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Teacher Education for Effective Science Instruction — A Social Cognitive Perspective

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Science education suffers from teachers' inadequate preparation and negative attitudes. Social cognitive theory offers teacher educators a model for understanding the reasons for inadequate science instruction and for developing teacher education practices that can overcome the obstacles to effective science instruction. Research showing the relationship between teachers' self-efficacy, anxiety, and teaching effectiveness is reviewed. Teacher education strategies that increase self-efficacy, lower anxiety, and increase teacher effectiveness are described, and problems in science education in need of further study are discussed.

Recent educational reform reports have portrayed teacher education programs negatively. These reports especially criticize the manner in which teachers are prepared to teach science and mathematics, often citing a general lack of content training and failure to develop an effective repertoire of teaching skills (Carnegie Task Force, 1986; Holmes Group, 1986; National Science Board Commission, 1983; Weiss, 1978, 1987). Often reported is teachers' avoidance of teaching science; for example, time for science is among the least allocated in the elementary school curriculum (Cawelti & Adkisson, 1985; Goodlad, 1984; Harms & Yager, 1981; Mechling & Oliver, 1983). Self-reports by elementary teachers indicate they prefer teaching other subjects over science (Czerniak, 1983; Czerniak & Chiarelott, 1985b; Harms & Yager, 1981). Achievement scores in science have declined nationally (Rakow, Welch, & Hueftle, 1984; Rotberg, 1984) and in international comparisons (Coleman, 1985; Comber & Keeves, 1983; Husen, 1983). Negative attitudes of students toward science increase by grade level (Yager & Yager, 1985). This problem seems particularly severe for females. Fewer women are enrolled in science classes than men (Matyas, 1985), and women report less positive attitudes toward science than do men (Handley & Morse, 1984).

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The reasons given for problems in science education include inadequate facilities, lack of resources and money, lack of time for adequate science instruction, teachers' lack of knowledge, and the poor preparation of elementary teachers to teach science (Harms & Yager, 1981; Mechling, 1984; Weiss, 1978, 1987).

In this article we show how social cognitive theory can provide insight into why these factors lead to inadequate science instruction, and we explain how social cognitive theory can guide the development of teacher education practices that will overcome the barriers to effective science education. Specifically, we discuss the relationship between teachers' sense of efficacy, anxiety, and teaching performance, and we identify teacher education strategies that can increase teachers' sense of efficacy, lower their anxiety, and increase student performance. Finally, we identify issues in science teacher education in need of further study.

Social Cognitive Theory

Bandura (1977, 1981, 1982, 1986, 1989) developed social cognitive theory from a program of research on social development that has spanned several decades. The major construct emerging from this research is the construct of self-efficacy, a cognitive processing mechanism that guides human action. Self-efficacy, according to Bandura (1977, 1981, 1982, 1986), is one's perceived performance capabilities in a given situation or activity. This perceived performance capability affects behavior. One has to believe that one's behavior can bring about a desired outcome if one is to execute the behavior required to achieve that outcome.

People gather information about their self-efficacy in various ways. Through vicarious experiences, people observe others succeeding or failing in given situations and develop expectations for their own performance accordingly. Social influences such as positive reinforcement and verbal persuasion contribute to perceived capabilities. The strongest factor affecting self-efficacy is actual performance attainment, that is, success. Also, physiological states such as sweating, increased heartbeat, and stomach upset influence judgment about capabilities and vulnerabilities in a given situation.

According to Bandura (1989), self-efficacy affects thoughts, actions, and emotions. Thoughts include how we think we can perform in a particular situation or activity. Self-efficacy judgments influence performance and aspirations, including career goals. Persistence at a task is enhanced when one believes in his/her own ability to continue the task despite the obstacles. For example, if one perceives oneself as incapable of comprehending science or mathematics and fails to persist in order to learn science and mathematics, it is unlikely one will pursue a career in medicine, technology, or other science/math-related areas. When one dwells on personal deficiencies, perceived or real, and imagines potential difficulties, anxiety is produced, and one is likely to form an image that leads to stress and anxiety and the physiological indicators of anxiety.

Teacher Self-Efficacy

In their study of self-efficacy related to teaching, Gibson and Dembo (1984) defined teacher self-efficacy as a belief that one's abilities can bring about positive changes in students' behaviors and achievement. Teachers may believe that environment and other factors beyond their control limit their abilities to bring about change in children. Such teachers feel helpless and give up trying to help children learn. The work of Dembo and Gibson (1985), as well as other researchers who studied teacher self-efficacy, suggests that without a belief in their ability to affect student performance teachers do not accept responsibility for motivating student learning.

Studies have suggested a relationship between teacher self-efficacy, teacher performance, and student achievement. High levels of self-efficacy have been associated with greater student achievement and greater teacher commitment to student achievement as well as higher expectations for children (Ashton & Webb, 1986; Gibson & Dembo, 1984). In these studies, teachers with high levels of self-efficacy seemed to take personal responsibility for students' learning. They tended to feel that if a student was not learning, it was not the student's fault or deficiency, but the inappropriateness of the teaching method, and these teachers changed their methods until success was reached. In other words, they persisted in helping students with difficulties in learning, and they were less critical in their feedback when students gave wrong answers. Gibson and Dembo (1984) found that teachers with higher self-efficacy had a strong academic focus in their classrooms, seldom used games for instruction, used more innovative teaching techniques, monitored student performances more closely, and taught by more whole class instruction than teachers with lower self-efficacy. In addition, the authors believed that these behaviors, which are closely related to those in the effective schools literature, provided more supervision and resulted in more on-task behaviors and less loss of time in transition from one activity to another. Finally, higher levels of teacher self-efficacy were associated with better lines of questioning. High-efficacy teachers were better able to lead children to answers and were less likely to give students answers than low-efficacy teachers.

In contrast, teachers with low levels of self-efficacy demonstrated less commitment to helping students learn. For example, they gave up quickly on children who failed and gave students answers rather than waiting for a response. In addition, these teachers had more small group instruction, became easily flustered with interruptions of routine in their classrooms, lacked "withitness," that is, they often failed to recognize off-task behavior in their classrooms while working with small groups, and preferred more rigid behavior controls (Gibson & Dembo, 1984).

The Relationship between Self-Efficacy and Anxiety

Numerous studies have indicated that anxiety is related to teacher and student performance in science. For example, in our research (Chiarelott & Czerniak, 1986; Chiarelott & Czerniak, 1987; Czerniak, 1983; Czerniak & Chiarelott, 1985a, 1985b) we found that (a) science anxiety was correlated with science achievement; (b) science anxiety was gender-related; (c) science anxiety emerged early in a student's exposure to science curriculum; (d) elementary teachers felt generally unprepared to teach science, and (e) teachers' attitudes correlated with their science anxiety.

Similarly, in other research on anxiety and performance, Gaudry and Spielberger (1971) indicated that a high level of anxiety accompanies poor student performance in most academic areas, and Shymansky (1978) reported that highly anxious students tend to lack self-confidence, curiosity, and adventurousness. These qualities are especially important for learning science.

Social cognitive theory suggests that anxiety is a result of feelings of inefficacy. Anxiety then leads to avoidance of situations tht arouse feelings of inefficacy. Providing evidence of this relationship, some teachers reported to us in informal interviews that they did not teach much science because they were not very good at it. They taught science only because they had to and even then they did it in a perfunctory manner. When possible, they traded this responsibility with someone who was better prepared. Thus, when we discussed science teaching with some teachers it was clear that they felt it would do more harm than good if they taught it.

The impression that these teachers felt powerless to affect, in a positive way, their students' science learning was disturbing but not totally surprising. Viewed in light of the research on science education in general and self-efficacy among students and teachers in particular, these teachers' attitudes and behaviors are understandable.

Teachers' repeated negative experiences with science may include personal failure in science as a student or bad experiences with science instruction. In addition, as a teacher, negative experiences may include lack of time allowed for preparing for science teaching, lack of science content background needed to teach the subject effectively, lack of administrative support, and poor funding for supplies or equipment. These repeated negative experiences, as a student and as a teacher, result in a low sense of self-efficacy that produces high levels of anxiety toward science and science teaching. Negative attitudes toward science teaching, lack of allocated time, and preference for teaching other subjects may result in low self-efficacy in science instruction and high science anxiety. Thus, teachers' anxiety over teaching science is likely to have noticeable effects on both the quantity and quality of science instruction.

Student Self-Efficacy

Results of studies of student self-efficacy have been consistent with studies of self-efficacy in general. Students' performance expectations influence their persistence at tasks, their achievement, and their aspirations (Bandura, 1982; Schunk & Gunn, 1986). Students' self-efficacy seems to affect their ability to learn science similarly. Students are likely to become anxious about science after repeated bad experiences, such as poor science instruction; few role models, especially for females; personal failure in science, and negative attitudes of adults and peers. Once students have had repeated bad experiences with science, their perceptions of their capabilities (self-efficacy) are affected negatively. This leads to inferior images of self and ability and results in anxiety, negative attitudes toward science, and poor performance. Low levels of science self-efficacy may lead to career anxiety, thus providing a possible explanation for fewer entries into scientific careers.

Recent research on science anxiety involving over 2,000 students and 50 teachers supports the social cognitive theory that low self-efficacy in science leads to high anxiety and reduced performance among many elementary students and their teachers (Chiarelott & Czerniak, 1986; Czerniak, 1983; Czerniak & Chiarelott, 1985a, 1985b). Students, as early as third grade, exhibit anxiety toward science (Chiarelott & Czerniak, 1986), and students' interest in science starts declining between third and seventh grade (Yager & Yager, 1985). Females, as early as third grade, exhibit more anxiety than their male counterparts (Chiarelott & Czerniak, 1986). This science anxiety may contribute to students', particularly females', low enrollments in science classes (Mallow, 1981; Tobias, 1985; Westerback, 1982, 1984).

Gender Differences

Numerous researchers have found gender differences in attitudes toward science, science anxiety, and science achievement (see Czerniak, 1983; Czerniak & Chiarelott, 1985b; and Chiarelott & Czerniak, 1986, 1987 for a review of these studies). Social cognitive theory suggests that the low levels of self-efficacy that many female teachers and students experience are related to gender expectations and beliefs (Bandura, 1989). In general, the findings indicate that females experience more science anxiety, have more negative attitudes toward learning science, and perform more poorly in science than males.

Certain school subjects are viewed as gender-related. Science, for example, is often viewed as a "male" subject. Stereotypically male attributes are viewed as necessary for successful performance in science classes. For example, mathematical skills, which are considered to be the cornerstone of scientific thinking and performance, are emphasized in courses dominated in enrollment by males.

Stereotypical gender role development may lead to females' low self-efficacy in science. For example, Dweck and Reppucci (1973) found gender differences in self-efficacy attributions. Boys attributed failure in school to motivation, whereas girls more often attributed failure in school to lack of ability. Fleming and Malone (1983) and Steinkamp and Maehr (1984) found small differences in males' and females' attitudes toward science, indicating that males had more positive attitudes than females.

Implications for Teacher Education

Four areas of research provide guidance in the design of teacher education strategies to increase teachers' sense of efficacy and student achievement in science: (a) self-efficacy, (b) anxiety, (c) science education, and (d) gender stereotypes in education.

In the literature, strategies commonly recommended to increase self-efficacy and lower anxiety are similar. Self-efficacy and anxiety research suggests that learning new concepts or skills in small, hierarchical steps, modelling desired behaviors or attitudes, and learning cognitive coping skills increase self-efficacy. The literature on science instruction suggests that certain pedagogical strategies such as inquiry teaching, individualized instruction, and adequate science content instruction can lower anxiety and increase efficacy. These procedures, as well as other educational strategies derived from science education and gender research, for increasing confidence and lowering anxiety will be discussed for their implications for teacher education in science.

Research on Self-Efficacy

Haury (1986) found that preservice teachers' levels of efficacy could be increased by using contract grading that required self-directed learning. This type of self-directed instruction may be beneficial in raising preservice teachers' levels of efficacy and should be tried in other educational settings.

Research on the impact of vicarious experiences on self-efficacy and effective performance suggests that role models for effective science teaching, especially for elementary teachers, are a necessary component in teacher education (Bandura, 1986). Many studies in education have determined that role models, especially in the field setting, greatly influence teachers. Lanier and Little (1986) summarized research in teacher education and concluded that role models such as cooperating teachers influence preservice teachers more than theoretical preparation on campuses. Therefore, it is crucial that preservice teachers have experiences with exemplary science teachers.

Researchers have found a connection between the level of control persons have in particular situations and level of self-efficacy. Teachers with high self-efficacy believe that they can control their own classrooms; they have good student behavior and classroom management skills, and they plan and select curriculum effectively (Ashton & Webb, 1986). Teacher education programs need to prepare teachers for the realities of classroom management, particularly in science. For example, if a teacher with a low sense of efficacy becomes easily flustered by classroom interruptions of routine and prefers rigid environments, this teacher would probably be easily bothered by hands-on instruction, open-ended instruction, or other less rigid teaching strategies shown to affect positively attitude and achievement in children. Experiences with management and control of science classes, which differ in some ways from other subject areas due to the laboratory, inquiry-based nature of science, should be an integral part of teacher education courses.

Degree of self-direction is also related to levels of efficacy. Ashton and Webb (1986) reported that the structure of organization in schools can affect teachers' sense of efficacy. Teachers often believe that they have little control over decision making that takes place in schools. Teacher educators should address this concern by involving prospective teachers in discussions of ways to influence classroom and curricular decisions and ways to cope with the subordinate position of teachers in school structures.

Research on Anxiety

For students who are enrolled in science classes, increases in anxiety may result in lowered achievement (Napier & Riley, 1985; Spielberger, 1966; Tobias, 1981). Sprung (1973) found that students gave "difficulty" as a reason for not enrolling in science, and Tobias (1980) found that anxiety increased with the increased complexity and difficulty of learning tasks. Studies of programmed learning and gradual mastery (i.e., taking tasks in small steps until skills are gained and mastered) have been shown to increase skills, knowledge, and confidence and to decrease anxiety (Bandura, 1982; Mallow, 1981; Sieber, O'Neal & Tobias, 1977).

Yurkewicz (1988) found that teachers who provided clear expectations, opportunities for remediation, and study support reduced anxiety toward science in their students. This supports earlier research by Sieber et al. (1977) in which students were less anxious in courses where they learned material in smaller chunks, received feedback, and had opportunities to master concepts before proceeding with further learning. In summary, the use of programmed learning and mastery learning models seems to benefit not only highly anxious students but also prospective teachers.

Skolnick, Langbort, and Day (1982) suggested several classroom instructional practices that could reduce anxiety and help females and minority students learn science and mathematics. These include building confidence by encouraging guessing, estimating, and testing in science. Instruction that places less emphasis on "right answers" and facts seems to build confidence. These authors also suggested that confidence could be increased by using a variety of social arrangements in the classroom, including single-sexed groupings, mixed-sex groupings, and cooperative learning groups.

In teachers, anxiety about teaching science seems to be lowered after experiences with science content and science pedagogy. Westerback (1984) reported that a sequence of hands-on science content courses reduced prospective teachers' anxiety about teaching science. Similarly, Czerniak (1989) found that anxiety toward teaching science was significantly lowered after completing science methods courses.

Research on Science Education

Many studies in science education have demonstrated positive student outcomes for instructional strategies promoted in the generation of science curricula in the 1960s and 1970s. These strategies included inquiry, open-ended experimentation, student-directed activities, and hands-on activities. For example, Bredderman (1983) used meta-analysis to investigate the effectiveness of three activity-based elementary science programs (Elementary Science Study, Science, A Process Approach, and Science Curriculum Improvement Study). He concluded that these programs had positive outcomes.

From a meta-analysis of 105 studies comparing new science curricula with traditional approaches, Shymansky, Kyle, and Alport (1983) concluded that elementary students had more positive academic and attitude outcomes when science curricula emphasized process skills. Consequently, addition of science process skills may increase efficacy, reduce anxiety, and improve academic performance.

In spite of research demonstrating that inquiry approaches to science instruction have positive effects on student attitudes and achievement in science, research by authors such as Weiss (1978, 1987), Stake and Easley (1978), and Goodlad (1984) indicates that the majority of elementary teachers in this country rely heavily on the use of lecture and textbooks. It is essential that teachers learn to use instructional practices that positively affect science learning instead of relying solely upon the use of textbooks and lectures.

Research on Gender Biases in Education

Research on gender biases in education seems to indicate that both the content of the curriculum and the delivery of the curriculum are equally important in addressing issues of efficacy and equity in science education. Women outnumber men five to one in elementary education nationally (National Education Association, 1982). The preponderance of women in elementary education, given the high levels of science anxiety among females, suggests that elementary students lack role models who can encourage positive attitudes toward science. Research on the impact of role models on student attitudes and performance suggests the need for career education, including equity education in all grades. The curriculum should include content that addresses equity issues in science. Skolnick et al. (1982) suggested several strategies with which to increase equity in science and mathematics, including integrating career education into science, providing female role models in science, and teaching spatial thinking to females. Skolnick et al. also recommended inquiry, hands-on, or manipulative materials for females. Although the authors pointed out that all students can benefit from concrete experiences, they emphasized that girls may need these experiences more because they are less likely to have had science-related, problem-solving, and spatial-type experiences outside of school. Bandura (1982), Mallow (1981), and Sieber et al. (1977) also reported that increased self-efficacy and decreased anxiety could be achieved through modelling. By watching other females succeed with science, being exposed to females in science careers, or observing competent female teachers, girls may elect to take more science and may choose science and science-related careers.

The report of the National Science Board Commission of Pre-College Education and Mathematics, Science and Technology (1983) suggested that science curriculum should, if it is to affect more than just the science major in science classes, extend beyond the classroom to include experiences with neighborhoods, nature centers, museums, zoos, airports, and other community resources. Integration of science into other settings and subject areas seems to have a particularly positive effect on females and minorities. Rakow et al. (1984) reported that females favored the social problems approach to teaching science more than did males. Females might learn science more effectively if scientific, societal, and technological concepts were integrated into the curriculum.

Finally, instruction that places emphasis on sex-role awareness appears to increase efficacy and lower anxiety of science for females. Research by Sadker and Sadker (1979) suggests that teachers need to be aware of general classroom and school practices that encourage sex biases. Teachers should be aware of and point out to children sex stereotypes in texts, films, media, educational materials, and society as a whole.

Science Teacher Education Issues in Need of Further Research

The research on efficacy, anxiety, sex equity, and science education yields some conflicting recommendations for teacher education. Further research is needed to resolve these conflicts. For example, resolution of the question of the relative importance of increased preparation in science content versus preparation in instructional strategies for improving teachers' sense of efficacy and student achievement is crucial to the success of the current reform movement in science education.

Several research reports support the view that teachers with a stronger science content background tend to exhibit attitudes and behaviors associated with effective science teaching. For example, a National Science Foundation report (Bonnstetter, Penick, & Yager, 1983) found that exemplary science teachers in the Search for Excellence in Science Education (SESE) study were older, more experienced, and had better subject-matter knowledge than a national sample of teachers. Exemplary teachers were also more professionally involved than a national sample of teachers. They had taken more coursework recently, and they were more involved in educational organizations and inservice programs. Amount of training in science has also been found to be associated with science anxiety. Westerback and Primavera (1987) concluded that teachers' lack of science knowledge and experience with science teaching strategies increases their science teaching anxiety.

Thus, increased teacher preparation in science content seems likely to lower anxiety and enhance teaching effectiveness; however, some research seems to indicate that the development of process skills in teachers may be more important to attitude changes and instructional improvement than the amount of science content training. For example, Yager, Hidayat, and Penick (1988) reported that the number of science content hours teachers obtained was unrelated to the quality of their science teaching. These authors concluded that although a strong science content background was necessary, it was not sufficient for effective teaching. A summary of National Science Foundation (NSF) literature reviews in science education published by ERIC (Blosser, 1979) and a meta-analysis by Sweitzer and Anderson (1983) indicate that inquiry-oriented inservices such as those provided by NSF institutes have lasting effects on teachers' attitudes toward teaching science and teachers' utilization of teaching skills and strategies. The NSF review also indicated that knowledge of science content was unrelated to the development of process skills. Goldsmith (1986) found that preservice teachers' levels of anxiety about teaching science could be reduced with a process-skill orientation in methods classes. Consequently, process-skill training may be important for lowering anxiety toward science teaching, improving attitudes toward science, and influencing the effectiveness of science instruction.

In contrast, Czerniak (1989) found that both science content preparation and methodological preparation were necessary to reduce science teaching anxiety and increase science teaching efficacy. Teachers who had taken more science content courses in college and who had experienced success with science content courses had lower levels of anxiety toward teaching science than teachers who had less science content training. Likewise, teachers who had learned a greater variety of pedagogical skills for teaching science had lower levels of science teaching anxiety and greater science teaching efficacy. These teachers were also more likely to use innovative, inquiry-based science instructional methods in their science classes. Hence, teacher education programs need to be increased in duration or changed in content to accommodate an increased emphasis on stronger science content as well as pedagogical training that includes experience with science process skills.

A second issue in need of research is the effectiveness of direct instruction versus inquiry approaches to science education. As discussed earlier, research on self-efficacy and anxiety suggests that mastery learning and programmed learning models are beneficial in lowering anxiety in students. For example, Haury (1986) found, in an experimental study, that preservice elementary teachers' sense of efficacy was raised when they were exposed to small group sessions where concerns were identified, individual consultations were devoted to identifying personal goals and evaluating progress toward these goals, and diagnostic feedback was given on science understanding. Thus, the self-efficacy and anxiety research suggests that teachers may benefit if teacher education programs provide science content, theoretical background, and pedagogical skills using direct instructional models in which preservice teachers are slowly paced in their clinical experiences in schools and gradually given more responsibility for educating children. This idea conflicts with recommendations in reports such as the Holmes Report (1986) and Carnegie Report (1986) that emphasize strong content training in the form of a bachelor's degree prior to teacher education courses or pedagogical training and also conflicts with the science education research that suggests that more open-ended, student-directed inquiry approaches are related to improved attitudes toward science and increased performance. Teacher education programs that delay experiences in teaching science content until late in students' preparation may lower science teaching efficacy and unnecessarily raise anxiety about teaching science. The question of appropriate strategies and timing of teacher education for effective science instruction needs further research.

A study by Boulanger (1981) may shed some light on the complexity of the relationship among instructional approach, efficacy, anxiety, and student achievement. From a meta-analysis of 56 science education studies, Boulanger concluded that although in general there were no differences between direct and indirect instructional strategies, direct instruction was more effective with junior high students in required courses, whereas indirect instruction was more effective with senior high students in elective courses. Thus, student ability and interest may play an important role in determining appropriate instructional strategies for increasing efficacy and student achievement.

Conclusion

Student and teacher science anxiety and efficacy and strategies that reduce anxiety and increase efficacy are worthy of attention in teacher education if we wish to improve the quality, quantity, and success of science curriculum and instruction. Furthermore, researchers should examine variables that influence science anxiety and efficacy and should attempt to identify methods that reduce science anxiety and increase self-efficacy in students and teachers.

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