Physical Science Misconceptions: Moving From Identification to Intervention

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Overview:
Research indicates that physics misconceptions develop early in life and often continue through adulthood despite the efforts of even the best education. This means that teachers, who have not had the benefit of tertiary science courses, often hold the same misconceptions as their students. Conceptual change interventions with young learners generally report disappointing results. Little research exists regarding success of interventions with young adults. This study focuses on preservice primary teachers and addresses these questions: Can knowledge of learners’ alternative conceptions be applied in instructional interventions to encourage conceptual change? Will preservice elementary teachers evidence conceptual change after involvement in discussions with peers holding different views on the concept? This study used the results of pre-service teachers’ responses to physical science, two-tier test items to assign them to discussion groups. Group members were then challenged to try to reach consensus through argument and persuasion. Preservice elementary teachers in Singapore, and the United States were involved in the initial study and Singapore primary pre-service teachers in this follow up.

Prior Research:
The study draws from conceptual change, social constructivist and andragogy theories as well as investigations into group learning. According to Posner, Strike, Hewson and Gertzog (1982) there are four requirements for conceptual change to occur: 1) the learner must be dissatisfied with a currently held conception, 2) the alternative conception must be intelligible, 3) the alternative conception must appear plausible and 4) the alternative conception must appear fruitful. This study implements this conceptual change model within a social constructivist context (Kim, 2002). Social constructivism supports the notion that learning occurs within a social context. Pintrich, Marx, and Boyle (1993) refer to instructional interventions based on logical change as "cold conceptual change," because they ignore the social components of learning. Andragogy refers to the way adults learn compared to pedagogy, the way children learn (Knowles, 1984). While adults may have similar science misconceptions as children, they are not children. Most conceptual change research has focused on strategies for changing the way young learners think about science concepts. Research has shown that children are often reluctant to abandon their alternative views (Stepans, Beiswenger, & Dyche, 1986). Little research has examined the influence more andragogical interventions might have on science conceptual change in more mature learners. Interest in sociocultural narrative, has resulted in the intensive study of the quality of classroom discourse (Lemke, 2001), (Roth, 2002), particularly in small groups (Forman & Cazden, 1985; Mercer, 1995; Moll & Whitmore, 1993; Palinscar & Brown, 1984). This study employed discourse analysis within selected groups of preservice teachers to ascertain the correspondence with current conceptual change models and other factors, such as group homogeneity and heterogeneity, identified in prior research on group learning (Webb & Mastergeorge, 2003; Webb, Nemer, & Zuniga, 2002).

Design/Procedure:
During the 2004-2005 academic year, an adaptation of the two tier test the Physical Science Conceptions Test (PSCT) (Hsiung & Riley 1989) was administered to a sample of 55 pre-service elementary teachers at the National Institute of Education (NIE) in Singapore and 50 pre-service elementary teachers at a large state university in the US. Both locations were sites of convenience. The results indicated that both groups of preservice teachers held similar physical science misconceptions as measured by the PSCT. A follow-up study during the 2005-2006 academic years occurred within the context of a three credit hour, one semester course on elementary science methods. Two non-randomly assigned groups of twenty five pre-service elementary teachers at NIE were administered the PSCT. Using the results of this assessment, the pre-service teachers in each class were assigned to 5 person discussion groups. Treatment consisted of from 5 to 15 minutes of group discussion about the
physical science concepts assessed by the 19 PSCT items. No direct or indirect teacher instruction was provided. Within the groups, participants shared their pre-discussion responses on the two-tier item and used this as the basis for discussion. The groups were asked to come to a consensus if possible. At the end of the discussion, the groups’ members recorded their answer and reason on the two-tier test item. The second methods class was used as a control for end of semester comparisons. This group took the pre test but did not participate in peer discussions. 9 weeks later that took a delayed posttest.

This research employs treatment and control groups as well as pre and post tests, but the study is mainly emergent in nature and not hypothesis testing. The purpose of the study is to examine small group interaction over a limited time on specific science concepts. The use of two different sites (US and Singapore), items with face validity and pre and post tests are designed to strengthen credibility, transferability and believability of the study. (Lincoln & Guba 1985). The research grows out of our practical work with preservice teachers.

Figure one provides an example item taken from the PSCT. Table 1 and 2 provide cross cultural comparisons between US and Singapore groups. Table 3 provides Singapore data on item 11 before participating in discussions. Table 4 is a record of their responses after discussion with their peers.

Figure 1.
PSCT Item 11
11. All the air is pumped out of a steel container. The empty container is weighed. Then it is filled with hydrogen gas and weighed again.

A [ ] [ ] [ ] [ ] [ ] [ ]

The weight of the container full of hydrogen compared to the weight of the empty container would be
A. less.
B, greater.
C. the same.
D. greater or less depending on the temperature of the gas in the container.

Reason:
1. Hydrogen is lighter than air. For example a balloon full of hydrogen can float in air, so the weight of container would be less.
2. Hydrogen is a kind of gas. Unlike air, it has no weight. The weight of the container would be no different.
3. The hydrogen gas is not a material; it cannot occupy space, so the weight of container would be no different.
4. The hydrogen gas cannot be seen but does have weight. So the weight would be more after filling with hydrogen.

Tables 1 & 2
Comparisons between U.S.and Singapore on item 11

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<td>4.00</td>
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<td>4.00</td>
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Analysis of the US and Singapore results were done for the whole test and for individual items. Follow up interventions were done at the item level, reporting the percentage of respondents choosing the correct responses, reasons and distracters. The interest in this study is focused on individual concepts. Interviews were conducted with selected participants. Tape recordings were made for selected groups and analyzed.

Findings:
Analysis comparing US and Singapore pre-service teachers’ scores the PSCT indicated that on a majority of items, close to 50% of elementary pre-service teachers in both countries held misconceptions similar to younger learners as documented in the literature. Significant differences were found on the total test in favor of the Singapore pre-service teachers. Item 11 is provided as a “best case” example. On Item 11 (figure 1), 56 % of the Singapore (N=55) and 36 % of the US pre-service teachers (N=50) selected the correct answer and reason. Group discussions were an effective strategy in moving Singapore participants toward consensus on answers and reasons reflecting current science thinking. In the case of item 11, all of the students who had selected answers indicating misconceptions before the discussion selected the appropriate answers on the post discussion assessment. Nine weeks later these changed conceptions were still evident in delayed post-test comparisons with the group that had no peer discussion. Not all of the items had this same success rate. Findings indicated that if groups had no member holding a conflicting view then no conceptual change occurred. Students in groups who shared the same misconception at the beginning of the discussion held the same misconception at the end of the discussion. Participant responses in interviews and in written response to questionnaires provided further insight into what happened in the groups and how students felt they benefited from the discussions. A few are summarized under emerging categories or themes;

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Table 3
Pre discussion responses of methods class on item 11

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Table 4
Post discussion responses of methods class on item 11

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</table>
**Metacognitive theme:**

“I understood why my friends thought in a certain way. I was able to decide for myself which concept was right, theirs or mine. It also made me ponder why I thought in a certain way. This was the best part of it.”

**Andragogy theme:**

“For older learners, a 5 to 10 minute discussion is enough to make a conceptual change in thinking. This is because adults can rationalize better and are aware that there are interpretations and varying views on any subject matter. We are more ready to accept conceptual change if there is a good rationale. It is not a matter of the length of discussion time, but rather the validity or strength of reasoning.”

**Concerns about peer discussion:**

“Some members who are able to argue their way through or present their argument more effectively might persuade other members who are less vocal to believe that they are right. Members who have initially correct concepts might be dissuaded and stumble by believing the other members.”

“I found that if every member in the group held similar alternative conceptions, there was little room to protest or point out the correct scientific conception. The group will then leave, still holding their alternative conceptions.”

Discourse analysis found evidence for three of the four requirements for conceptual change suggested by Posner, Strike, Hewson and Gertzog (1982). This analysis looked for evidence within the group of helping, seeking help, discussion of science content, evidence of cognitive conflict, exposure of reasoning, occurrences of disequilibrium, and emergence of higher quality understanding.

**Contribution to Teaching/learning**

Pre-service elementary teachers in the U.S. and Singapore hold misconceptions similar to those of their students. In the case of Singapore students, this study suggests that peer discussions among primary pre-service teachers holding varying alternative frameworks may be a fruitful part of a conceptual teaching strategy. The participants appear willing to abandon some of their alternative conceptions when discussing and listening to peers who hold different views and these changes remain evident 9 weeks later. Based on interviews and questionnaires, peer discussion while effective, appears not to be sufficient. The students expressed a need for follow up hands-on activities to provide more conclusive evidence. The results of this exploratory study suggest that peer discussion can play an important role in conceptual change for this age learner. Questions about the role of peer-discussion in inquiry learning and its logical place in an instructional sequence remain unanswered. The results could provide a focus for experimental designed studies with more control for internal and external validity.

**References**


Tan, Goh, Chia and Treagust (2002). Development and application of a two-tier multiple choice diagnostic instrument to assess high school students’ understanding of inorganic chemistry qualitative analysis. Journal Of Research In Science Teaching, 39, 4, pp.283-301


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