Learning and Instruction 44 (2016) 53–64

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Schema-based instruction: Effects of experienced and novice teacher implementers on seventh grade students' proportional problem solving

Asha K. Jitendra*, Michael R. Harwell, Stacy R. Karl, Danielle N. Dupuis, Gregory R. Simonson, Susan C. Slater, Amy E. Lein

University of Minnesota, Department of Educational Psychology, 56 East River Road, Minneapolis, MN 55455, USA

A R T I C L E I N F O

Article history:
Received 21 September 2015
Received in revised form
6 March 2016
Accepted 14 March 2016
Available online 23 March 2016

Keywords:
Schema-based instruction
Experienced and novice implementers
Seventh-grade students
Proportional problem solving

A B S T R A C T

This study examined the effects of a research-based intervention, schema-based instruction (SBI), implemented by experienced- (taught SBI in previous study; Jitendra et al., 2015) and novice-teacher implementers (taught SBI for the first time with professional development) on the mathematics outcomes of seventh-grade students. SBI is a multicomponent intervention that emphasizes the mathematical structure of problems through the use of schematic diagrams and incorporates problem solving and metacognitive strategy instruction. Results indicated that both experienced- and novice-teacher implementers delivered SBI with similar levels of fidelity; there was no SBI experience effect on the immediate and 10-week retention tests of proportional problem-solving, on a general measure of problem solving, or on the end of the year state mathematics achievement test. These results provide evidence that the effectiveness of SBI generalizes over time to different cohorts of teachers and that the impact of SBI on student mathematics outcomes is maintained over time without additional PD.

1. Introduction

Ratio and proportional relationships are of primary importance during the upper elementary and middle school grades. These relationships, along with the interrelated topics of fractions, decimals, and percent, provide a critical foundation for algebra. Proportionality involves the concept of ratio and is central to topics in mathematics such as linear functions, scale drawings, similarity, trigonometry, and probability. In the Common Core State Standards (CCSS; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), instructional time focused on proportionality occurs in middle school when students "develop understanding of proportionality to solve single and multi-step problems … solve a wide variety of percent problems, including those involving discounts, interest, taxes, tips, and percent increase or decrease" (p. 46).

Researchers in mathematics education (e.g., Lamon, 2007; Lobato, Ellis, Charles, & Zbiek, 2010) note that ratio and proportional relationships are situated in the broader landscape of the multiplicative conceptual field (e.g., whole number multiplication and division, fractions, linear functions). While young students' difficulty with ratio and proportional relationships is related to their development of multiplicative versus additive reasoning (Lamon, 1995), secondary school students who learn to reason proportionally following instruction in various linear functions tend to apply the notion of linearity to most situations, even when it is not applicable (see Fernández, Llinares, Van Dooren, De Bock, & Verschaffel, 2012; Van Dooren, De Bock, Hessels, Janssens, & Verschaffel, 2005).

Solving even simple proportion problems is challenging for many children and adolescents as they may not understand the problem situation or know when a solution strategy is applicable (Weinberg, 2002). Yet, only few intervention studies have focused on improving students' learning of ratios and proportions. Most studies were short-term and did not address the broad domain of ratios and proportional relationships (Adjiage & Pluvinage, 2007; Fujimura, 2001; Miyakawa & Winslow, 2009) or used quasi-experimental research designs or teaching experiments, which limited causal inferences. Also, few studies have tested the

* Corresponding author.
E-mail addresses: jiten001@umn.edu (A.K. Jitendra), harwe001@umn.edu (M.R. Harwell), karlx028@umn.edu (S.R. Karl), dupui004@umn.edu (D.N. Dupuis), gsimonso@umn.edu (G.R. Simonson), slat0013@umn.edu (S.C. Slater), leinx032@umn.edu (A.E. Lein).

http://dx.doi.org/10.1016/j.learninstruc.2016.03.001
0959-4752/

effectiveness of a comprehensive curriculum package (e.g., Connected Mathematics Project; see Ben-Chaim, Fitzgerald, Benedetto, & Miller, 1998) or conducted randomized studies. The few randomized studies conducted have examined the efficacy of schema-based instruction (SBI), a multicomponent approach to teaching proportional problem solving (e.g., Jitendra, Star, Dupuis, & Rodriguez, 2013; Jitendra et al., 2015).

In this article, we report findings from the second year of a 2-year study of the efficacy and sustainability of SBI. In the first experimental study (Jitendra et al., 2015), teachers were randomly assigned to either the treatment condition (Cohort 1), in which they received professional development to implement SBI five days a week for approximately 6 weeks to teach problem solving involving ratio, proportion, and percent, or to the control condition (Cohort 2) to teach the same topics from their district-adopted mathematics textbook. Results indicated that students in the SBI classrooms outperformed students in the control classrooms on a proportional problem solving measure and maintained their improved performance nine weeks later. Scores on the Process and Application subtest of the Group Mathematics Assessment and Diagnostic Evaluation (GMADE) were equivalent for the two groups.

Many teachers, even though highly motivated, may find it challenging to use new instructional materials to teach ratios and proportional relationships and effectively use visual representations to prime the underlying problem structure, foster problem solving and metacognitive strategy skills, and develop procedural flexibility (essential features of SBI implementation). Implementing a new instructional approach can pose a range of challenges even when teachers are provided with instructional materials (Obara & Sloan, 2010; Remillard, 2005). Factors such as initial mismatch between principles underlying the innovative approach and teachers' philosophy of teaching and learning, time to cover the rest of the curriculum, and the methods of assessment may restrict innovation that attempts to find a balance between (a) providing instruction to ensure meaningful learning and (b) having teachers “reflect on the mathematical value of the study of the topic” (Bennie & Newstead, 1999, p. 5). Despite these challenges, there is some research suggesting that instructional materials in conjunction with professional development can change teacher practices to align with the innovation (Cohen & Hill, 2000).

In response to the challenges of using new instructional materials, we invited all teachers who participated in the first study (Year 1; Jitendra et al., 2015) to continue in the study a second year to evaluate the effects of professional development (PD) and sustainability of SBI by examining both teacher implementation and student learning in classrooms of teachers who received PD and implemented SBI in the past year and possibly gained more expertise with this method (experienced-teacher implementers) and teachers implementing SBI for the first time with PD (novice-teacher implementers). Previous research on the long- and short-term effects of teachers' professional development is sparse, with one study (Fennema et al., 1996) documenting that when teachers participate in PD and develop expertise with instructional techniques for promoting students' mathematical thinking, greater gains are seen in subsequent cohorts of students than prior cohorts. Therefore, the purpose of this study was to examine whether teacher participation in PD along with more or less experience with SBI would differentially affect teacher implementation and influence their students' proportional and mathematical problem solving skills as well as mathematics achievement.

1.1. Theoretical framework

1.1.1. Teacher learning in organized professional development

Research has shown that high quality professional development can not only affect teacher attitudes and classroom practice, but also influence student learning (Garet, Porter, Desimone, Birman, & Yoon, 2001). Several conceptual frameworks of professional development have been proposed for enhancing teacher and student learning (e.g., Borko, 2004; Desimone, 2009). One theory involves a link between the PD, teachers, and students such that teachers participate in PD, they implement the practices learned in PD in their classrooms, and these practices affect student achievement (Desimone, 2009). Features of high-quality PD that have been associated with changes in teacher practice and subsequent improvements in student performance include content focus, active learning, coherence, duration, and collective participation. A sustained focus on *content* appears to be a critical feature of high-quality PD (Blank & de las Alas, 2009). Content-focused PD activities designed to help teachers understand what they teach and how students learn the content can support teacher knowledge and practice to improve student learning (Sample McMeeking, Orsi, & Cobb, 2012; Perry & Lewis, 2011; Saxe, Gearhart, & Nasir, 2001).

There is evidence that teachers engaged in *active learning* strategies through observation, discussion, practice, and reflection are particularly effective (Desimone, Porter, Garet, Yoon, & Birman, 2002). Such strategies may include implementing new approaches to teach familiar content that support teachers' thinking and reflecting on mathematical ideas or helping teachers understand students' difficulties in specific content by reviewing student work (Carpenter, Fennema, Peterson, & Loef, 1989; Cohen & Hill, 2000). One exemplary PD program that not only supports teachers' own knowledge of the relevant mathematics, but also enhances their understanding of children's mathematical understanding is Cognitively Guided Instruction (CGI). Research on CGI, which focused extensively on instructional practices, showed that the 4-week PD program led to changes in classroom teaching practices (e.g., fostered discussions of problem-solving strategies) and subsequent improvement in children's mathematical word problem solving performance. Students in CGI classrooms solved a variety of mathematics problems using multiple-solution strategies and demonstrated confidence in their mathematical ability compared to students in control classrooms. Furthermore, findings of a longitudinal study of CGI (Fennema et al., 1996) indicated that CGI teachers developed their own practices as they gained expertise with CGI approaches over time, which led to further improvements in subsequent cohorts of students.

Another core feature of effective PD programs is *coherence*, which refers to the extent to which the content taught aligns with state standards and assessments, is consistent with teacher goals for their professional development, and presents opportunities for communicating with other professionals (Garet et al., 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Effective PD also requires considerable time that is carefully structured, organized, and focused on both content and pedagogy (Guskey & Yoon, 2009). Content-focused PD along with extended *duration* (more than 30 h over a span of time) can lead to changes to teacher practice and student achievement (see Blank & de las Alas, 2009; Desimone et al., 2002; Guskey & Yoon, 2009; Yoon, Duncan, Lee, Scarloss, & Shapeley, 2007). Furthermore, *collective participation* of groups of teachers working together is more likely to influence teacher learning (see Desimone et al., 2002; Penuel et al., 2007; Penuel, Sun, Frank, & Gallagher, 2012). Although there is some evidence that PD with all or most of these characteristics can support better curriculum implementation (Perry & Lewis, 2011) and enhanced student learning (Perry & Lewis, 2011; Sample McMeeking et al., 2012; Saxe et al., 2001), there is very limited causal evidence of the effects of teacher PD on improving student mathematics achievement (Gersten, Taylor, Keys, Rolfhus, & Newman-Gonchar, 2014).