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The effects of mathematics instruction using spatial temporal cognition on teacher efficacy and instructional practices

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ABSTRACT

This paper examined the effects of an instructional approach known as Spatial Temporal Mathematics (ST Math) on teacher beliefs about mathematics teaching. Participants were 339 elementary teachers teaching grades 2–5 who were randomly assigned to a control or treatment group. Hierarchical linear modeling was used to determine the effects of the intervention on self-efficacy, outcome expectancy, and instructional practices using scientific reasoning. While the treatment did not yield significant effects in teacher outcomes, our secondary analysis indicated that time on ST Math and the integration of ST Math into daily instructions were positively associated with teacher efficacy and instructional practices using scientific reasoning. Implications of the results on teacher beliefs about mathematics teaching are discussed.

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1. Introduction

Through extensive research on teacher instructional practices, our understanding of effective mathematics teaching and learning has improved markedly, allowing us to provide students with a variety of instructional activities in the classroom. These activities include computer-mediated games and other curricular approaches. However, while the information-technology revolution continues to spread around the globe, the influence of technological change on mathematics instruction is less well understood. We do not know, for example, whether technological innovations can be used to facilitate mathematics instructions and the impact they have on teachers' efficacy and classroom practices. Emerging research is beginning to fill this gap. In this paper we report the effects of a computer-based teaching tool known as Spatial Temporal Mathematics (ST Math) on teacher self-efficacy, outcome expectancy, and instructional practice.

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2. Theoretical framework

2.1. Self-efficacy and outcome expectancy

Self-efficacy is defined by Bandura (1977) as beliefs individuals hold about their own abilities to perform a particular kind of task. These beliefs affect the level of effort that individuals exert, their persistence in working through challenges, their resiliency when experiencing failures, and their means of coping with change. Bandura (1997) posited that self-efficacy depends upon the context in which the task is performed—that is, a person may produce different outcomes under different circumstances. For example, while teachers' content knowledge in mathematics affects their instructional practices, those who judge themselves as efficacious in teaching mathematics are expected to be more successful. Having similar content knowledge, teachers who view themselves as inefficacious in teaching mathematics will, other factors being equal, be less effective in the classroom. In this way, individuals who see themselves as capable may come to expect negative outcomes for a given task due to the specific context or environment in which the task must be performed. This phenomenon is referred to as outcome expectations. The distinction between these two concepts can be summarized as follows:

> Perceived self-efficacy is a judgment of one's capacity to accomplish a certain level of performance, whereas an outcome

> expectation is a judgment of the likely consequence such behavior will produce (p. 391). ... In social, intellectual, and physical pursuits, those who judge themselves highly efficacious will expect favorable outcomes, self-doubters will expect mediocre performances of themselves and thus negative outcomes. (Bandura, 1986, p. 392)

The construct of teacher efficacy was first conceived of by the RAND researchers as "the extent to which the teacher believed he or she had the capacity to affect student performance" (Berman, McLaughlin, Bass, Pauly, & Zellman, 1977, p. 137). Teacher efficacy initially measured by responses to two survey items: (1) "If I really try hard, I can get through to even the most difficult or unmotivated students," and (2) "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." The first item measures a teacher's sense of self-efficacy while the second item assesses a teacher's sense of outcome expectancy. Collectively, these two items describe teacher efficacy, which has been shown to be associated with teacher practice and gains in student proficiency (Berman et al., 1977; Gibson & Dembo, 1984).

Self-efficacy typically precedes outcome expectancy—that is, based on the teacher's sense of self-efficacy, he or she formulates the outcome expectancy of a given task (Tschannen-Moran, Hoy, & Hoy, 1998). Drawing upon Bandura's theory of social learning, Gibson and Dembo (1984) define teacher efficacy (self-efficacy and outcome expectancy) as follows:

> Outcome expectancy would essentially reflect the degree to which teachers believed the environment could be controlled, that is, the extent to which students can be taught given such factors as family background, IQ, and school conditions. Self-efficacy beliefs would indicate teachers' evaluation of their abilities to bring about positive student change. (p. 570)

2.2. Teacher efficacy and instructional practices

Two decades after its inception, Tschannen-Moran et al. (1998) offered a more precise definition for teacher efficacy as a "teacher's beliefs in his or her capability to organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context" (p. 233). This conceptualization accounts for teachers' perceptions of their own competence as well as their assessment of the teaching context. Tschannen-Moran et al. further suggested that teacher efficacy is a malleable trait, one influenced by the teacher's performance and experience.

If teacher efficacy is malleable rather than fixed, it follows that teacher efficacy varies depending upon teacher experience. For elementary pre-service teachers, efficacy for teaching mathematics is in part a function of past experiences with mathematics, instructional strategies, and mathematics anxiety (Gresham, 2009; Swars, 2005; Swars, Daane, & Giesen, 2006). Building on their model, Tschannen-Moran et al. (1998) investigated how teacher efficacy can change over time. They found that pre-service teachers develop efficacy beliefs through coursework and student teaching in the field. For novice teachers (those completing their first year of teaching), efficacy was most associated with stress, commitment to teaching, support, and preparation. The authors noted that "changes in efficacy beliefs among inservice teachers seem to be more difficult to produce and sustain" (Tschannen-Moran et al., 1998, p. 236). In fact, practicing teachers may experience a lower sense of efficacy at the onset of any instructional change, with their teaching efficacy increasing again when they acquire new strategies to cope with the changes and observe an increase in student learning as a result of these changes. These findings are important in setting realistic expectations for how teacher efficacy is likely to change at the onset of any programmatic intervention and can inform ways to provide the proper support for teachers implementing new teaching strategies. Of course, teacher efficacy is not developed only through self-reflection. Ross (1994) found, for example, that teacher efficacy could be enhanced through district-wide professional development using cooperative learning techniques. This study suggested that teachers' knowledge gained from the professional development was associated with positive changes in their efficacy beliefs.

Teacher efficacy is particularly important because it can moderate important variation in teachers' attitudes and behavior. Gibson and Dembo (1984) postulated that teachers who exhibit high self-efficacy and outcome expectancy would have relatively high confidence in their abilities to teach, persist longer, focus on academic instructions, and provide students with constructive feedback. On the other hand, teachers who have low self-efficacy and outcome expectancy would have less confidence in their abilities to be effective teachers and give up easily on being effective. Through classroom observations with a small number of teachers ($N = 8$), Gibson and Dembo (1984) found that low-efficacy teachers spent a greater amount of time focusing on non-academic activities compared to high-efficacy teachers who spent a lesser amount of time on these activities (and thus more time on academic materials). High-efficacy teachers also allocated less time (28%) to small group instruction compared to low-efficacy teachers who spent a greater amount of time on small group instruction (48%). High- and low-efficacy teachers also differed in the feedback they provided to students, with high-efficacy teachers communicating higher expectations and persisting with students through challenging problems. While the small sample used in this study precludes definitive conclusions about the practices exhibited by teachers with varying degrees of efficacy, it does highlight a critical point: teacher efficacy influences the ways teachers interact with students in the classroom thus shaping students' learning experiences in ways that are nearly certain to impact learning.

Teachers influence student learning and development in multiple ways. They directly provide students with content knowledge, but also indirectly shape students' educational experiences that lead to the formation of key aspirations and expectations. These indirect influences can be strong enough to affect student academic attainment. Benner and Mistry (2007) found that teacher expectations for students affect students' own expectations and educational attainment. This shows that the relationship between teacher expectations and students' academic outcomes is mediated by student expectations and self-concept of ability—that is, teacher expectations shape students' expectations and self-concept, which in turn affect their academic performance. Of course, students may not have accurate assessments of teachers' expectations in the classroom. However, Chouinard, Karsenti, and Roy (2007) found that teacher beliefs and expectations, regardless of whether they are accurate, can influence students' beliefs about learning mathematics among secondary school students. This research showed that perceived support from social agents (namely, teachers and parents) affects students' beliefs about mathematics, which affects their achievement goals, and in turn moderates effort in learning mathematics. Teachers, along with parents, influence students' competency beliefs, their attitudes about the utility of mathematics, and their mastery goals and effort in learning mathematics. These findings suggest that while teacher beliefs and expectations may not directly link to student performance, they can shape students' perceptions about their ability to learn, which ultimately affects their achievement. These effects are evident in another study conducted by Lavigne, Vallerand, and Miquelon (2007), which revealed that teachers' support for the development of students' autonomy affects students' beliefs about their own competence and autonomy toward science learning, which then influences