Chapter 31
Science Teaching Efficacy Beliefs

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During the last few decades, educators have placed increasing emphasis on the scientific literacy in science education programs. Scientific literacy is based on a premise that all students should have the opportunity to learn and do science. In an effort to better prepare students in science, the science teacher is considered one of the most influential factors in increasing the quality of students' learning processes and outcomes. However, previous studies have indicated that many preservice and in-service teachers demonstrate a low confidence in their abilities to teach science and help students learn. Teachers who do not believe in their ability to teach science effectively, that is, teachers with low science teaching efficacy beliefs might avoid teaching difficult concepts in science or tend to spend less instructional time on science. For that reason, efficacy beliefs are one of the most powerful variables predicting both teachers' behaviors in science classrooms and student achievement in science.

The chapter begins with the theoretical foundation of self-efficacy, including origins, definition, and distinctive features of self-efficacy beliefs. Then we provide a brief explanation of teachers' sense of efficacy, including its conceptual framework and critical measurement issues. Next we focus on science teaching efficacy beliefs by summarizing major findings. Finally, we propose an agenda for future research.

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Meaning of Perceived Self-efficacy

Self-efficacy, which stands at the core of social cognitive theory, has generated a growing body of literature in psychology, medicine, education, and business administration since the publication of Albert Bandura's (1977) article Self-efficacy: Toward Unifying Theory of Behavior Change. Perceived self-efficacy refers to personal beliefs about one's capabilities to perform actions at designated levels (Bandura 1997). Self-efficacy beliefs can influence human functioning in numerous ways. They "influence the courses of action people choose to pursue, how much effort they put forth in given endeavors, how long they will persevere in the face of obstacles and failures, their resilience to adversity (Bandura 1997, p. 3). These subsequent performances are influenced by self-efficacy, whereas the self-efficacy beliefs are affected and altered in turn by how individuals interpret the results of their performance attainments (Pajares 1996).

The definition of self-efficacy is sometimes clouded by similar or related constructs such as self-concept, self-esteem, and locus of control. However, Bandura (1997) points out that although all other self-constructs are self-referential, self-efficacy is clearly different from each of them in that self-efficacy involves judgments of capabilities specific to a particular task. On the other hand, self-concept is a more global construct that contains many perceptions about the self, including self-efficacy. Self-esteem refers to perceptions of self-worth and does not include judgments of capabilities. There is no preset relationship between individuals' beliefs about their capabilities and whether they like or dislike themselves. For example, a man may judge himself as inefficacious in a given activity but not suffer any loss of self-esteem.

Although self-efficacy and locus of control often are viewed as the same construct, they correspond to entirely different phenomena (Bandura 1997). Originally developed under the umbrella of Julian Rotter's (1966) social learning theory, the locus of control construct refers to the degree to which an individual believes the occurrence of reinforcement is contingent on his or her own behavior as opposed to under the control of others. The factors involved with reinforcement expectancy are labeled internal and external control, respectively.

Bandura (1997) stated that locus of control is an outcome expectancy that could be defined as "a person's estimate that a given behavior will lead to certain outcomes" (p. 193). High locus of control does not necessarily indicate a sense of efficacy. For example, students may believe that high academic grades are entirely dependent on their performance (high locus of control), but feel hopeless because they believe they lack the skills to produce those superior academic performances (low self-efficacy).

Although other self-referential constructs may be more global (e.g., self-esteem, self-concept), self-efficacy is defined and measured as specific to behaviors in specific contexts or situations (Bandura 1997). Therefore, Bandura (1997) cautioned researchers assessing self-efficacy beliefs that they should use assessments that correspond to the specific task and the domain of functioning being analyzed. Otherwise, the resulting omnibus-type instrument would not only create problems of prediction, but also be unclear about what is being assessed.

Teachers' Self-efficacy Beliefs

Considering the task-specific nature of self-efficacy, Megan Tschannen-Moran et al. (1998) defined teacher self-efficacy as "teacher's belief in his or her own capability to organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context" (p. 233). In their review paper, Tschannen-Moran et al. proposed a model suggesting that teacher self-efficacy is produced as a result of the interaction between analysis of teaching task in context and analysis of personal teaching capabilities. The resulting efficacy beliefs influence the teachers' professional goals, their effort expenditure, and their resilience when faced with difficulties.

The model also refers to the sources of efficacy information described by Bandura (1997): mastery experience, vicarious experience, social persuasion, and physiological states. Among these four sources of information, Bandura proposed that enactive mastery is the most influential source. A sense of efficacy to teach is enhanced when accomplishments are present in a person's history of teaching and particularly when these past successes are attributed to the individual's own efforts and abilities. Opportunities to observe a model's (colleague or mentor) accomplishments might be a source of vicarious experience that supports the efficacy judgments. Social (or verbal) persuasion refers to the specific positive talk about teaching performance from an administrator, colleague, mentor, or a student. Finally, physiological or affective reactions to a teaching task also add to the efficacy information, depending on how the arousal is interpreted. For example, if seen as anxiety, the arousal may lower efficacy expectation, whereas interpretations of excitement and readiness may raise efficacy expectations. These four sources of efficacy information are cognitively processed, that is, they are "selected, weighted, and integrated into self-efficacy judgments" (Bandura 1997, p. 79).

This process of selecting and weighting efficacy information differs for each individual as different factors may influence each person. Elizabeth Labone (2004) proposed that factors such as preexisting self-schema, task difficulty, and effort invested may influence the extent to which enactive mastery would enhance efficacy judgments. The cognitive process is considered as essential in the Tschannen-Moran et al. (1998) model because such processing will impact how the analysis of teaching task and personal competence interact with each other to form future efficacy beliefs.

Measurement of Teachers' Self-efficacy Beliefs

Two theoretical frames have shaped the measurement of teachers' sense of efficacy, Rotter's locus of control and Bandura's self-efficacy theory.

Rotter

Under the influence of Rotter's article published in 1966, the RAND Corporation included two efficacy items in their examination of teacher characteristics and student learning (Armor et al. 1976). Those researchers defined teacher efficacy as "the extent to which the teacher believes that he or she has the capacity to affect student performance" (McLaughlin and Marsh 1978, p. 84). In these studies, teachers were asked to respond to the two 5-point Likert-type items. Two items used to measure teacher efficacy were designed to measure the degree to which teachers consider environmental (external) factors as overwhelming any power that they can exert in schools or accept personal (internal) responsibility for what happens to them (Guskey and Passaro 1994). See Table 31.1 for further information. After this, other instruments with more items were developed such as Responsibility for Student Achievement (Guskey 1981), Teacher Locus of Control (Rose and Medway 1981), and The Webb scale (Ashton et al. 1982). Despite the important implications of these studies for teacher efficacy research, several researchers tried to expand the construct of teacher efficacy, and to develop longer and more reliable measures (Tschannen-Moran et al. 1998; Woolfolk Hoy et al. 2009).

Bandura

Patricia Ashton and Rod Webb (1986) expanded the Rand methodology by using Bandura's social cognitive learning theory, in which they made a distinction between outcome expectations and efficacy expectations. They believed that outcome expectation was assessed in the first Rand item, whereas efficacy expectation was captured in the second Rand item. Sherri Gibson and Myron Dembo (1984) developed a 30-item instrument called Teacher Efficacy Scale (TES) based on these two dimensions and later reduced it to 16 items. Through factor analysis of 208 elementary teachers' responses, they reported a 2-factor model that accounted for 28.8% of the total variance. Gibson and Dembo noted that Factor 1 represented a teacher's sense of personal teaching efficacy, and corresponded to Bandura's self-efficacy dimension. On the other hand, the second dimension stood for a teacher's sense of teaching efficacy, and corresponded to Bandura's outcome expectancy dimension. These two dimensions are now referred to as personal teaching efficacy (PTE) and general teaching efficacy (GTE), respectively. Gibson and Dembo presented alpha coefficients of 0.78 for PTE, and 0.75 for GTE. They recommended the use of the revised scale of 16 items for further research. Other instruments were adapted based on TES for specific subject matters. For example, Iris Riggs and Larry Enochs (1990) developed the Science Teaching Efficacy Belief Instrument (STEBI) to measure efficacy of science teaching and Larry Enochs et al. (2000) developed a similar instrument to measure efficacy of mathematics teaching.

John Ross (1998) reported that TES (or adaptations of TES) has been used in almost half of the studies performed up to 1998 to assess teacher efficacy. Despite its common use, there are both conceptual and statistical problems

Table 31.1 Measures of teacher self-efficacy

Instrument	Developers	Characteristic	Sample item
The RAND measure	Armor et al. (1976)	• Based on Rotter's theory • Two 5-point Likert type items	When it comes right down to it, a teacher really can't do much because most of a student's motivation and performance depends on his or her home environment. If I really try hard, I can get through to even the most difficult or unmotivated students.
Teacher Efficacy Scale	Gibson and Dembo (1984)	• Based on Bandura's theory • 30-item 6-point Likert scale • Two subscales: personal teaching efficacy (PTE) and general teaching efficacy (GTE)	I have enough training to deal with almost any learning problem. (PTE) Teachers are not a very powerful influence on student achievement when all factors are considered. (GTE)
Teachers' Sense of Efficacy Scale	Tschannen-Moran and Woolfolk Hoy (2001)	• Based on Bandura's theory • 24 items on a 9-point rating scale • Three subscales: efficacy for classroom management (CM), efficacy for instructional strategies (IS), and efficacy for student engagement (SE)	How much can you do to control disruptive behavior in the classroom? (CM) To what extent can you use a variety of assessment strategies? (IS) How much can you do to get students to believe they can do well in schoolwork? (SE)
Science Teaching Efficacy Belief Instrument A and B	Riggs and Enochs (1990) Enochs and Riggs (1990)	• Building on Gibson and Dembo's work • Two subscales: personal science teaching and science teaching outcome expectancy • STEBI-A: 25-item 5-point Likert scale • STEBI-B: 23-item	I am typically able to answer students' science questions. (STEBI-A) I will typically be able to answer students' science questions. (STEBI-B)
Self-Efficacy Beliefs about Equitable Science Teaching and Learning (SEBEST)	Ritter, Boone, and Rubba (2001)	• Based on STEBI • 34 items • Two subscales: personal efficacy (PE) and outcome expectancy (OE)	I will have the ability to help children from low socioeconomic backgrounds be successful in science. (PE) Good teaching cannot help children from low socioeconomic backgrounds achieve in science. (OE)

(Henson 2002; Tschannen-Moran et al. 1998). Some researchers stated their concerns particularly regarding the second factor, GTE (Guskey and Passaro 1994; Henson et al. 2001). For example, Thomas Guskey and Perry Passaro (1994) noticed that there are some biases in the wording of the items. Items measuring personal efficacy used the referent "I" and were positive; while items measuring teaching efficacy used "teachers" and were negative. For that reason, they changed the wording of the items in order to have balanced characteristics throughout the instrument (both positive and negative "I" items and both positive and negative "teachers" items).

When Guskey and Passaro administered this balanced scale, their results confirmed internal and external dimensions instead of personal and teaching efficacy dimensions. This categorization stems from locus of control theory rather than self-efficacy theory. Tschannen-Moran et al. (1998) discussed this theoretical distinction in detail, drawing upon the findings of the Guskey and Passaro study. Based on a reliability generalization study, Henson et al. (2001) concluded that use of the GTE subscale as a measure of teacher self-efficacy is questionable not only because of conceptual problems but also for measurement error problems. They suggested not using the GTE subscale.

Another commonly used teacher self-efficacy instrument is the Teachers' Sense of Efficacy Scale (TSES) developed by Tschannen-Moran and Woolfolk Hoy (2001). Taking Bandura's suggestions for constructing a self-efficacy scale (Bandura 2006) and using the Tschannen-Moran et al. model as a base, they developed an instrument assessing teachers' beliefs about their abilities to accomplish a variety of teaching tasks. After different validation studies, they generated a short form with 12 items and a long form with 24 items. Analyses of both forms indicated that the TSES could be accepted as a reliable and valid instrument for assessing the teacher efficacy construct. Both versions supported a 3-factor model with high subscale reliabilities. The factors were named efficacy for student engagement, efficacy for instructional strategies, and efficacy for classroom management. The authors argued that TSES could be used for assessment of either three domains of efficacy or of one generalized efficacy factor. The instrument was adapted to other languages such as Turkish (Capa et al. 2005), Greek, Korean (Klassen et al. 2009), and Chinese (Kennedy and Hui 2006).

Correlates of Teacher Self-efficacy Beliefs

Researchers have consistently found a strong relationship between teacher efficacy, teacher classroom behavior, and student achievement. For example, teachers with higher levels of self-efficacy tend to be open to new ideas, demonstrate greater levels of planning and enthusiasm, and are committed to their profession (Tschannen-Moran et al. 1998). Furthermore, higher levels of teacher self-efficacy have been related to positive classroom behavior management (Emmer and Hickman 1991). Further, efficacious teachers tended to be less critical of students when they made errors and worked longer with struggling students (Gibson and Dembo 1984).

In addition to the teacher variables, teacher efficacy is also linked to students' affective growth, student motivation, student self-esteem, and achievement (Midgley et al. 1989). Findings related to the relationship between teacher self-efficacy, and both teacher and student outcomes were discussed in Ross's (1998) article reviewing 88 teacher efficacy studies.

Science Teaching Efficacy Beliefs

Reinforcing Bandura's definition of self-efficacy as both subject-matter and context-specific construct, Riggs and Enochs (1990) developed the Science Teaching Efficacy Belief Instrument (STEBI) to measure efficacy of science teaching. Building on the Gibson and Dembo work, the authors identified two uncorrelated factors within STEBI, which they named personal science teaching efficacy (PSTE,13 items) and science teaching outcome expectancy (STOE, 12 items). The PSTE refers to teachers' belief in their ability to perform science teaching, whereas the STOE refers to the teachers' belief that effective science teaching can change student behaviors (Riggs and Enochs 1990). The original 25-item STEBI Form A was developed for in-service teachers in a 5-point Likert-response format (Riggs and Enochs 1990). Enochs and Riggs modified STEBI-A to a 23-item questionnaire suitable for preservice teachers (STEBI-B) by rewording the items to the future tense to reflect the anticipatory nature of preservice teachers.

By extending the level of specificity and using STEBI as a base, other subject-matter-specific instruments were developed including STEBI-CHEM (Rubeck and Enochs 1991) assessing chemistry teaching efficacy, the Environmental Education Efficacy Belief Instrument (EEEBI; Sia 1992) assessing efficacy beliefs in environmental education, and Self-efficacy Beliefs about Equitable Science Teaching (SEBEST; Ritter et al. 2001) assessing the self-efficacy beliefs of preservice elementary teachers with regard to science teaching and learning for diverse learners.

Studies with In-Service Teachers

Numerous studies investigated the construct of teacher efficacy and found that efficacious teachers tended to use activity-based science instruction and spent more class time teaching science (at the elementary level). They also used inquiry approaches, small-group learning, cooperative learning, and more student-centered instructional approaches. In contrast, teachers with low efficacy beliefs tended to utilize teacher-centered instructional methods and whole-class instructional techniques (Enochs and Riggs 1990). Considering the fact that student-centered approaches have gained importance in recent years in science education field, researchers have focused on how to improve teachers' self-efficacy beliefs. However, research findings are contradictory regarding the enhancement of different dimensions of STEBI. For example, some interventions have produced significant enhancement of teachers' PSTE, some in teachers' STOE or some in both.

To illustrate these contradictions, in a 32-week professional development program, Tracy Posnanski (2002) found that PSTE was significantly enhanced but their STOE was not. However, Ian Ginns et al. (1995) found significant changes only in STOE. In her study, Posnanski suggested that components of the professional development model positively impacting PSTE were the presence of long-term training, support from colleagues, experimenting with new strategies through practice, and innovative science instructions. The nonsignificant change in STOE was attributed to its stability and/or its measurement problems. In another study, specific to the field of chemistry education, Claudia Khourey-Bowers and Doris Simonis (2004) explored the influence of specific professional development design elements (e.g., instruction in fundamental chemistry concept, modeling the learning cycle, and guided discussion of learning theories). Their results indicated that professional development enhanced both participants' PSTE and STOE. Similar findings were obtained in a 3-year longitudinal study in which both PSTE and STOE increased as a result of participating summer workshops (Chun and Oliver 2000).

There is some evidence suggesting that finding significant increases in efficacy requires that participants enter with lower levels of teacher self-efficacy beliefs. For example, results of a study with 330 science teachers participating in an in-service program that varied from 2 to 6 weeks indicated that in-service interventions had the greatest impact on the efficacy of teachers who began the program with the lowest level of efficacy beliefs. The researchers suggested there was not much room for the growth in self-efficacy for the teachers with high levels of PSTE (Roberts et al. 2001). Consistent with this result, Riggs (1995) reported that teachers who began training with low scores on both PSTE and STOE made gains in PSTE while STOE scores remained constant.

Studies with Preservice Teachers

A large body of research has examined preservice teachers' science teaching efficacy beliefs because once efficacy beliefs are established they appear to be somewhat resistant to change (Woolfolk Hoy et al. 2009). Teaching experiences, courses, and other interventions have produced mixed results regarding teacher efficacy beliefs. Many of these studies have used the STEBI-B as the primary instrument for data. For example, Judith Mulholland et al. (2004) found that the number of science classes completed at the high school level was positively related to preservice teachers' PSTE but not to their STOE. Robert Bleicher (2004) presented similar findings. In addition, he found that age, ethnicity, and teaching experience showed no relationship to either PSTE or STOE. Tarik Tosun (2000) emphasized the importance of preservice teachers' quality of past experiences in shaping their science teaching self-efficacy. Using both quantitative and qualitative data, Watters and Ginns (1995) found that beside their previous experience, a supportive learning environment in teachers' training programs enhanced their teaching efficacy.

Authors suggested that positive self-efficacy stemmed from experiencing exciting, hands-on practical activities. In addition, they attributed the improvement in participants' STOE to experiences with teaching science to young children.

Science Content Knowledge

A few authors have studied science content knowledge as a factor that has been linked with increased self-efficacy of elementary teachers. For example, Kenneth Schoon and William Boone (1998) found that preservice teachers who held fewer numbers of alternative concepts in science had significantly higher efficacy levels. These alternative conceptions act as fundamental barriers to fully understanding scientific phenomena presented in science courses and thus preservice teachers feel less able to teach science to others. However, Patricia Morrell and James Carroll (2003) claimed that science content knowledge alone is not sufficient to improve self-efficacy. In their study, they found that students enrolled in the science methods course showed significant gains in PSTE.

Methods Courses

David Palmer (2006a) also examined the retention of efficacy beliefs after a science method course. He reported that positive changes were recorded for both PSTE and STOE over the period of the course itself and after the delay period. A mixed-method design study by Bleicher and Lindgren (2005) explored the relationship between changes in levels of science teaching self-efficacy and participation in a constructivist oriented science methods course for preservice elementary teachers. Results showed that preservice teachers demonstrated significant increase in conceptual understanding, PSTE and STOE. Consistent with Watters and Ginns (1995), hands-on activities, minds-on activities, and discussion were effective in increasing teaching self-efficacy. Similarly, Posnanski (2007) found that preservice teachers' efficacy beliefs improved more in a constructivist-based science content course than in a traditional one. This constructivist-based course included a nature-of-science aspect and means to mediate self-efficacy beliefs such as vicarious experiences and a positive emotional tone. Regarding the sources of self-efficacy in a science methods course, Palmer (2006b) found that the main efficacy source for preservice teachers was cognitive pedagogical mastery in accordance with Bandura's (1997) assertion that enactive mastery is the most important source of efficacy information.

Discussion and Implications for Further Research

Since its inception in 1977, teacher efficacy has been extensively described and interpreted in the literature as a strong indicator of the teacher's ability to be productive and successful. Not only in science teaching, but also in teacher efficacy research in general, quantitative studies are dominant. Although many quantitative studies assessing science teaching self-efficacy have been conducted, methodological limitations persist regarding the characteristics of the scales that are used. A common concern raised by the researchers regarding teacher self-efficacy scales is the unrealistic optimism of teachers who rate themselves above the average, that is, most preservice and in-service teachers avoid the lower end of the scales and tend to select only the higher values. This presents a problem in intervention studies. Significant changes were observed only for teachers with low self-efficacy at the entry level. Hence, statistical analysis suffers from low variability and ceiling effects.

The STEBI is the most commonly used instrument assessing science teaching efficacy. Henson et al. (2001) stated that the problem of more measurement error in the outcome expectancy (or GTE) sub-dimension also occurred in the STEBI, as it was developed from the TES. In addition, concerns about the construct validity of TES (Tschannen-Moran et al. 1998) also apply to the STEBI as well. A promising instrument, the TSES, was developed based on a model of teacher efficacy. However, the study of science teaching efficacy still suffers from psychometric issues. Considering the well-grounded arguments, we echo the need for a new or revised measure(s) that would reliably assess science teaching efficacy and its components. Ignoring these arguments and going with the already existing measures would suppress the advancement of science teaching efficacy research. More investigations employing qualitative or mixed method designs would help better understanding of this elusive construct (Labone 2004).

Because efficacy beliefs are shaped early, it would be useful to better understand factors that support the development of a strong sense of efficacy among preservice and novice teachers. Future research is warranted to determine possible ways to develop stronger efficacy beliefs by focusing on the sources of self-efficacy beliefs: enactive mastery, vicarious experiences, social persuasion, and arousal. We recommend conducting follow-up longitudinal studies of the science teaching efficacy beliefs of preservice teachers as they progress through the teacher education program and of science teachers at different career stages – early, mid, and late career. It would be desirable to monitor how these beliefs are formulated and sustained throughout the teaching career. Such knowledge would enable teacher educators to modify courses and field experiences to enhance preservice teachers' efficacy beliefs. Several studies have demonstrated that well-designed science methods courses are quite effective in improving science teaching self-efficacy. Courses that are structured to be inquiry based, constructivist in nature, and include use of hands-on activities and group investigations could be beneficial in bringing about appropriate change. In addition, these courses should provide such experiences for preservice teachers as microteaching, cooperative learning, good role models, and a supportive learning environment. Of course, the final question to explore is if these changes in methods courses lead to improvements in teaching efficacy and finally to increases in the science literacy of students in the teachers' classrooms.

Extending the notion of teachers' sense of efficacy, Hoy, Woolfolk Hoy, and their colleagues have discussed the importance of "academic optimism" at the school

(Hoy et al. 2006) and individual teacher levels (Woolfolk Hoy et al. 2008). At both the collective school and individual teacher levels, teacher's sense of efficacy, teacher trust in parents and students, and academic emphasis combine to form a single, strong second-order factor – teacher's academic optimism. Teacher efficacy is a cognitive aspect of academic optimism, the thinking and believing side; teacher trust in students and parents is the affective and emotional side of the general construct; and teacher academic emphasis is the behavioral side, that is, the enactment of the cognitive and affective into actions. Academic optimism has been related to teacher beliefs about instruction and management and to student achievement. Much remains to be done in examining academic optimism and its associations with other variables, particularly in science education field.

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