



# Emerging Themes from Early Research on Self-Efficacy Beliefs in School Mathematics

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## Abstract

Self-efficacy, an individual's belief about his or her ability to engage in a task and accomplish it, has been investigated across multiple domains of human action. Students' perceived efficacy in school mathematics in particular, has been extensively explored by psychologists and educational researchers. We review literature from this field published prior to the year 2000 with the aim of extracting the fundamental themes that have drawn researchers' attention. The topics presented include the relationship between self-efficacy and mathematical performance, the interplay of self-efficacy with self-concept, properties of self-efficacy measurements, the relationship between self-efficacy and goal setting and modeling, the accuracy of self-efficacy judgments, and gender differences and career choice with respect to self-efficacy beliefs. We review the important concepts and notable findings for each theme, and conclude with implications for educational practice and future research.

**Keywords:** mathematics self-efficacy, measurement of self-efficacy, gender differences, career choices.

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## Resumen

La autoeficacia, una creencia individual sobre la propia capacidad para ejecutar de forma correcta una tarea, ha sido investigada desde múltiples perspectivas. La eficacia percibida por los estudiantes en el área de las matemáticas ha sido profusamente explorada por psicólogos e investigadores educativos. Realizamos una revisión de la literatura relacionada con este campo previa al año 2000 con la intención de extraer los temas fundamentales que han llamado la atención de los investigadores. Los temas tratados incluyen la relación entre autoeficacia y ejecución matemática, la interacción entre autoeficacia y autoconcepto, las propiedades de las medidas de autoeficacia, la relación entre autoeficacia y establecimiento de objetivos, la exactitud de los juicios sobre la autoeficacia, las diferencias de género y la elección de carrera en relación con la autoeficacia percibida. Revisamos los conceptos importantes y los hallazgos más notables de cada tema para concluir con las implicaciones para la práctica educativa y la investigación futura.

**Palabras Clave:** autoeficacia matemática, medida de la autoeficacia, género, elección de carrera.

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## **Introduction**

In social cognitive theory, people's sense of personal efficacy to exercise some control over events that affect their life is considered to be the most influential aspect of self-knowledge, and a key element in the exercise of control and personal agency. "Perceived self-efficacy is defined as people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). Thus, it exerts great influence on behavior, on the choices individuals make and where they direct their actions. Research in the field of educational psychology has demonstrated the influence – direct or as a mediator to other predictors – of efficacy beliefs on academic performance, and motivation (Bandura 1986, 1997; Pajares & Kranzler, 1995; Schunk, 1991).

Research on self-efficacy has paid special attention to mathematics because of its critical place in the school curriculum, its centrality in high-stakes testing, selection and placement and its importance for career choices (Pajares & Graham, 1999). The focus of this paper is on the research that has been carried out on self-efficacy beliefs in school mathematics before the year 2000. Themes that emerge from the review of this research are: the relationship between self-efficacy and mathematical performance, the interplay of self-efficacy with self-concept in particular, the essential attributes of self-efficacy measurements, the relationship of self-efficacy with goal setting and modeling, the accuracy of self-efficacy judgments, and gender differences and career choice. In this paper, the conceptual issues are briefly presented followed by a review of empirical evidence on mathematics self-efficacy. Methodological issues are addressed as well. Finally, some educational implications are drawn in the light of current research in the area of mathematics self-efficacy.

## **Mathematics self-efficacy: Concepts, measures, and findings**

A large body of empirical findings supports the predictive and mediational role of self-efficacy across various domains of human functioning (Bandura, 1997). In school mathematics, research has shown that perceived self-efficacy contributes to academic performance irrespective of the level of intellectual ability, and correlates strongly with academic outcomes, such as performance in problem solving, attitudes towards mathematics and math anxiety. It has also been shown to be a better predictor than ability or acquired skills, and that it mediates the influence of other determinants of academic outcomes, such as skills and past perform-

ance (Pajares & Graham, 1999). Social cognitive theory proposes that beliefs in personal efficacy can be better predictors than actual ability or previous performance because they are instrumental in determining how individuals will use the knowledge and skills they have (Pajares & Miller, 1995); self-efficacy beliefs influence the choices, the amount of effort students make, the level of anxiety they experience, their persistence when they face adversity, and whether failures are demoralizing or informative for remedial action. Constructs such as self-concept, anxiety and perceived usefulness are “common mechanisms” of personal agency influencing academic outcomes, as well (Bandura, 1986). However, they are considered to be influenced by self-efficacy, hence their strong correlations with the latter.

Typically, mathematics self-efficacy is assessed by asking students to indicate on a Likert-scale their strength in solving mathematical tasks (Pajares & Miller, 1997). They judge how confident they are in dealing with specific problems. Pajares and Miller (1995) mention that the first measure of confidence for solving math problems, which corresponded to a specific assessment, was the Dowling’s Mathematics Confidence Scale. “Students were first asked to provide judgments of confidence to solve these math problems and later were asked to solve an alternate-forms test of the problems on which their confidence was assessed” (p. 191). Betz and Hackett (1983) added two more subscales to the Mathematics Confidence Scale to create the more widely used Mathematics Self-Efficacy Scale. The additional subscales referred to the confidence with which students performed math-related tasks, and the confidence to earn a particular grade in certain math-related courses. The three subscales gave a composite score for mathematics self-efficacy.

In a design involving children of high and low mathematical ability and within each of those groups children of perceived high or low mathematical self-efficacy, Collins (1982) tested difficult problem solving. In each of the two ability levels, those who perceived themselves as high in self-efficacy exhibited the following characteristics: solved more problems, persisted more on the problems they failed, they discarded faulty statements more quickly than their classmates and held more positive attitudes toward the subject. Using path analysis, Pajares and Miller (1994) showed that efficacy in problem solving was more predictive of the performance in mathematical problem solving than other variables – math anxiety, gender, mathematical background, math self-concept and perceived usefulness of mathematics. Self-efficacy was found to mediate the effect of gender and prior experience on math self-concept, problem-solving performance and perceived usefulness of mathematics. Similar results were

obtained with examination scores as outcomes (Pajares & Graham, 1999). Pajares and Kranzler's study (1995) confirmed these findings and in addition introduced a general ability measure. They reported that the influence of self-efficacy on performance was as strong as the influence of general mental ability. They also provided support for self-efficacy mediating the effects of ability and math experience on anxiety and performance, as well as a direct influence of self-efficacy on anxiety.

### **Generality, specificity and quality criteria for self-efficacy measures**

Constructs, such as self-concept, self-esteem, and effectance motivation are related to, however they are distinct from self-efficacy (see Bandura (1997) for a discussion). Often measures for these constructs are used in self-efficacy studies (see for example studies of Pajares and associates). Self-concept in particular, combines diverse beliefs about self-worth, whether an individual respects and accepts himself/herself. It is a composite measure at a relatively global level. Because it refers to diverse attributes of the self it loses explanatory and predictive power for behavior (Bandura, 1997). In contrast, self-efficacy is a context specific assessment of competence in carrying out a particular task (Pajares & Miller, 1994). What clearly differentiates it from self-concept is the level of specificity. Bandura (1997) argues that this difference is what makes self-efficacy measures consistently more predictive than general constructs and he cites empirical findings across a variety of domains supporting the conceptual and methodological superiority of domain-linked measures over general ones.

Domain specificity in self-efficacy ratings however, does not necessarily mean specificity in behavior as well. The level of generality of the assessment, i.e. the extent to which the assessed performance is defined, could vary. Judgments of self-efficacy are context specific and, in contrast to self-concept judgments, could even be item or task specific. Therefore, as regards specificity, a self-concept statement could only go down to "Are you a good math student?" while a self-efficacy statement is much more exact: "Can you solve this specific problem?" (Pajares & Miller, 1994). The argument underlies additionally the multidimensionality of self-efficacy belief systems. "Combining multidomain measures, weighted by their relative importance, provides a more sensitive, integrated predictor of overall level of functioning ... [than] indistinct omnibus measures" (Bandura, 1997, p. 49). What is problematic with general academic self-perceptions of competence is that students are asked to generate judgments about their capabilities in an academic domain and they bring vaguely related

activities in mind, instead of specific tasks (Pajares, 1996). The predictiveness of broader constructs, like self-concept for example, is expected to increase as assessment tasks become more precise and less general. The assessment of self-efficacy, which is operationalized to task-specific beliefs, is hypothesized to be a cause for its predictive power on performance over other motivational variables (Pajares & Graham, 1999).

Apart from specificity in assessment, two additional features are suggested as guidelines to avoid mismeasurement of self-efficacy: it must correspond directly to the criterion of performance and must be measured closely in time to the performance (Bandura, 1986). Pajares and Miller (1994) cite examples of research that did not follow the three criteria and produced ambiguous findings and inconsistent results. In a meta-analytic study, Multon, Brown, and Lent (1991) confirmed the usefulness of the three characteristics and their necessity for consistent and valid research on self-efficacy.

Pajares and Miller (1995) examined the need for judgments of self-efficacy to be task specific, and measures of self-efficacy to be tailored to the assessed criterial task and the related domain of functioning in order to predict outcomes. They administered three types of mathematics self-efficacy judgments: confidence to solve mathematics problems, confidence to succeed in math-related courses and confidence to perform math-related tasks – the Mathematics Self-Efficacy Scale-Revised. The confidence in solving problems was the most powerful predictor from the three self-efficacy types for the problem-solving performance task. Similarly, the choice of math-related majors as a criterion, was more strongly predicted by the perceived confidence to succeed in math-related courses, as expected.

Given the task-specific nature of self-efficacy judgments, it may be speculated that such judgments may generalize across courses. A student, for example, may hold strong efficacy perceptions for mathematics which generalize to other subjects like statistics or physics. Bong (1997) has found modest evidence that efficacy beliefs may generalize beyond specific tasks and school subjects, particularly in the quantitative domain. Her data revealed strong positive relationships among efficacy beliefs in math and science courses (Algebra, Geometry, Chemistry), but not in verbal ones (English, US History, Spanish). Still, she cautions that predicting academic self-efficacy from one subject to another or from the quantitative domain to a specific quantitative subject may not be justified. Pajares & Miller (1995) suggest that global and generalized self-efficacy assessments might predict performances that are not spe-

cifically related. If this were the case, then the relationship between assessed self-efficacy and performance would be stronger. These studies gave lower correlations between a generalized measure of self-efficacy (the composite score of the Mathematics Self-Efficacy Scale) and outcome measures than between specific self-efficacy, math attitude or self-concept measures and outcomes. Therefore, if the aim of a study is prediction of performance outcomes from self-efficacy judgments, then specificity and correspondence to the actual performance task should guide the formulation of the research questions and design (Pajares, 1996).

### **The relationship between self-efficacy and goal setting and modeling**

Setting goals which are proximal, manageable and preferably personally determined, is a cognitive motivator and also a means for developing personal efficacy (Bandura, 1997). Initiating activities to accomplish proximal goals provides mastery experiences. Cognitive efficacy is built with feedback on the progress in mastery experiences and strengthened with goal achievement.

Several studies illustrate the benefits of setting goals in performance and motivation. Giving children specific goals in a long division unit enhanced their self-efficacy; coupled with comparative information about similar peers led to higher skill acquisition (Schunk, 1983a). Difficult goals, compared with easier ones, in an arithmetic instruction program heightened children's motivation, persuasory information increased their self-efficacy and both led to highest skill (Schunk, 1983b). Unlike distant or general goals, providing proximal goals in a subtraction program raised children's motivation, self-efficacy and acquired skills (Bandura & Schunk, 1981).

Modeling in social cognitive theory is a way to advance efficacy beliefs and improve the level of performance, because vicarious experiences is a source through which people observing others undergoing the experience and comparing themselves with them can make inferences about their own capabilities (Bandura, 1997). Schunk (1991) summarized findings of studies in this area. He reported that observation of a model solving a puzzle with high persistence and confidence, promoted children's persistence on the same task. With his associates he carried out a series of studies comparing various types of modeling. They found that observations of peer mastery and peer coping models resulted in almost equally successful

performance in subtraction problems, but in the former case more positive attitudes were noticed and higher verbal self-efficacy statements were made by the children. Peer models increased efficacy and skills better than teacher models. These findings are consistent with evidence from studying change in mathematical thinking; Siegler (1995) found that children studying number conservation, produced more learning in training sessions that provided feedback to their answers and were asked to explain the experimenter's reasoning compared to children who received feedback only, or received feedback and were asked to explain their own reasoning. Moreover, Schunk (1991) reports that observation of any model, in contrast to no modeling, had positive outcomes on motivation. Children observing multiple models in fraction problems had better performance outcomes than children observing single models. Children who were videotaped as they solved problems and showed the tape, outperformed children who did not observe their tape, or were not videotaped at all. The latter implies that self-modeling is another way of improving self-efficacy.

### **The accuracy of self-efficacy judgments**

The personal judgments made about one's capabilities can be overestimated or underestimated. Bandura (1986) argued that efficacy judgments that slightly exceed what one can do at any given time are probably the most functional, because then the individual possibly undertakes challenging, proximal tasks, and feels more motivated to succeed. People underestimating their capabilities are more likely to limit their actions and restrict themselves from acquiring potential experiences and accomplishing tasks. Research on mathematics self-efficacy illustrates that students were consistently found to overestimate their capabilities; the confidence they reported in solving problems did not match their actual performance – the term used for the discrepancy is poor calibration (Hackett & Betz, 1989; Pajares & Miller, 1994, 1997; Pajares & Kranzler, 1995).

Pajares and Miller (1997) investigated the issue of calibration in an experimental design. They assigned students randomly in one of four groups where self-efficacy and the performance assessments varied in form. Traditional multiple-choice, or alternative open-ended formats were presented for each of the two assessments; in the open-ended format the options were not given to the students. The forms of assessment did not affect self-efficacy judgments. However, students taking the open-ended performance test did not get as high scores as those who took the multiple-choice test, therefore they had poorer calibration. The inaccu-

racity between the ratings of self-efficacy and the performance in open-ended assessments translates to poorer predictive utility of efficacy judgments. The researchers concluded that students' self-perceptions of mathematics capabilities may be less accurate than has previously been reported and that their familiarity with the multiple-choice format makes them anticipate this method of assessment, which is easier compared to other types of assessment. Lack of match between self-efficacy and non-traditional assessments, performance assessment in particular, was detected elsewhere as well (Pajares & Miller, 1995). This is clearly a topic that needs further investigation, particularly as alternative forms of assessment become more popular in education (Hambleton, 1996).

### **Gender differences and career choices**

The discrepancy between male and female performance in mathematics has been a major issue in the literature (Dweck, 1986). Though evidence usually supports that the discrepancy, if any, is not large (Pajares & Kranzler, 1995), it is apparent that girls do not choose mathematics courses in their secondary and tertiary education as often as boys do. There is a further obvious difference in carrier choices as well; for example, women are under-represented in math-related occupations, such as engineering and the natural sciences compared to men.

Research in motivation suggests that sex differences in attitudes towards mathematics are noticeable in high school (Wigfield, Eccles, & Pintrich, 1996) and that motivational patterns and associated behavior appear to be larger among the brightest students (Dweck, 1986), with girls displaying shakier expectancies and lower persistence in the face of failure or confusion. Fennema and Sherman's work (1978) in gender differences pointed to the critical role of affective variables. Bussey and Bandura (1999) emphasized the influence of sociostructural factors that operate through biological potentialities in shaping human behavior. Stereotypes that exist in the society, whether in the family, the classroom, the peer-group, the school, the mass media, or the culture in general, undermine girls' sense of efficacy in school mathematics. In the framework of social-cognitive theory, self-efficacy is hypothesized to mediate gender differences in mathematics performance and attitudes towards the subject.

In beginning middle-school students, Pajares and Graham (1999) did not find any gender differences in self-efficacy beliefs. Pajares and Kranzler (1995) did not report any

significant gender differences in high-school mathematics performance (only close to significance), or mathematics self-efficacy, however they are not very confident in their claims because of the small sample size of their study. They did find differences in anxiety, which was strongly influenced by efficacy beliefs. Pajares and Miller (1994) found gender differences in mathematics problem solving performance in favor of males at the university level. In general, males reported higher mathematics self-efficacy, while females expressed higher anxiety levels. Girls made lower judgments of their capabilities and this explained for the most part their poorer performance. Path analysis showed that differences in performance were due to differences in perceived self-efficacy.

Gender differences exist in choices with regard to the college majors and careers, and particularly in science fields that require quantitative and technical background. Efficacy beliefs are considered to play a mediating role between gender and career choice, as in the case of performance in school mathematics. Individuals with a strong sense of self efficacy tend to consider a wider range of potential careers, prepare better for different careers, and stay longer in the field they have chosen (Lent, Brown & Hackett, 1994). Hackett and Betz (1989) used the Mathematics Self-Efficacy Scale to study major choice. They pointed out that undergraduate students' beliefs on mathematics self-efficacy were highly predictive of their choice of major after controlling for mathematics aptitude and anxiety. Women's lower sense of self-efficacy for math-related courses has been found to influence the subsequent choice of their career (Betz & Hackett, 1983; Hackett, 1985; Hackett & Campbell, 1987). In predicting interest to pursue a career in science and engineering, O'Brien, Kopala, and Martinez-Pons (1999) found direct effects of gender and self-efficacy, which was further predicted by prior achievement and ethnic identity.

### **Mathematics self-efficacy research: recent directions and educational implications**

The predictive power of perceived efficacy on performance has been well documented. How does this translate into classroom practice? To what directions for further research does it point to? Teachers typically consider mathematical ability as the underlying reason for the difficulty that students face with mathematics. However, perceptions of competence and non-competence might account for lack of motivation to engage in mathematical activities and for persistence in the face of difficult problems, thus resulting in avoidance of the subject matter and low performance. Failure might also result from anxiety due to low

efficacy beliefs. Therefore, at the classroom level, educators need to recognize the importance of students' perceptions of their capabilities and try to identify the sources of low self-efficacy in order to alter them.

This line of research supports a mastery-oriented classroom environment over a competitive one, since “[e]nactive mastery experiences are the most influential source of efficacy information because they provide the most authentic evidence of whether one can muster whatever it takes to succeed” (Bandura, 1997, p. 80). Through guided mastery of challenging tasks within the strengths of their students, teachers can enable the building of robust self-efficacy beliefs. Schunk and Lilly (1984) conducted a study in which female students initially rated their self-efficacy lower than males, but following an instructional training with performance feedback and practice opportunities on a novel mathematical task, gender differences in self-efficacy were eliminated. Modeling treatments have also been found to raise efficacy beliefs, thus increasing persistence and outcome performance.

Educational activities should be interesting to students to be effective. Self-efficacy is involved in developing interest in a task; when people feel efficacious about it and obtain self-satisfaction from experiencing mastery while working on it, they are likely to be interested in and persist on it (Bandura, 1997). Anxiety and attitudes toward mathematics have been shown to relate to efficacy beliefs, too, often with gender differences.

More recent research has continued to investigate the relationship between self-efficacy and self-concept. Pietsch, Walker, and Chapman (2003) found that self-efficacy items are related to competency components of self-concept, but not to affective ones, and that self-efficacy is more highly related to mathematics performance than self-concept. Further clarification of these relationships is needed. Developmental issues should be considered, because previous research suggests that important changes occur in adolescence, differentially so for girls than for boys.

The issue of generality and specificity in the assessment measures of self-efficacy, as well as the degree of correspondence of the measures to the criterial tasks and the temporal closeness of administering the measures are key principles for preserving consistency in conducting research in the area of social cognitive theory. Bong (2001, 2004) further investigated specificity of efficacy beliefs in Korean middle and high school students and claimed

that students form subject-matter motivational patterns, and that some beliefs like performance-approach and performance goals are more generalizable across domains compared to task-value and mastery goals, and attributional beliefs.

The low efficacy beliefs in mathematical competence may account partly for the avoidance of math-related courses and careers (Pajares & Kranzler, 1995). Zeldin and Pajares (2000) studied components of self-efficacy beliefs of women who were successful in the areas of mathematics, science and technology; verbal persuasions and vicarious experiences were critical sources of their self-efficacy beliefs. While women relied on relational episodes to persist in male-dominated disciplines, men constructed their self-efficacy beliefs primarily through interpretations of their achievements and successes in those fields (Zeldin, Britner, & Pajares, in press). Such information is useful for counselors and career advisors on the issue of gender differences in career choices. Prospective designs, like the one employed by Bandura, Barbaranelli, Caprara, and Pastorelli (2001) provide insights into gender differences in career choices and how they relate to perceived occupational self-efficacy.

More recently, researchers have investigated cultural aspects of self-efficacy, demonstrating distinct motivational patterns across ethnic groups. O'Brien et al. (1999) found that the measure of ethnic identity correlated positively with self-efficacy. Motivational systems were found to function similarly in Hispanic and Caucasian students, but with differences in the strength between prior achievement and self-efficacy (Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). Mathematics performance was strongly predicted by self-efficacy beliefs in South Asian and Anglo Canadian students, but there were differences in the sources of self-efficacy, the predictiveness of the motivational variables and dimensions of individualism and collectivism (Klassen, 2004). Cross-cultural studies will further inform self-efficacy theory on commonalities and differences across cultures.

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