary teacher training program at the National Institute of Education. Their results were compared with earlier results obtained from preservice primary teachers at the University of Georgia and Taipei Teachers College, Taiwan. Both of these samples were collected in 1989. Any attempt to compare results should take into account this timeframe. The main purpose of this research is to identify misconceptions and not compare scores among groups. The time frame does provide some indication that misconceptions are similar over time and across borders.

Results

Examples of items and teacher trainer response are presented in Appendix A. Underlined percentages represent the correct answer. Results indicated that U.S. students showed improvement on all but one item when compared to their 1989 cohorts. The higher scores could be attributed to a number of variables. Entry requirements in terms of SAT scores are higher now than they were in 1989. Students must also take more science courses in high school than did students in 1989. While the exact cause of the improved scores cannot be determined, the data does indicate that the 2004 student teachers had a better conceptual understanding of physical science than did students enrolled in the same teacher education program 15 years ago. In comparison to Singapore students, the U.S. students closed the gap on some selected concepts. However the Singapore students scored higher on the majority of the items. Taiwan students were tested in 1989 and again in 2004. At press time the 2004 analysis was not available but will be presented at the session. Taiwan scored significantly higher than US students in the 1989 comparisons.

Findings and Implications

The use of a two tier test as both a diagnostic measure and prescriptive teaching tool appears to hold some promise as an efficient means of encouraging conceptual change. More research needs to be conducted to see it the observed conceptual change is sustainable over time. .

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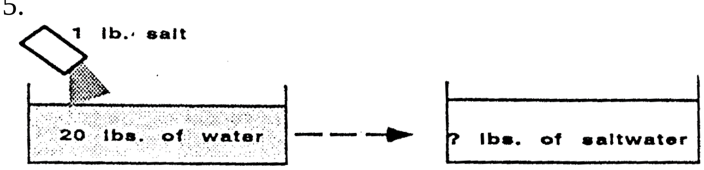
Appendix A

5.



One pound of salt is completely dissolved in twenty pounds of water. The resulting saltwater will weigh

A. less than 20 pounds.
B. twenty pounds.
C. twenty-one pounds.
D. The weight cannot be calculated.

Reason:
1. The salt absorbs water as it dissolves- The weight of saltwater would be less than the weight of water.
2. The dissolved salt disappears so the weight of the water remains the same.
3. The density of the water would increase, but the weight of the saltwater would be the same as the weight of the water.
4. The weight of saltwater would be equal to the sum of the weight of salt and water.

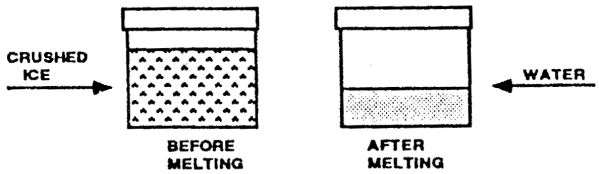
U.S. 1989	**Item 5 Reason**				**U.S. 1989**
Content	**1**	**2**	**3**	**4**	**Total**
A	**5.41**	**0.00**	**0.00**	**0.00**	**5.41**
B	**0.00**	**20.27**	**33.78**	**1.35**	**55.41**
C	**0.00**	**0.00**	**1.35**	**29.73**	**31.08**
D	**5.41**	**0.00**	**2.70**	**0.00**	**8.11**
Total	**10.81**	**20.27**	**37.48**	**31.08**	**100.00**

U.S. 2004	Item 5 Reason				U.S. 2004
Content	1	2	3	4	Total
A	8.00	0.00	2.00	0.00	10.00
B	2.00	14.00	28.00	2.00	46.00
C	0.00	0.00	2.00	<u>40.00</u>	42.00
D	0.00	0.00	2.00	0.00	2.00
Total	10.00	14.00	34.00	42.00	100.00

Singapore 2004	Item 5 Reason				Singapore 2004
Content	1	2	3	4	Total
A	0.00	0.00	0.00	0.67	0.67
B	0.67	5.33	51.33	1.33	58.66
C	0.00	0.00	0.00	<u>54.00</u>	54.00
D	0.00	0.67	4.00	0.00	4.67
Total	0.67	6.00	55.33	56.00	100.00

Taiwan 1989	Item 5 Reason				Taiwan 1989
Content	1	2	3	4	Total
A	0.00	0.00	0.00	0.00	0.00
B	0.00	O.97	10.68	1.94	13.59
C	0.00	0.97	1.94	<u>83.49</u>	86.41
D	0.00	0.00	0.00	0.00	0.00
Total	0.00	1.94	12.62	85.44	100.00

9. The can below was filled with crushed ice, sealed, and weighed. The ice was melted by slowly warming the can and its contents. No water vapor escaped, and no air entered the can.



The can was then weighed again. Which one of the following results would you expected to find?
A. The can weighed the same before and after.
B. The can and ice weighed more before melting than it did after melting.
C. The can and melted ice (water) weighed more than the can and ice.

Reason:
1. The can contains the same material but in different forms, so it should have different weight.
2. Although can contains the same materials in different forms, it should have the same weight, because change of forms does not affect the weight.
3. Most material in solid form weighs more than in liquid form.
4. Most material in solid form weighs less than liquid form.

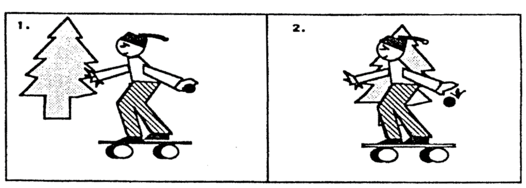
U.S. 1989	Item 9 Reason				U.S. 1989
Content	1	2	3	4	Total
A	3.90	54.55	1.30	0.00	59.74
B	3.90	1.30	9.09	0.00	14.29
C	5.19	0.00	2.60	18.18	25.97
Total	12.99	55.84	12.99	18.18	100.00

U.S. 2004	Item 9 Reason				U.S. 2004
Content	1	2	3	4	Total
A	2.00	56.00	2.00	0.00	60.00
B	6.00	2.00	6.00	0.00	14.00
C	12.00	0.00	2.00	12.00	26.00
Total	20.00	58.00	10.00	12.00	100.00

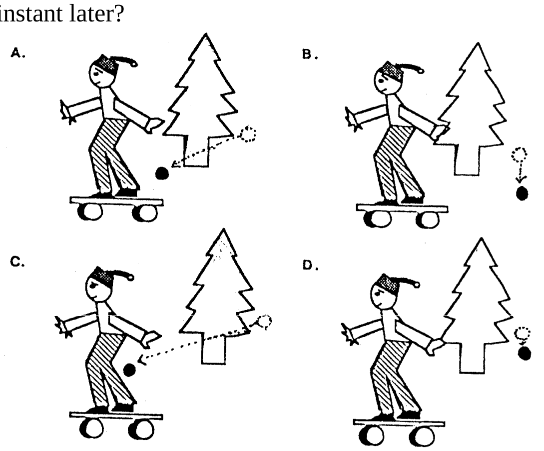
Singapore 2004	Item 9 Reason				Singapore 2004
Content	1	2	3	4	Total
A	1.97	82.00	0.00	0.00	83.97
B	5.26	0.65	3.94	0.65	10.5
C	3.28	0.00	0.00	1.31	4.59
Total	10.51	82.65	3.94	1.96	100.00

Taiwan 1989	Item 9 Reason				Taiwan 1989
Content	1	2	3	4	Total
A	1.89	75.47	0.94	0.00	78.30
B	2.83	1.89	4.72	0.00	9.43
C	5.66	0.00	0.94	5.66	12.26
Total	10.38	77.36	6.60	5.66	100.00

13.



A boy whizzing along on a skateboard drops a stone. Which picture below shows where the stone will be an instant later?



Reason:
1. The stone would immediately fall downward because of gravity.
2. The stone would fall downward and forward because it is moving with the boy.
3. 'The stone would hesitate before falling because of inertia.
4. The stone would fall more forward and downward after the boy dropped it because it would be traveling at a greater speed than the boy.

U.S. 1989	**Item 13 Reason**				**U.S. 1989**
Content	**1**	**2**	**3**	**4**	**Total**
A	**23.38**	**10.39**	**0.00**	**1.30**	**35.06**
B	**45.45**	**1.30**	**6.49**	**1.30**	**54.55**
C	**2.60**	**0.00**	**0.00**	**1.30**	**3.90**
D	**0.00**	**0.00**	**5.19**	**1.30**	**6.49**
Total	**71.43**	**11.69**	**11.69**	**5.19**	**100.00**

U.S. 2004	**Item 13 Reason**				**U.S. 2004**
Content	**1**	**2**	**3**	**4**	**Total**
A	**16.00**	**16.00**	**2.00**	**0.00**	**34.00**
B	**36.00**	**8.00**	**2.00**	**2.00**	**50.00**
C	**0.00**	**8.00**	**0.00**	**2.00**	**10.00**
D	**0.00**	**2.00**	**4.00**	**0.00**	**6.00**
Total	**52.00**	**34.00**	**8.00**	**4.00**	**100.00**

Singapore 2004	Item 13 Reason				Singapore 2004
Content	1	2	3	4	Total
A	0.67	25.67	0.00	03.37	29.71
B	57.43	03.37	0.67	0.67	62.14
C	0.00	0.67	0.00	0.67	1.34
D	02.70	0.00	02.70	1.35	6.75
Total	60.8	29.71	3.37	6.06	100.00

Taiwan 1989	Item 13 Reason				Taiwan 1989
Content	1	2	3	4	Total
A	9.52	40.00	3.81	0.95	54.29
B	12.38	3.81	2.86	1.90	20.95
C	0.95	14.29	3.81	1.90	20.95
D	0.95	0.95	1.90	0.00	3.81
Total	23.81	59.05	12.38	4.76	100.00