Research on Science Teaching: summary and implications [1)]

Wayne W.Welch
University of Minnesota

During the fall of 1982, I conducted a fairly extensive needs assessment of research in science education for the National Institute of Education (Welch, 1983). My task was to examine the current state of research knowledge as portrayed in several research reviews and meta-analyses and to identify those areas which seemed most promising for future research.

A portion of my needs assessment included research on topics relevant to teacher education: teacher training, teacher characteristics, teacher behaviors and instructional systems. In the remainder of this paper, I present results of my investigations in these areas and describe several policy implications of the findings.

Teacher Training

As part of the meta-analyses carried out at the University of Colorado (Anderson, 1982), Sweitzer (1982) examined the effectiveness of preservice and inservice training activities on teachers. Some examples of these activities include methods courses, modeling strategies, and questioning analysis.

Meta-analysis is a quantitative procedure for synthesizing the results from a number of similar research studies (Glass and Smith, 1979). Mean correlations and average effect sizes are used as the synthesizing statistic. Effect sizes are differences between experimental and comparison groups expressed in standard devation units. For example, suppose that treatment A yields a mean score of 48 while a comparison group achieves a mean of 42 and the pooled standard deviation is 12. The effect size in this situation is +0.50 ([48-42] : 12). Mean effect size is the average for those studies devoted to specific topics, e.g. teacher training.

When using various teacher outcome criteria as the dependent measures Sweitzer (1982) noted a mean effect size of 0.77 for 153 different studies that he found in his literature review. These results are presented in Table 1.

	Mean effect size	Number of studies
Treatment Type		
Field-base program	0.35	8
Workshop	0.73	16
Methods course	0.79	22
Teachers science course	0.97	9
Inquiry instruction	0.63	9
Use of laboratory	0.75	20
Student self-directed study	0.81	44
Questioning analysis	1.38	8
Total	0.77	153
Time of Treatment		
Preservice	0.78	122
Inservce	0.72	31
Outcome Criteria (examples)		
Science knowledge	0.52	7
Science process	1.08	33
Indirected verbal behavior	0.72	18
Questioning level	0.70	7
Attitude toward science	0.39	10

Table 1 Effects of teacher training

Teachers who received the various training programs tended to outperform the comparison groups on measures of science knowledge, process, attitude, and desired teaching behaviors, e.g. questioning. The effectiveness of preservice and inservice training on teachers was nearly the same. There was some variation on the dependent measures used. The greatest effect was noted on science process criteria (+1.08) while attitude criteria showed the least effect (+0.39).

It is possible to provide some basis for interpreting the magnitude of these results by knowing that the mean effect size for science curriculum materials is about 0.35 (Shymansky, Kyle and Alport, 1982; Weinstein, Boulanger and Walberg, 1982). The mean effect size for teaching training efforts is approximately twice this value. (Cohen ´1969` considers an effect size of 0.20 small, a value of 0.50 medium, and a value of 0.80 large.) Thus, it would appear that teacher education efforts are quite effective, at least short-term, for influencing teacher performance. Whether this change is permanent and in turn affects student performance is unknown at present. Little research was found on this topic. Certainly, this is an important area for future work in teacher education.

Teacher Characteristics

An important consideration for teacher educators would seem to be the characteristics, e.g. age, gender and personality, of those people who choose science teaching as a career. Knowledge of these traits and the way they influence student learning could be used for teacher selection, professional development, and to provide clues on anticipated teacher behavior in the classroom. However, Druva's (1982) meta-analysis yielded very little relationship between teacher characteristics and their subsequent teaching behaviors. The mean correlation between various indicators of teacher traits and measures of presumed effective teaching was only +0.05. It is very difficult to predict how teachers will behave in the classroom given knowledge of such things as age, gender, personality measures, experience and attitudes.

Druva (1982) also found low correlations between her measures of teacher characteristics and measures of student outcomes. The results from 300 cases for both cognitive and affective outcomes are shown in Table 2.

Note that previous training in science accounts for very little of the variation in student performance. This is contrary to the beliefs held by many scientists and science educators that science knowledge is highly related to effective teaching. Less than 4 percent of the variation in student learning can be explained by this variable. Furthermore, the confounding effects of age, and sex on this variable may further decrease this relationship. Note, also, that experience and attitudes are correlated low with student performance measures.

Characteristics	Student Outcomes	
	Cognitive	Affective
Sex	0.04 (4)	0.08 (7)
Age	0.13 (7)	0.26 (1)
Training in science	0.19 (24)	0.18 (9)
Experience	0.10 (23)	0.12 (11)
Personality	0.01 (144)	-0.02 (53)
Attitudes	0.10 (6)	0.04 (11)
Total	0.05 (208)	0.04 (92)

Table 2 Teacher characteristics and student outcomes (mean correlations). Number of students are shown in parentheses

of advance organizers and inductive versus deductive teaching behaviors. He found a mean effect size of 0.24 for 22 studies using advance organizers, and 0.06 for the studies which examined inductive versus deductive teaching behaviors. His results are lower than those found by Wise and Okey (see thabel 3), but they used a broader definition of the categories than did Lott.

In summary, the effects due to various teaching strategies are disappointingly low. They average only 0.22 for the 812 cases used in these three meta-analyses. Cohen (1969) would consider this a small effect. I do too! The influence of what the teacher does in the classroom appears minimal. Perhaps a different research focus is needed.

Little work has been done in science on teacher style variables and teacher as manager. Rosenshine and Furst (1971) argue that behaviors such as organization, enthusiasm, and expectation are key factors in facilitating learning. They believe that direct teaching strategies have greater impact than indirect ones. Some data reported here tend to support this claim in science teaching; see, for example, effects of focusing, learning contracts, and mastery learning. These strategies are also those which shift much of the responsibility for learning to the student instead of the teacher.

Indirect teaching strategies, e.g. inquiry teaching, self-directed systems, and inductive teaching, seem less successful. Although many science educators are strong advocates of these teaching strategies, these results suggest caution. Direct teaching with heavy emphasis on student responsible learning seems far more effective.

Conclusions and implications

Based upon my analysis of research on science teaching, I conclude that teacher characteristics and behaviors have only slight influence on student learning. Furthermore, the area has been researched far more than the other components of the domain of science education. (The four areas I have reviewed here are but a part of a 22-cell grid that I use to define the discipline of science education).

What seems to make a greater difference in the learning of science are: 1. student learning behaviors; 2. home, school and classroom environments; and 3. exposure to instructional resources (Welch, 1983). All of these variables have mean effect sizes of 0.50 or greater and the research appears more fruitful than continued research on teachers' characteristics and behaviors. I believe that a research agenda is needed which focuses upon the behaviors of students rather than on the behavior of teachers.

The implications of my conclusions for teacher education are substantial. Of primary importance is the need for science teachers to become acutely sensitive to the behaviors of students in their classrooms. Teachers must learn techniques to stimulate student responsible behaviors in science learning. Techniques of this sort that have been successful include such things as cooperative learning, learning contracts, personalized system of instruction and mastery learning. In each instance, the emphasis is shifted from what the teacher does to what students do. Teachers need to be trained to implement these and similar techniques.

Another challenge for teacher educators is to convince teachers of the need to actively recruit students into their science classes. A major shortcoming to learning science is the lack of exposure to science experiences. Declining science enrollments are a symptom of this problem. Teacher educators need to demonstrate to science teachers ways in which they can 'sell' their courses to students. They need to be sensitized and trained to get more students into science, especially elective courses. Increasing enrollment will increase student achievement and help to improve the profession of science education.

Teachers will also need to be more cognizant of the important role the home, community, school and classroom environment are in science learning. Teacher educators will need to train teachers to recognize effective environments and strive to creative those that will enhance learning. Extensive research and development efforts are required here but the pay-off potential is great. We have only stratched the surface on how to capitalize on these important determiners of learning.

Finally, given the student-based approach I am advocating as an alternative to 50 years of a teacher-centered approach, research and development is needed on how to select and train teachers to effectively function in learner-based classrooms. Issues of engaged time, task responsibility, cooperative learning, enhanced student interest, effective homework, and the like, need to be researched and if continued to be found effective, become the backbone of our preservice and inservice programs. We seem to have exhausted the well, with little pay-off in our focus on teacher-based science instruction. It is time to shift our attention in more fruitful directions. I believe student responsible behaviors represent an optimistic new direction for science teacher education.

Notes

1. Paper gepresenteerd op het 'Bat Sheva Seminar on Preservice and Inservice of Science Teachers', Rehovot, 1983.
   Een uitgebreidere versie is verschenen in *Science Education, 69*, 3, 421-447, 1985.

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Note: alle references marked with an (*) were subsequently published in the *Journal of Research in Science Teaching, 20*, 5, 1982.1