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ABSTRACT

This study examined the effect of a teacher enhancement project combining training on the National Science Education Standards, problem solving and equity education on middle school science teachers' attitudes and practices and, in turn, the attitudes of their students. Participating teachers reported changes in their instructional methods that included increases in the use of cooperative learning, scientific inquiry, creative problem solving and questions directed toward higher order cognitive processes. Participating teachers' students indicated positive changes in attitudes and views toward science, particularly in the responses of female students and students of color. (Contains 25 references.) (Author/WRM)

The Impact of a Standards Guided Equity and Problem Solving Institute on Participating Science Teachers and Their Students

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Abstract

This study examines the effect of a teacher enhancement project combining training on the *National Science Education Standards*, problem solving and equity education on middle school science teachers' attitudes and practices and, in turn, the attitudes of their students. Participating teachers reported changes in their instructional methods that included increases in the use of cooperative learning, scientific inquiry, creative problem solving and questions directed toward higher order cognitive processes. Participating teachers' students indicated positive changes in attitudes and views toward science, particularly in the responses of female students and students of color.

The Impact of a Standards Guided Equity and Problem Solving Institute on Participating Teachers and Their Students

Advocates for the *National Science Education Standards (*National Research Council 1996) have provided a response to the Standards that has been strong and supportive (Loucks-Horsley, 1998; Zeidler, 1998; Bereiter et al, 1997; Collins, 1997; Mergendoller, 1997). The *Standards* have been described as "instrumental in efforts to improve science education," and "easily the most significant document of this decade" (Bybee and Champagne, 1995, p. 40). Riechard (1994) discusses the *Standards* as a component of a modern educational reform movement that appears to be well on its way to avoiding many of the pitfalls that undermined the effectiveness of previous reform movements, such as those that occurred in the wake of Sputnik.

The outcome for potential school reform as described by the *Standards* depends on how the *Standards* are implemented and, consequently, on how teachers are assisted and supported in making the transition to the practices advocated by the *Standards* (Bybee and Champagne, 1995; Bybee, 1995; Pratt, 1995; Riechard, 1994). Moving any reform effort from the arena of national and state policies to classroom practice is a difficult task that takes time and requires teachers to take risks. In the case of the *Standards,* the challenges are likely to be especially demanding due to the nature and degree of change implicit in successful implementation. As stated in the *Standards,* the ". . . reform effort requires a substantive change in how science is taught; an equally substantive change is needed in professional development practices" (NRC, 1996, p. 56). Bybee and Champagne (1995) advocate that in-service teachers be supported in making the transition to the new learning environments envisioned in the *Standards* because, ". . . the burden is too heavy and the changes too extensive for them to assume responsibility without support" (p. 42).

A panel of university science educators and middle school science teachers was selected by CAPE, the Consortium for the Advancement of Public Education in the Southeastern United States, to review the *Standards* for learning areas they felt science teachers would find the most difficult to implement. The two areas identified by the panel as problematic were the implementation of problem solving and addressing equity issues in science instruction. The purpose of this study was to assess the effectiveness of a summer institute designed to provide support for science teachers in implementing problem solving and equity education as advocated in the *Standards.*

Background

The view of excellence within the *Standards* envisions learning environments where students are actively engaged in "hands-on" and "minds-on" learning activities and demands that students have ". . . access to skilled professional teachers, adequate classroom time, a rich array of learning materials, accommodating work spaces, and the resources of the communities surrounding their schools" (NRC, 1996, p. 4). The NRC, in stating "The *Standards* apply to all students regardless of age, gender, cultural diversity, or ethnic background" (p. 2), recognizes that equity-based education critically underpins the concept of excellence in science teaching and learning.

The changes in science teaching practices required by the *Standards* are illustrated in Figure 1, comparing "traditional practices" with the "best practices" supported by the *Standards* (based on information provided in NRC, 1996). Implementation of the *Standards* entails a decreased emphasis on traditional strategies and placing increased emphasis on those strategies that reflect "best practices." The shift from "traditional practices" to "best practices" may also require substantial changes in teacher skills as well as changes in core values and beliefs about science and how it should be taught.

Insert Figure 1 about here

Two of the thrusts identified by the *Standards* relate to problem solving and equity. Teachers must become skilled problem solvers because problem solving is central to science, and teachers must model viable and attractive attitudes towards science and scientific inquiry. As the *Standards* detail, "Teacher learning is analogous to student learning, [teachers must] articulate questions, pursue answers to those questions, interpret information gathered, propose applications, and fit the new learning into the larger picture of science teaching" (NRC, 1996, p. 68). By doing so, students will experience their teachers as learners and see the roles of teachers and students as more congruent and complementary.

Although the value of problem-solving skills is most obvious with respect to the *Standards,* a relationship to the equity goals can also be made. The student-centered, inquiry-driven philosophy in the *Standards* appears consistent with the constructivist approach to science found in the strategies advocated as "multicultural science" (Lebow, 1993; Wachtel, 1996). Atwater (1995a) writes that constructivist approaches honor different styles of learning. In much the same way, equity is enhanced by using a broad range of assessment criteria (Lebow, 1993); recognizing the need for teachers to validate students' prior knowledge (such as their cultural contexts); and, consequently, tailoring their teaching of science accordingly (Atwater, 1995a; Johnson & Kean, 1992). Wachtel's (1996) perspective of science as "a social and cultural construct" (p. 82) appears very consistent with the views of the *Standards* in which "Learning science is something students do, not something that is done to them," and where students ". . . ask questions, acquire knowledge, construct explanations. . . and test those explanations in many different ways" (NRC, 1996, p. 20).

To be able to implement multicultural education, and particularly such equity standards as, "Display and demand respect for the diverse ideas, skills and experiences of all students" (NRC, 1996, p. 46), teachers need much more than strong problem-solving skills. To meet these expectations, teachers need the skills of effective multicultural science teachers. Effective multicultural teachers need to reflect on their own teaching actions and question their own assumptions and stereotypes (Atwater, 1995). For example, Shakeshaft (1995) says that teachers must recognize culturally-based gender differences in informal science learning, such as the informal science learning associated with cooking, which has traditionally been viewed as a female task in many cultures. In addition, teachers need to hold high expectations for all students (Shmurak and Ratliff, 1994) and to use strategies that counter the negative peer pressure students of color and females experience (Lebow, 1993). Such strategies include monitoring classroom participation to guard against the scenarios in which more confident and aggressive problem-solving approaches of some boys intimidate girls or students with less experience with science-related equipment (Lebow, 1993). Substantial knowledge is required if teachers are to use strategies, such as the biology instruction example proposed by Melear (1995, p. 23), where content addresses issues of real concern to cultural groups including alcohol abuse, domestic violence, AIDS education, prenatal care, and contamination of water. Finally, teachers need to provide opportunities for girls and students of color to meet and talk with role models who are women and people of color.

It appears that additional instruction, directed specifically towards issues of equity, would be very valuable given the demanding skills required of effective multicultural teachers. It also appears that helping teachers develop problem solving skills would facilitate their transition to the best practices of teaching embodied in the *Standards*, especially with respect to issues of "excellence."

Experimental Design

Overview of Experimental Design

A six-day workshop on creative problem-solving and equity education was offered as a means to help in-service middle school science teachers implement the *National Science Education Standards*. This study was designed to assess changes in perceptions and practices of teachers and the impact on their students. A pretest/posttest comparison group experimental design was used. The primary data sources consisted of pretest and posttest Likert-scale questionnaires administered to both the participating teachers and their students and a comparison group of teachers and students. The questionnaires used in the pre- and posttests were a shortened version of an instrument used to evaluate the equity module of the Biological Sciences Curriculum Study (BSCS) program "Decisions in Teaching Elementary School Science" (BSCS & AIT, 1998). The questionnaires elicited respondents' views by directing them to choose among five levels of agreement or disagreement with statements about science and science instruction. Questionnaires were administered to both groups of teachers as a pretest in the spring and to the student groups as a pretest in August of the same year. Posttest questions were administered to teachers and students in December. For both the teacher and student data, the null hypothesis for each analysis was that there would be no change between pretest and posttest.[1]

Subjects

The study consisted of 46 inservice middle school science teachers, 27 of whom attended the summer institute, and the students they were assigned to teach in the next school year. The teachers were randomly selected for the workshop from 45 responses to a mass mailing to 150 regional middle school science teachers inviting them to attend a summer institute. The mass mailing was designed to reach all middle grades science teachers in the service region of this medium sized university in the Southeastern United States. Each of the participant teachers was asked to identify a science teacher in their school who had a similar approach to their own in teaching methodology. Surveys were sent to all participant and comparison teachers. Nineteen complete sets, including both participant and comparison teacher responses, were received. Participating teachers' responses were included in the post data analysis only if they returned to their previous teaching post and were matched with a comparison group teacher that also returned to their previous position in the same school. Therefore, 14 of the 19 participating teachers were included in the post data analysis. For the student comparisons, 14 participant teachers and 14 comparison teachers were randomly selected and their students were surveyed. Seven complete sets of student data, consisting of pre and post data for both participant and comparison group teachers, were received and included in the data analysis.

[1]Copies of the full paper including questionnaires and tables are available at http://www.uncwil.edu/people/huberr/

Treatment

The 27 teachers in the experimental group participated in a five-day summer institute on creative problem solving and equity education and in follow up activities during the fall of the same year. These included a one-day implementation workshop and the completion of a final reflection report on the project implementation. The five-day summer institute consisted of 45 hours of education in creative problem solving and multicultural education. Four full days were devoted to instruction and practice in creative problem solving. During this time, teachers were taught how to use a problem solving model that requires students to ask questions and find answers through investigation. The model used, "Search, Solve, Create and Share (SSCS)," involved students in finding and refining a researchable problem, designing and conducting an appropriate investigation, processing data, and sharing conclusions (for a complete description of SSCS see Wilson & Pizzini, 1994; Pizzini, Shepardson & Abell, 1992; Pizzini, Abell, & Shepardson, 1988; Pizzini, Shepardson, & Abell, 1989). Teachers were taught how to assist students in the selection of a problem to research and how to state that problem in the form of a research question. They were then taught how to assist students to solve their research questions and to develop ways to share the results of their research.

During the four-day period, teachers used the SSCS model for three different problem-solving cycles:

1. researching which of four brands of paper towel to purchase;
2. exploring how temperature sensitive strips, called biodots, could be used to determine the effect of various activities on the temperature of a person's hand; and
3. exploring how changing various parameters affects the buoyancy of raisins that are bobbing up and down in a bottle of clear, carbonated soda..

During all three problem-solving cycles of the SSCS model, the pattern of instruction described by Abell (1989) was followed:

- expose teachers to a new topic or strategy through an activity that models effective teaching;
- analyze the merits of the strategy through reading and discussion;
- have teachers conduct the activity, collect data and report their findings to the group; and
- discuss results and various modifications to fit individual needs.

In addition to being taught how to use the SSCS model of problem solving, the teachers were introduced to the National Science Education Standards (NRC, 1996) and shown how the SSCS model was supported by the *Standards* (See Figure 1).

Equity education was included both as a full day focus as well as being integrated throughout the institute. Both of the main presenters emphasized the connections between best practices and the goals of equity education. Equity education was a recurring theme throughout the institute. Examples of equity integration included discussion of stereotypes of scientists, introduced on the first day, in which each participant was asked to draw a picture of a scientist at work. This was followed by a presentation by a female university scientist on the obstacles and challenges she faced in pursuing a career in a traditionally male dominated field. The one-day focus on equity sought to draw upon the teachers' own experiences in answering such questions as "What is Multicultural Science?" and "Why is there a need for Multicultural Science?" Twenty-four of the 29 participants were female, which provided a natural tension for an equity focus geared to increase female participation. Participants were asked to examine their own cultural identities as a way of increasing awareness of how culture influences learning. Other topics included: the characteristics of an effective multicultural teacher, multicultural science teaching strategies, and participation in a cross cultural simulation.

While support for a constructivist view of science and the importance of equity in teaching science are fairly widely accepted ideas of multicultural science, some multiculturalists challenge the universality of science itself claiming that what is taught in science refers to "Western modern science" or a Eurocentric world view (Ogawa, 1995). From this latter perspective, an important goal of multicultural science is to change science education from the teaching of a Eurocentric world-view to one that embraces multiple perspectives of science (Stanley & Brickhouse, 1994). Given the limited time available in the workshop, the arguments relating to each of the perspectives of science were not specifically included.

Results

The results from each of the two institute focus areas, best practices and equity, are analyzed separately to facilitate comprehension. This division is not clear-cut and some question items were considered under both categories. The data from the teachers is presented first, followed by the data on students.

Teachers

The data indicate broad positive outcomes of institute participation. For most of the items on the teacher questionnaires, the authors viewed agreement with the questionnaire item as the response consistent with "best practices" as set forth in the philosophy and goals of the *Standards*. Thus, our analysis focused on the percent of respondents indicating that they either agreed or strongly agreed with questionnaire items (response ratings of 4 and 5). While the pretest results showed consistent responses between the experimental and comparison groups, the two groups differed substantially in posttest measures. In the comparison of pre- and post-participation results for the group of teachers who participated in the institute, an increase in agreement was shown for every survey item. In contrast, for the non-participating group, there was little or no change for many items and, where change did occur, the general pattern reflects decreased agreement.

The marked differences between the group of participating teachers and the comparison group, as measured through the self-report pretest and posttest questionnaire data, is depicted graphically in Figures 2 and 3. In these figures, the charted points graph pre- and posttest responses (percentages of agree and strongly agree responses) to individual questionnaire items. The diagonal line depicts where scores showing no change between the two tests would fall. Points plotted above this line represent increases in agreement percentages (improvements) in the posttest results. For the participating teachers (Figure 2), data points for all questionnaire items plotted above the "no change" line. A very different picture is portrayed for the comparison group (Figure 3) with many of the points clustered around the "no-change" line and the general pattern is one of decreased agreement with the questionnaire items[2].

Insert Figures 2&3 About Here

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[2] It is possible to determine the extent to which the two distributions differed by calculating the difference between pretest and posttest percentage scores for each item, then matching the calculated differences for each item between participant and comparison groups. Given the non-normality of the distributions involved, the non-parametric Wilcoxon matched-pairs signed-ranks test was used as the test statistic. The null hypothesis for this statistic is that there is no difference between the two distributions. The test produced a value of $z = -4.3558$ with a two-tailed significance level of $p < .001$. Thus, the hypothesis of there being no difference between the distributions for participant and comparison groups was rejected at the .05 level.

Teachers - Best Practices

Comparison of pre- and posttest results for the participating teachers revealed a consistent and statistically significant increase in percentages of combined "agree" and "strongly agree" responses for the set of questionnaire items. For 10 of the 26 total items an increase of 25 percentage points or higher was observed. Responses to the item "encourage students to plan their own experiment" revealed a particularly large increase (23 to 93 percent) with large increases for "use creative problem solving" (52 to 100 percent) and for "acknowledge that I sometimes do not know the answers" (56 to 100percent)[3].

Teachers - Equity Education

Analysis of questionnaire items related specifically to multicultural science revealed marked increases from pretest to posttest. Comparison group responses to these same items decreased or remained the same. With a single exception, over 50% of the participating teachers agreed or strongly agreed with every equity item on the questionnaire in the posttest results. In the one case where the 50% mark was not reached, "Give students opportunities to interact with female and minority role models in science," pretest results were very low (8%) and a noteworthy increase occurred in the posttest results(36%).

Students

Students were asked to respond (pre- and posttest) to questions relating to their views of science and science class. Student responses of agreement with the questionnaire item were taken as an indication of their teacher's implementation of "best practices" as set forth in the

[3] Copies of the full paper including questionnaires and tables are available at http://www.uncwil.edu/people/huberr/

Standards. Thus, the analysis focused on the percent of respondents indicating that they either agreed or strongly agreed with questionnaire items (response ratings of 4 and 5).

Generally, the data from students were consistent with the changes reported by teachers. Although the filtering process of transmitting the workshop benefits to these students through the participating teachers appears to have had a dampening effect, positive consequences of workshop participation are revealed in the data as well. As with the teacher data, the impacts were broad and in selected areas pronounced. The findings also indicate that the positive outcomes were especially evident among female students and students of color[4].

<u>Students - Best Practices</u>

Analysis of data obtained from students revealed positive outcomes from their teachers' participation in the workshop. For the majority of questionnaire items related to issues of how students feel about science and their science class (9 of 14), the percentages of agree and strongly agree responses increased. While most of the positive changes were of modest degree, the amount of change for some of the items was over ten percentage points.

For one item, "Bored in science class," there was a decrease in agreement from 80% to 72% (analysis of 1 and 2 responses, rather than 4 and 5 responses, were considered for this item). For the remaining four questionnaire items, modest decreases in agreement scores were obtained for the participating teachers' students. Data for the comparison students exhibited an increase in agreement for only four of the 14 items, with the largest increase being six percentage points.

[4] Similar to the comparison made for the teachers, and for the same reasons of non-normality, the non-parametric Wilcoxon matched-pairs signed-ranks test was used as the test statistic for comparing pretest/posttest differences between student groups. The test produced a value of $z = -2.6672$ with a two-tailed significance level of $p < .01$. Thus, the null hypothesis of there being no difference between the distributions for participant and comparison group was rejected at the .05 level.

Especially noteworthy was the apparent improvement in student attitudes towards science and how they saw themselves as practitioners of science. Students indicated increased levels of confidence in their abilities to set up experiments, ask questions and succeed in science, and increased agreement with statements presenting group activities in a positive light. There were also increases in the number of students reporting agreement with statements about science being useful and fun.

Students - Equity Education

Gender

Relevant questions related to how students feel about science and their science classes were further analyzed by gender. Overall, data from the participating teachers' students demonstrated positive increases for all but three items, two directly related to boys or girls being better at science and one about being bored in science class. The responses of the males showed increases on two of the items ("The things I learn in science are useful" and "Being a scientist would be fun"). The responses of the females, on the other hand, increased for all but two items, with increases ranging from 3 to 20 percentage points. Most notably, the female responses to "Feel successful in science class" increased from 44% to 64%. This compared to the responses of males that showed a decrease from 62% to 54%. The percentage of female students on the pretest who responded positively to the question "Feel successful in science class," was 18 percentage points below that of the males. On the posttest, female responses were ten percentage points higher than those of the males. The other increase was in response to the question "Like to be a scientist," in which female responses increased from 29% to 40%. This compared with the male responses that showed a slight decrease from 36% to 35%. Control group responses decreased across all selected items except for one, "Being a scientist would be fun," which showed a slight increase for both male and female.

Race

Pertinent student questions were further analyzed by race. For the purposes of the survey, "students of color" were those students who identified themselves as Black, Hispanic, Asian or Native American. Comparisons of pretest and posttest scores for white students and students of color indicated that both groups showed increases on most of the items. For students of color, the item "Being a scientist would be fun" showed a sizable increase from 17% to 59%. Similarly, the number of students of color who indicated they felt successful in science class increased from 52% to 62%. The percentage of students of color who agreed that "People of color make valuable contributions" increased only slightly (39% to 41%).

Discussion

Analysis of the findings suggest that support structures for inservice teachers, such as the six-day institute described above, can be effective in facilitating the transitions the teachers need to make toward implementation of the science *Standards*. It is no small matter that teachers reported increases in agreement for all questionnaire items after one full semester of implementation. All increases out-paced those of comparison teachers by wide margins. Perhaps the most important effect of the workshop was to produce positive changes for the participants on those aspects of science teaching that diminished for comparison teachers. For 17 items, participant teacher agreement increased while agreement decreased for the comparison group. Further, for half of these, participant and comparison teachers' pretest agreement levels were nearly identical (within 10 percentage points). The items included: help students understand the process of science inquiry, encourage students to apply the science content to their personal lives, help students understand the nature of science and acknowledge that I sometimes do not know the answers to all students' questions. In addition, there were three equity items: examine the content of instructional materials to ensure that women and people of color are represented, monitor female and minority students' achievement and participation, and include goals that target equity in female and minority students' participation. One could reasonably conclude from these results that the two groups of teachers had very different experiences during the implementation semester, and the participant teachers were more successful in implementing the *Standards*.

The investigation also supports the notion that providing teachers with assistance in implementing the *Standards* can have a positive impact on students' perceptions of science. Comparisons of results for the two groups of students indicated noteworthy improvements among the participating teachers' classes, especially considering the potential variability of the instruction over the course of the semester. Analogous to the findings for the teachers, five of the student questionnaire items increased for the participant teachers' students while decreasing for comparison students, though few of the contrasts in changes were as dramatic as for the teachers. A salient point of the analysis is the extent to which equity, a key emphasis of the summer institute, was reflected in the largest changes for target groups of students. For female students of participating teachers, the largest gain in agreement percentage was for the item "Feel successful in science class," while the largest change for students of color in the same group was for the item "Being a scientist would be fun." Given the positive increases in responses to such items as "Enjoy learning science," "The things I learn are useful in science" and "I feel successful in science class," it is puzzling why there was not a decrease in responses to the item "I am bored in science class." Overall, however, the results demonstrate that equity education is an attainable goal in science education and that teacher inservice training can play a vital role in facilitating the inclusion of historically underrepresented groups in science.

Three factors would appear relevant in explaining why there were such positive changes in teacher attitudes from a short inservice workshop on problem solving, national *Standards* and equity education.

1. The SSCS problem solving method is fairly straightforward and easy to implement. Teachers were trained in the four-step process that provided structure and guided their implementation of problem solving in their classrooms.
2. The workshop's focus on the *Standards* and on equity education gave teachers a rationale and justification for making changes to their practice. Teachers want to do the right thing for their students and that includes implementing what the experts on equity and science education have to say about best practices. Additionally, teachers know that they frequently need to explain or justify their practices to school administrators and parents. Thus, to be comfortable with innovative methods and approaches, teachers need to feel confident they not only know the "how" but also the "why" of the techniques. Therefore, experiential learning using expert-validated approaches may be especially helpful in providing teachers the support they need to feel capable of not merely practicing but championing new strategies.
3. Many of the teachers had been together in other science workshops. Consequently, the cohort group that developed provided encouragement and support as they worked to implement a new approach in their classrooms.

Inevitably, there are limitations on the extent to which results of this type of study can be generalized to other groups of teachers and students. Since the teachers participating in the workshop were randomly selected for participation from a list of applicants, it is possible that they are not representative of science teachers in general. Teacher posttest results in the study were recorded six months after the end of the summer institute, which leaves open the question of whether reported changes would still be present if more time had elapsed. Another limitation concerns the accuracy of the self-reporting nature of the study.

Even given these limitations, however, the significant contrast in results between the participant and comparison groups of teachers, as well as the differences in student outcomes, supports the conclusion that participation in the institute provided substantial assistance to the teachers in implementing the *Standards*. One of the important implications of this study is that the three-pronged approach used here—providing training in the areas of (1) the *Standards*, (2) problem solving, and (3) equity education—may be particularly effective in providing inservice teachers with the support they need to implement the *Standards*. However, additional research is needed to explore this tentative conclusion, especially given the limitations of self-report data, as used here. Future professional development efforts emphasizing problem solving in the teaching of science might benefit from the collection of more qualitative information from teachers. Possibilities include the use of teacher self-reflection journals and the videotaping of *Standards* based lessons. A further topic for examination suggested by the study is the long-term effects of professional development on teacher change.

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Figure 1: Comparison of traditional practices with best practices envisioned in the *Standards.*

Value/Belief Areas	Traditional Practices	Standards
Science content knowledge and process skills. . .	Should be separated. . .	Should be integrated. . .
With an emphasis on. . .	Science content knowledge as facts	Understanding science concepts
Through a coverage designed to provide. . .	Exposure to a broad range of science content	In-depth treatment of key concepts.
Science is taught as. . .	The memorization of terms	Argument and explanation. . .
Where students learn. . .	The right answers	Strategies for using evidence
Where diversity of students is…	Given little attention	Incorporated into the teaching of science
And students analyze and synthesize data. . .	Working alone without defending a conclusion	While working in groups and to defend a conclusion

Figure 2. Percentages of Participating Teachers Agreeing or Strongly Agreeing with Numbered Survey Items (Pretest n=19; posttest n=14)

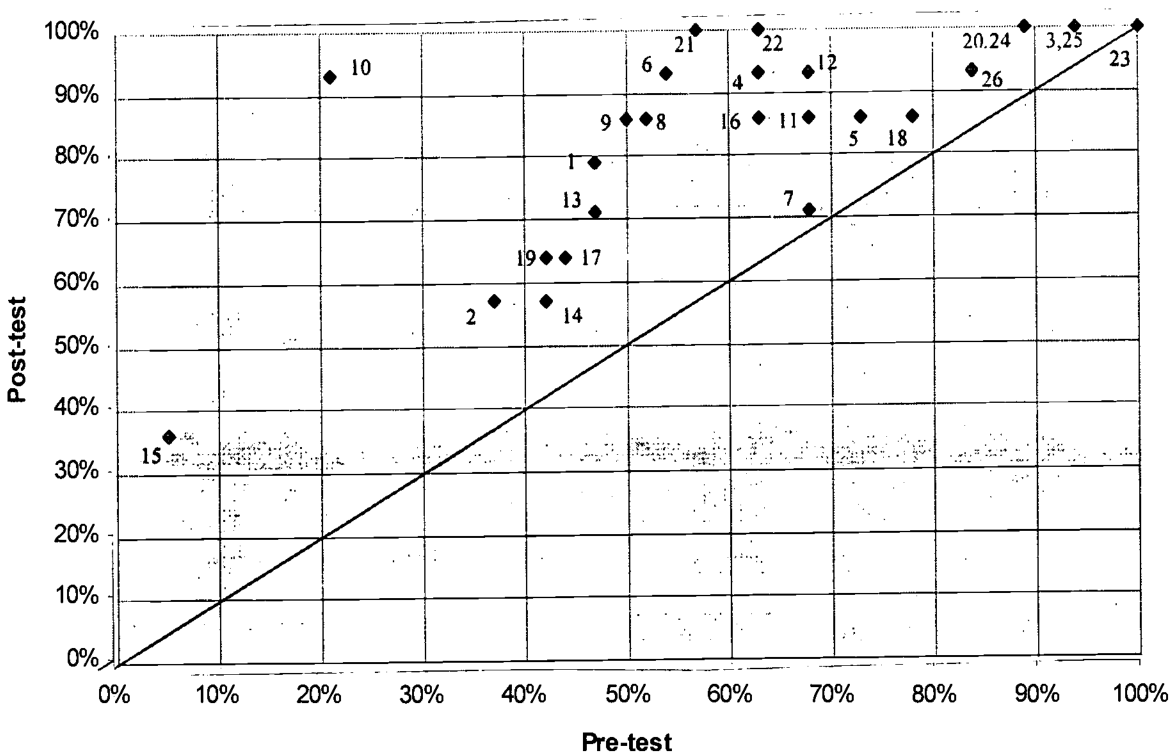

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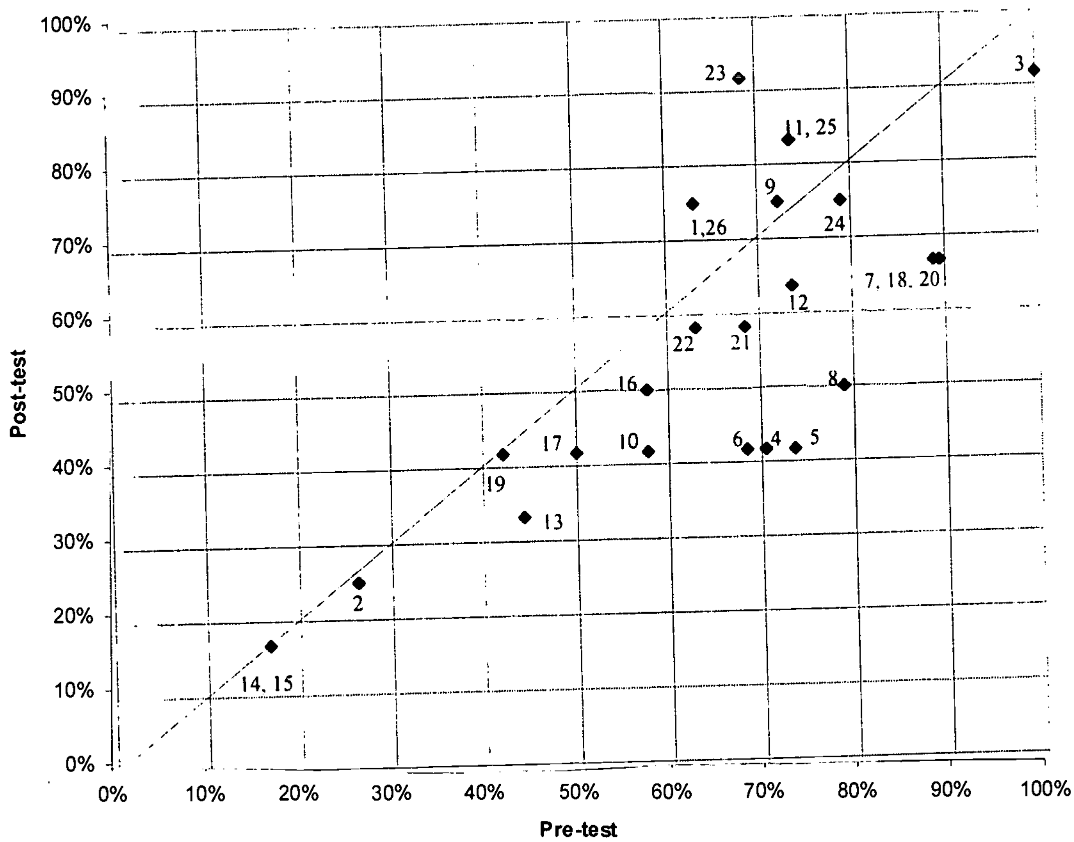
Figure 3. Percentages of Comparison Teachers Agreeing or Strongly Agreeing with Numbered Survey Items (Pretest n=19; posttest n=12)



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