How Teachers Teach: Seventh- and Eighth-grade Science Instruction in the USA

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Introduction

At the U.S. Secretary of Education's Second Conference on Mathematics and Science four themes for reform were identified. These were the need for national standards, the improvement of mathematics and science teaching, the improvement of instructional materials, and the need for systemic change (McKinney, 1993). National standards have been released (National Research Council (NRC), 1996), multiple plans exist for improvement of science and mathematics instruction, and both state and national initiatives exist to promote system-wide change (American Association for the Advancement of Science, 1989, 1992; NRC, 1996; Michigan Statewide Systemic Initiative (MSSI), 1995; Reed & Calhoon, 1992). But what is actually going on in schools? If we looked into the junior high classrooms across the United States, what would we see happening during science instruction? Are teachers implementing the standards, objectives, and procedures advocated by these change efforts? What about the materials being used during class time? And are there any characteristics common to teachers who make greater use of exemplary teaching practices?

Alan McCormack (1992) proposes that U.S. science education is currently in its second revolution, which began in 1980. As part of this revolution, both national and state-level initiatives exist to promote educational reform in science. None of these projects is exclusive of the others, rather, each is complementary. National initiatives include Science, Technology, and Society (STS); the *Project on Scope, Sequence, and*

Coordination (SS&C) (National Science Teachers Association, 1992); National Science Education Standards (NRC, 1996); and *Project 2061* (AAAS, 1989, 1992).

While each of these reform movements has its own unique characteristics, it is possible to identify several common attributes. With few exceptions, these are the common goals:

1. an integrated, thematic approach that emphasizes connections within science and with "other" subject areas
2. relevance of science education to daily life
3. teaching for understanding, which includes in-depth treatment of core concepts rather than superficial treatment of many topics
4. use of hands-on and constructivist learning activities
5. inclusion of important societal topics
6. integration of technology, and
7. inclusion of higher-order thinking and decision-making skills (AAAS, 1989, 1992; Ahlgren, 1993; Ahlgren & Rutherford, 1993; McCormack, 1992; McKinney, 1993).

The instructional methodologies called for could be classified as primarily constructivist in nature. Constructivism requires active, problem-based learning and the assessment of a student’s conceptual understanding before beginning instruction. Constructivism and absorption represent opposite ends of the instructional continuum in science education (Tobin & Fraser, 1990). Absorption involves passive information transfer from the teacher or textbook to the student.

Science educators can make use of the knowledge base on school-change to aid in the understanding and implementation of systemic reform. Teacher efficacy has been identified as an important predictor of implementation of educational innovations and student achievement (Armor et al., 1976; Ashton, Webb, & Doda, 1983a, 1983b; Berman, McLaughlin, Bass, Pauly, & Zellman, 1977; Brookover, Beady, Flood, Schweitzer, & Wisenbaker, 1977; Tracz & Gibson, 1986). Berman et al (1977) identified a teacher's sense of efficacy as the most important factor related to student achievement and teacher innovation.

The dictionary defines efficacy as “the power to produce an effect.” This study was based on Bandura’s cognitive social learning theory (Bandura, 1977). Bandura’s theory assumes that cognitive processes create and strengthen personal efficacy expectations. He perceives efficacy as composed of two parts: outcome expectancy and efficacy expectations and bases his theory on the interaction of these two constructs. An outcome expectancy is defined as “a person’s estimate that a given behavior will lead to certain outcomes,” while efficacy expectations are defined as “the conviction that one can successfully execute the behavior required to produce the outcomes” (p. 193). We can look to Alcoholics Anonymous for a practical example. If a person believes that participation in AA will lead to sobriety, that is an outcome expectancy. The person’s belief as to whether he or she has the ability to successfully participate in AA is an efficacy expectation.

In Bandura’s conceptualization, self-efficacy expectations predict a person’s willingness to initiate and persevere in stressful situations. Applied to education, Bandura’s theory can be used to explain a teacher’s use or avoidance of certain instructional practices. According to Bandura, successful classroom episodes function as corrective experiences that reinforce personal efficacy beliefs. Since the implementation of innovation creates job-related stress, self-efficacy expectations would predict both a teacher’s willingness to attempt an innovation and the teacher’s perseverance during the implementation of an innovation. Let's look at a practical example of Bandura's theory applied to science education. A science teacher's beliefs about the ability of inductive thinking strategies to increase student learning is an outcome expectation, whereas beliefs about his or her ability to teach inductively are efficacy beliefs.

Identification of Variables

The research questions that guided this study were as follows:

1. What instructional practices are used by seventh- and eighth-grade science teachers?
2. To what extent are these practices used by teachers in seventh- and eighth-grade science instruction?
3 What is the relationship between teacher efficacy and the use of specific instructional practices?

Based on these research questions, this study explored possible relationships between three variables: teacher efficacy; the use of instructional practices, and context variables.

Teacher efficacy in this study was defined as consisting of two sub-variables: science teaching outcome expectancy and personal science teaching efficacy belief. Science teaching outcome expectancies (outcome expectancies) refers to a general belief in the ability of science teachers to affect students' achievement through instruction (Ashton et al., 1983a, 1983b; Gibson & Dembo, 1984; Guyton, Fox, & Sisk, 1991; Riggs & Enochs, 1990; Woolfolk & Hoy, 1990). Outcome expectancies is operationally defined as a teacher's score on the "science teaching outcome expectancy" subscale of the Science Teachers Efficacy Beliefs Instrument (STEBI).

Personal science teaching efficacy beliefs (efficacy beliefs) refers to teachers' specific beliefs in their own perceived competencies in increasing student science achievement through instruction (Ashton et al., 1983a, 1983b; Gibson & Dembo, 1984; Guyton et al., 1991; Riggs & Enochs, 1990; Woolfolk & Hoy, 1990). Efficacy beliefs is operationally defined as a teacher's score on the “personal science teaching efficacy beliefs“ subscale on the STEBI.

In this study, instructional variables included instructional methods, computer use, and instructional materials. Based on the review of the literature and feedback from science education professionals, the instructional methods listed on the Science Methods and Materials Scale were placed in two categories: absorption and constructivist.

Methodology

I chose to study seventh- and eighth-grade science teachers in the United States. This population includes teachers from public, private, and parochial schools. The survey instrument for this study consisted of three sections: context variables (demographics), the Science Methods and Materials Scale, and the Science Teaching Efficacy Beliefs Instrument (STEBI) (Riggs & Enochs, 1990). The Science Methods and Materials Scale was adapted for this study from instruments used in two previous national studies (Weiss, 1978, 1987).

This study utilized standard mail survey techniques for data collection. The prestudy goal of 300 returns was reached, as a total of 303 returns were received. This resulted in a gross return rate of 55.8% of the 543 teachers sampled. Two hundred eighty-five teachers returned survey instruments which were included in data analysis. Therefore, the net return rate was 52.5%. The 285 returns used for data analysis represented 95.0% of the prestudy goal of 300 returns.

Descriptive Data

In looking at the demographic data from this study, it is possible to create a picture of the typical seventh- and eight-grade science teacher. That teacher is a male (52%) and has taught 16 years. He works as a science specialist (82%) not in a self-contained classroom. He perceives his colleagues as cooperative (76.8%). He feels at least adequately qualified to teach life science (94.0%), physical science (90.2%), earth/space science (93.0%), and mathematics (75.8%).

While 52 percent of science teachers in grades seven and eight are male, the gender distribution in these grades has become more balanced in the past 18 years. In 1977, only 38 percent of science teachers in grades seven through nine were female (Weiss, 1978). By 1985-86 this had risen to 41percent (Weiss, 1987). In my 1995 study the number of female science teachers in American junior high grades was up to 48 percent.

In looking at the entire group of teachers in my study, it is possible to identify teaching practices commonly used and those rarely used. Some of the results are significant when they are compared with the stated reform goals and national standards for science education.

Instructional methods used *at least* weekly included discussion (94.4%), lecture (72.3%), hands-on / lab work (68.7%), real life application (68.1%), worksheets (65.6%), inductive thinking (63.8%), problem solving (62.8%), cooperative learning (61.7%), and seat work (56.5%).

Instructional methods rarely used (less than once a month *or* never) by science teachers included field trips (91.2%), role play (75.1%), the learning cycle (63.2%), programmed learning (61.1%), student reports (56.5%), simulations (51.9%), and student projects (50.5%).

Almost half of the science teachers in this study indicated they used two types of instructional materials used at least weekly. These were lab supplies (60%) and the overhead projector (48.5%). Instructional materials used rarely by more than 90 percent of the teachers included camcorders (94%), guest speakers (91.5%), cameras (90.5%), and slides (90.5%).

The study revealed some interesting findings related to materials use. Fifty-nine percent of teachers indicated they rarely or never use living plants or animals in the classroom, and 49 percent of teachers rarely or never use collections in their science classroom. Sixty-one percent of teachers rarely or never use instructional television, but 69 percent use videos or filmstrips at least once a month. Laser discs are rarely or never used by 79 percent of science teachers in grades seven and eight.

The most significant finding about the use of computers in seventh- and eighth-grade science education is that it typically doesn’t happen. This does not tend to be the choice of the teacher, however. It appears that most science teachers do not have access to adequate computer facilities to integrate their use into science instruction. The highest reported use of computers was for learning science content (20.8%), as a lab tool (16.3%), students writing programs (15.9%), and problem solving (15.9%). Conversely, the lowest reported usage of computers in the science classroom were for robotics (2.5%), networks, (5.7%), databases (6.7%), and drill and practice (9.5%). This result is consistent with data national released last April (Survey finds . . ., 1995).

Hypothesis Testing

The research hypotheses investigated in this study dealt with relationships between variables. Since most variables were ordinal, Spearman correlation procedures were used to test the significance of relationships. The alpha for testing the hypotheses was set at .05.

The first null hypothesis stated: There is no relationship between the use of specific instructional methodologies and teacher efficacy. A summary of the results of this statistical procedure for constructivist teaching methodologies is presented in Table 1. This data analysis yielded 17 weak but statistically significant relationships. The relationships with the greatest significance for the efficacy beliefs subscale were indicated for lab work, inquiry, and problem solving ($p < .00001$). Three additional significant relationships were indicated for efficacy beliefs and constructivist methods at $p < .0001$: inductive thinking, real-life applications, discovery. The smallest significant correlation between efficacy beliefs and constructivist methods was student projects ($p < .01$).

On the outcome expectancies subscale, several weak relationships were indicated between outcome expectancies and constructivist methods. The strongest of these weak relationships was between outcome expectancies and simulations. The correlation was positive and significant ($p < .001$). Other significant correlations include projects, lab work, cooperative learning, and discovery($p < .01$); use of the learning cycle, application to real life, inductive thinking, role play, and problem solving, ($p < .05$).

To complete testing of the first hypothesis, an identical correlation analysis was run for absorption teaching methodologies and teacher efficacy (see Table 1). Unlike the correlations for constructivist methods and teacher efficacy, there were relatively few significant correlations and they were typically smaller. In looking at the correlations for absorption methods and efficacy beliefs, weak negative relationships exist for seat work ($p < .01$) and programmed learning ($p < .05$). A weak, positive relationship exists between efficacy beliefs and student reports ($p < .05$). The correlations for absorption methods and outcome expectancies yielded a positive relationship for reports ($p < .001$) and a negative relationship for the use of worksheets ($p < .05$).

Calculation of correlation coefficients for teaching methods yielded several statistically significant correlations. In these cases the null hypotheses were rejected and the research hypotheses were supported.

The second null hypothesis stated: There is no relationship between the use of specific computer use practices and teacher efficacy. This hypothesis was tested through Spearman's correlation.

Three weak relationships were indicated between teacher efficacy and computer use practices. The existence of relationships was supported between efficacy beliefs and teacher demonstrations on the computer $r(282) = .17$, $p < .01$, use of computer as a lab tool $r(282) = .12$, $p < .05$, and learning content on the computer $r(282) = .12$, $p <$

.05. One relationship was supported on the outcome expectancies scale with the use of computer networks, $r(282) = .15$, $p < .05$ (see table 2).

Calculation of correlation coefficients for computer use practices and teacher efficacy yielded four statistically significant correlations. In these cases the null hypotheses were rejected and the research hypotheses were supported.

The third null hypothesis stated: There is no relationship between the use of specific instructional materials and teacher efficacy. This hypothesis was tested through Spearman's correlation.

The most significant of these weak relationships for instructional materials and teacher efficacy was between efficacy beliefs and use of lab supplies. It was both positive and significant, $r(284) = .38$, $p < .00001$. Other relationships were supported between efficacy beliefs and the use of scopes, $r(284) = .21$, $p < .001$; the use of models, $r(284) = .22$, $p < .001$; and the use of slides, $r(284) = .14$, $p < .05$.. Weak relationships were also supported between outcome expectancies and the use of lab supplies, $r(284) = .15$, $p < .05$; cameras, $r(284) = .14$, $p < .05$; collections, $r(284) = .12$, $p < .05$; and slides, $r(284) = .15$, $p < .05$ (see Table 3).

Calculation of correlation coefficients for instructional materials and efficacy beliefs yielded eight statistically significant correlations. In these cases the null hypotheses were rejected and the research hypotheses were supported.

Discussion

Twenty-five of 56 (44.6%) correlations computed were found to be statistically significant for teacher efficacy and specific instructional practices. While these correlations were statistically significant, they were typically quite small. The descriptive data suggested the use of a variety of teaching practices by seventh- and eighth-grade science teachers in general. The large number of small yet significant correlations further supports this conceptualization for efficacious teachers specifically.

Of the 26 correlations computed for teacher efficacy and constructivist instructional methods, 17 (65.3%) were statistically significant. Correlations between teacher efficacy and absorption instructional methods yielded only four significant correlation coefficients from the 14 (28.6%) coefficients calculated, and three of these were negative. The relationship between teacher efficacy and the use of absorption instructional methods is only supported for the use of student written reports. While in this study, student reports were classified as am absorption instructional method, they would tend more toward the constructivist end of the absorption-contructivism continuum than would other absorption techniques such as lecture or seat work. It is possible that efficacious science teachers assign student reports to foster rudimentary research skills.

It is also interesting to note what absorption instructional methods efficacious science teachers report using significantly less than the average science teacher. These are seat work, worksheet, and programmed learning. The use of constructivist instructional methods by efficacious science teachers is supported by this data more than is the use of absorption instructional methods. This is consistent with the findings of Treagust (1991); Tobin and Fraser (1990); Yager, Hidayat, &Penick, (1988); and Searles and Kudeki (1987).

These data suggest a stronger relationship between teachers' use of constructivist practices and beliefs about their personal science teaching abilities (efficacy beliefs) than for their beliefs about science teaching in general (outcome expectancies). The only correlation coefficient greater than .20 for the outcome expectancies subscale was found between outcome expectancies and use of simulations. Tracz and Gibson (1986) also found a greater number of significant correlations for efficacy beliefs as compared to outcome expectancies. Science teachers in this study tended to credit more instructional power to themselves as individuals than to science educators as a group.

Conclusions

The major conclusions drawn from this study are directly related to the use of instructional practices and teacher efficacy. These conclusions include the following:

1. While many significant relationships were found between instructional practices and the use of specific instructional practices, the correlations were weak. There are at least two reasons the correlations were not stronger: confusion about the definition of terms (ie. inquiry, induction, problem solving, etc.), or the fact that the data was collected with a self-report instrument.
2. More than two-thirds of seventh- and eighth-grade teachers in the United States do not use computers in science instruction. Many of these teachers do not have access to computers or computer labs.
3. Statistically significant positive relationships exist between the use of specific constructivist instructional methods and teacher efficacy (see Table 1). These

findings are consistent with studies that showed a relationship between teacher efficacy and effective teaching, and teacher efficacy and the implementation of innovation (Armor et al., 1976; Berman et al., 1977; Tracz & Gibson, 1986).

4. Statistically significant relationships, both positive and negative, exist between the use of absorption instructional methods and teacher efficacy (see Table 1). A significant positive relationship was found between teacher efficacy and the use of student reports. Significant negative relationships were found between teacher efficacy and assigning seat work from the textbook, worksheets, slides, and programmed learning. Positive relationships between teacher efficacy and use of absorption instructional practices were not predicted from the review of the literature, which supported a relationship between teacher efficacy, effective teaching, and the implementation of innovation (Armor et al., 1976; Berman et al., 1977; Tracz & Gibson, 1986). However, it may be that effective teaching makes use of a wide variety of techniques, both absorption and constructivist, rather than depending on only one type of instruction.

Recommendations

1. Broad-based studies, encompassing the traditions of both quantitative and qualitative research, should be conducted to gather a wide range of data on science education, including observations of classroom practices, interviews, teacher efficacy assessment, and student achievement.
2. A longitudinal study should be conducted that traces science teachers' efficacy beliefs before training, during training, and throughout the implementation of a

constructivist-based teacher-training program. This would provide empirical data on the stability or changeability of the teacher efficacy trait.

3. Teacher education programs and teacher in-service training could be designed around the instructional practices positively associated with science teacher efficacy beliefs. Evaluation of these efforts would reveal their success or failure in changing teacher instructional behaviors in the science classroom.
4. Develop and evaluate a pre-service science methods course based on the methods with positive correlations to science teacher efficacy beliefs.

TABLE 1

CORRELATIONS FOR TEACHER EFFICACY
AND CONSTRUCTIVIST PRACTICES

Practice	Efficacy beliefs	Outcome expectancies
	Constructivist Methods	
Discussion	.01	.08
Projects	.16**	.18**
Lab work	.31*****	.18**
Cooperative learning	.11	.17**
Inductive thinking	.25****	.12*
Simulations	.08	.22***
Role play	.11	.12*
Field trips	.03	.11
Inquiry	.29*****	.08
Discovery	.23****	.16**
Problem solving	.27*****	.14*
Learning cycle	.03	.15*
Real life application	.23****	.15*
	Absorption Methods	
Lecture	-.06	-.06
Reports	.12*	.20***
Seat work	-.19**	-.07
Worksheets	-.07	-.12*
Tests and quizzes	.08	.02
Teacher demonstrations	.09	.08
Programmed learning	-.12*	.01

*$p < .05$. **$p < .01$. ***$p < .001$. ****$p < .0001$. *****$p < .00001$.

TABLE 2

CORRELATIONS FOR TEACHER EFFICACY
AND COMPUTER PRACTICES

Practice	Efficacy beliefs	Outcome expectancies
	Computer Practices	
Computer Programming	.04	.07
Computer as lab tool	.12*	.08
Computer simulations	.09	.06
Problem solving on computer	.12	.09
Interactive software	.07	.04
Computer databases	.04	.09
Robotics	.03	-.02
Computer networks	.01	.15*
Teacher demos on computer	.17**	.00
Learning content	.12*	.00
Drill and practice	.02	.02
Games	-.07	.01
Testing and evaluation	.02	.00
Multi-media, CD-ROM	.10	-.01

*p < .05. **p < .01.

TABLE 3

CORRELATIONS FOR TEACHER EFFICACY
AND INSTRUCTIONAL MATERIALS USE

Practice	Efficacy beliefs	Outcome expectancies
	Instructional Materials	
Camcorder	-.01	.09
Plants and animals	.00	-.02
Collections	.11	.12*
Lab supplies	.38*****	.15*
Scopes	.21***	.08
Models	.22***	.11
Cameras	.08	.14*
Videos, films	.01	.03
Recordings, compact discs, tapes	.01	.10
Slides	.14*	.15*
Overhead projectors	.11	-.03
Television or ITV	-.04	.08
Games and puzzles	.04	.00
Guest speakers	.07	.10
Student workbooks	.00	.01
Activity cards	.01	.11
Laser discs	.06	.05

*$p < .05$. **$p < .01$ ***$p < .001$. ****$p < .0001$. *****$p < .00001$.

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