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Further evidence for teacher knowledge: supporting struggling readers in grades three through five

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Abstract We report the results of a study with 30 teachers designed to examine the effects of teacher knowledge on the achievement of struggling readers. We worked with teachers of grades three, four, and five during a 10-day intervention focused on literacy instruction and related linguistic knowledge, and we assessed their students' learning across the year. Hierarchical models of student outcomes indicated that lower-performing students in intervention classrooms showed significantly higher levels of performance at year end on all literacy measures, compared with their peers in control classrooms ($n = 140$). In addition, teacher's linguistic knowledge was related to improved student performance, regardless of condition. Additional analyses including all students ($n = 718$) indicated that benefits for the lower performing students in intervention classrooms were shared by their classmates, but to a more limited extent.

Keywords Reading instruction · Teacher knowledge · Phonological awareness · Linguistic knowledge

Specifying the disciplinary knowledge needed to teach reading in the elementary school is difficult not only because instruction changes across the elementary grades, but also because reading instruction is typically embedded within the language arts, an often amorphous mixture of reading, writing, and literature instruction that includes a variety of epistemological perspectives on what it means to become literate (Grossman, Valencia, & Hamel, 1995; Shanahan, 1994). In

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addition, differences exist in how teacher knowledge has been operationalized in research studies. Teachers' knowledge of reading has at times been framed in terms of academic preparation or state certification standards (Bader, 1975; Braam & Oliver, 1970; Nolen, McCutchen, & Berninger, 1990; Winkeljohann, 1976), and more recently, there has been considerable discussion of best practice in reading instruction (Baumann, Hoffman, Duffy-Hester, & Moon, 2000; Burns, Griffin, & Snow, 1999; National Reading Panel [NRP], 2000; Pressley, 1998), with inferences about knowledge based on differences in practice. Although there has been research that directly examines the disciplinary knowledge needed to teach effectively in other areas (Ball, 1991; Grossman, 1991; Shulman, 1987; Wineburg & Wilson, 1991), there has been less research on the knowledge base needed to teach reading. The relevant research base is growing, however (Bos, Mather, Dickson, Podhajski, & Chard, 2001; Cunningham, Perry, Stanovich & Stanovich, 2004; Ehri & Williams, 1995; Hoffman & Pearson, 2000; Mather, Bos, & Babur, 2001; McCutchen et al., 2002a; Moats & Foorman, 2003; Phelps & Schilling, 2004), as the articles in this special issue demonstrate.

Professional standards have outlined relevant disciplinary knowledge at a general level. A position paper (Brady & Moats, 1997) endorsed by the International Dyslexia Association recommended that teacher preparation in reading include, among other topics, knowledge of the structure of language (e.g., phonology, orthography, morphology, and text structure). Such linguistic knowledge is only one aspect of the knowledge base needed to teach reading effectively (Lane et al., 2009), but the ability to provide accurate and explicit instruction in the alphabetic principle underlying English orthography seems especially important for teachers of the primary grades (Adams, 1990; Ball & Blachman, 1991; Cunningham, 1990; Ehri, 1995; Ehri & Williams, 1995; Share & Stanovich, 1995). Despite the importance of such linguistic knowledge, one survey of teachers indicated that fewer than a third of teachers reported familiarity with even the term *phonological awareness* (Troyer & Yopp, 1990), and another revealed fewer than 20% could answer questions about English phonology and orthography with much accuracy (Moats, 1994). In a more recent study, we found that teachers' phonological knowledge was still not extensive, although kindergarten teachers' phonological knowledge correlated positively with measures of their students' word reading (McCutchen et al., 2002b).

For students beyond the earliest grades, instruction that also supports fluency and comprehension becomes increasingly important (Hall & Moats, 1999; NRP, 2000). In a study of fourth grade children who failed the state-mandated reading test in Washington, Riddle Buly, and Valencia (2002) documented six distinct profiles that reflected various combinations of strengths and weaknesses in word identification, comprehension and reading fluency. Across profiles, over 40% of the students showed difficulties in word identification. Despite the contribution of multiple skills to reading success, explicit instruction focusing on the phonological and orthographic structure of words can continue to benefit many older students who struggle with reading (Olson, Wise, Ring & Johnson, 1997; Torgesen, 1997).

It is easy to underestimate the depth of linguistic knowledge that is necessary for teachers to be truly effective in helping struggling readers. As literate speakers of English, all teachers undoubtedly possess some knowledge of English phonology and orthography; they are accomplished readers themselves, after all. However, being a reader does not guarantee that a teacher has the depth of explicit knowledge necessary to navigate students through the complexities of written English (see Venezky, 1970). For most literate adults, knowledge of word sounds and spelling patterns are so intertwined that they are difficult to separate, and adult confusions between sounds and spellings can result in needless student confusions during instruction. Consider, for example, the following conversation we observed between a postdoctoral researcher from our own lab and a beginning first grade student:

Researcher: Do you hear the word *car* inside the word *carpet*?
Student: Yes.
Researcher: Good. Do you hear the word *bun* inside *bunk*?
Student: No.
Researcher: Listen again. Do you hear the word *bun* inside *bunk*?
Student: (Looking closely at adult). Yes?
Researcher: Good.

Our colleague was trying to assess the student's phonological skill; however, her own phonological knowledge was not sufficient to recognize that the student's initial response about the word *bunk* was correct. Although the letters *b*, *u*, and *n* are contained within *bunk*, coarticulation effects influence the pronunciation of /n/ before the velar consonant /k/, resulting in the phoneme /ŋ/. The student astutely noticed that he did not hear the word *bun* in *bunk*, but rather something that rhymed with *sung*. Our colleague was so influenced by her knowledge of spelling patterns that she considered the student's initial response an error. This student, who was a relatively strong emerging reader, hesitated for a moment and then offered an alternative to his initial, correct response. Such an exchange may constitute merely a momentary bump in the road for this student, and for many beginning readers; however, for students still struggling to identify separate sounds within words, such misinformation can cause a great deal of unnecessary confusion.

Over the past several years we have worked closely with elementary school teachers helping them develop knowledge of structural aspects of spoken and written English. Our professional development strategies have been consistent with the recommendations of Brady and Moats (1997) and have been influenced, in part, by the finding that so few teachers have extensive linguistic knowledge (Moats, 1994). Each year of the project we focused on a different grade level, kindergarten through fifth grade. The results of the kindergarten and grade one data have been reported previously (McCutchen et al., 2002a). In that study, which was targeted to teachers of emergent readers, we found that an intervention focused on increasing teachers' own linguistic knowledge was effective in deepening their knowledge of English phonology and orthography. Furthermore, kindergarten students in classrooms of intervention teachers made greater gains across the year in orthographic fluency (i.e., their ability to produce legible letters), and first-grade students taught by teachers in the intervention condition outperformed their control-classroom peers in phonemic awareness and on all of our reading and writing measures (comprehension, vocabulary, spelling, and composition).

In the present article, we examine the effectiveness of a similar intervention with teachers of grades three through five. As in the previous study (McCutchen et al., 2002a), our intervention focused on deepening teachers' linguistic knowledge so they could better address the needs of their struggling students, but for these teachers of older students, we emphasized combining word-level work with explicit instruction in comprehension and composition. We first describe the intervention briefly and then report analyses of learning outcomes for the lower-performing students in the classrooms in which we worked, followed by analyses of classroom-wide learning outcomes. The primary research questions underlying the study were: (1) Can we document changes in teachers' linguistic knowledge as a result of our intervention, and (2) can we document differences in the learning outcomes of struggling students related to teacher knowledge?

Method

Participants

Teachers

Thirty teachers from 17 schools in the Greater Seattle area volunteered to participate. Teachers were recruited by letters of invitation to join a collaborative school–university project on reading instruction, and they received honoraria for their participation. Based on general demographics (percentage of students receiving free or reduced lunch, percentage of minority students), schools were matched and then assigned either to the intervention condition or a wait-listed control condition. (Control teachers were invited to participate in the professional development the summer following our classroom observations and assessments.) Within each matched pair of schools, assignment to condition was quasi-random, with the stipulation that once a school had been assigned to the intervention condition, it remained an intervention school if additional teachers participated in subsequent years of the study (to minimize possible effects of within-school diffusion). (Examination of the data indicated that only two schools in the intervention condition had taken part in the previous study (McCutchen et al., 2002a), but we worked previously with none of the teachers described here and only one of the students.) Analyses indicated no significant differences between intervention ($M = 35.2\%$, $SD = 21.0\%$) and control ($M = 36.5\%$, $SD = 25.0\%$) schools in the percentage of students reporting non-majority heritage, F (1, 16) = .01, $p > .90$, or between intervention ($M = 19.1\%$, $SD = 20.0\%$) and control ($M = 28.1\%$, $SD = 24.1\%$) schools in the percentage of students qualifying for free or reduced lunch programs, F (1, 16) = .76, $p > .30$.

Based on school assignment, 16 teachers were assigned to the intervention condition and 14 to the control condition. Five teachers were male; one was African American. Within the intervention condition (i.e., treatment group) the average number of years teaching was 13.7 years ($SD = 7.2$) and within the control condition, the average number of years teaching was 17.4 years ($SD = 8.1$). An F-test indicated no significant differences between groups in time in the profession, F (1, 29) = 1.5, $p > .20$). The majority of teachers taught fourth grade ($n = 18$; 12

intervention, 6 control) or third grade ($n = 9$; 3 intervention, 6 control); one control teacher taught a grade 3/4 split, one control teacher taught a 4/5 split, and one intervention teacher taught fifth grade. An F-test indicated no significant differences between groups in grade level taught, F (1, 28) = 2.5, $p > .10$.

Students

Data were collected from 718 students from the 30 teachers' classrooms, 389 from intervention classrooms and 329 from control classrooms. Forty-eight percent of the students were female; 61% reported as European American, 11% as Asian American, 6% African American, 3% Hispanic, 1% Native American, and 18% reported another ethnicity or declined to report.

At the first testing wave in the fall, all participating students in the 30 classrooms completed the comprehension and vocabulary subtests of the Gates-MacGinitie Reading Tests (MacGinitie & MacGinitie, 1989), as well as the writing fluency subtest of the Woodcock-Johnson III (WJ Writing Fluency; Woodcock, McGrew, & Mather, 2001), and a group-administered adaptation of the spelling subtest of the Wechsler Individual Achievement Test (WIAT Spelling; Wechsler, 1991), which included the first 40 items. The reading and vocabulary subtests of the Gates-MacGinitie Reading Tests for grades three through five have Kuder-Richardson Formula 20 reliability coefficients ranging from .90 to .93. Reliability coefficients for the WJ writing fluency subtest range from .72 to .81 across ages 8 through 11. Split-half reliabilities for the spelling subtest ranged from .93 to .94 for 7- to 10-year olds. We also assessed children's composition with a story written in response to picture prompts (Klecan-Aker & Brueggerman, 1991) in which narrative development was assessed on a five-point scale, based on the number of story grammar elements children included in their texts. The order of tests was counterbalanced across classrooms, and when possible, the test battery was administered on a single day, but always within a window of three days.

Based in part on comprehension scores from the first wave of testing, teachers referred their five lowest performing students for inclusion in the main study. This subset of students was screened with individual administrations of the Woodcock Reading Mastery Test-Revised (WRMT-R; Woodcock, 1987, 1998) word identification and word attack subtests. The word identification subtest has split half reliability coefficients of .97 for third graders and .89 for fifth graders, and the word attack subtest has coefficients of .97 for third graders and .91 for fifth graders. Although there was a wide range of performance across classrooms, only those students performing at or below the 50th percentile on word identification (age-adjusted standard score of 100 or below) were considered part of the subgroup of "lower performers." Application of this criterion resulted in a subgroup of 140 students from 29 of the original 30 classrooms (one control classroom had no students meeting criterion). These students cannot be labeled reading disabled, or even uniformly at-risk, but they did represent a group of students who were performing sufficiently poorly, relative to their classmates, to warrant teacher concern. Within this sub-sample, 45% of the students were female; 62% self-reported as European American, 9% as Asian American, 8% African American, 2%

Hispanic, 1% Native American, and 18% reported another ethnicity or declined to report.

Procedure

Prior to the start of the school year, we worked with intervention teachers during a 10-day summer institute. During the summer institute we devoted considerable time to deepening the intervention teachers' understanding of phonology, phonemic awareness, and their role in balanced reading instruction that emphasizes both word-level and text-level instruction (see McCutchen & Berninger, 1999, for a detailed description of the intervention used with teachers of younger students). We summarized with teachers the basic phonology of English and the articulatory features associated with vowels (e.g., height) and consonants (e.g., place, manner, voicing), the pronunciation of frequently encountered orthographic units, multi-letter as well as single-letter units (Berninger, 1998). For these teachers of older students, we included an extended discussion of English morphology, which we considered especially important in light of the increase in multi-morpheme vocabulary encountered in the intermediate elementary grades (Anglin, 1993). We summarized with teachers a brief history of English, from its Anglo-Saxon roots to the influx of French forms after the 11th century and borrowings from Greek for technical terms. We explored with teachers how, for older students, instruction in phonological awareness can be embedded in discussions of morphology and vocabulary, especially the technical vocabulary drawn from science or social studies texts. However, we provided more than a mini-course in linguistics. We also outlined for teachers the typical developmental sequence of children's phonemic awareness, from awareness of subparts within compound words to awareness of syllables, then onset and rimes, and finally individual phonemes (Berninger, Thalberg, DeBruyen, & Smith, 1987; Hall & Moats, 1999; Rosner, 1979). We provided examples from children's work to illustrate links between phonemic awareness, morphological awareness, spelling and reading. It was through analysis of children's reading miscues and misspellings that teachers came to see the purpose of deepening their own understanding of the structural features of English; so they could diagnose, for example, the source of the error when a child spelled *train* as *chran* (an error involving primarily a phonological confusion), or *produced* as *produst* (and error implicating both phonology and morphology), and most importantly, what the next instructional steps might be in each case.

Because we were working with teachers of older students, we also emphasized the importance of developing students' reading comprehension and composition skills, consistent with recent recommendations regarding literacy instruction beyond the early grades (Biancarosa & Snow, 2004; NRP, 2000). For example, we discussed the importance of modeling comprehension processes and provided teachers with methods and materials to scaffold comprehension (e.g., Palincsar & Brown, 1984). We examined the structural components of text genres (Meyer, Brandt, & Bluth, 1980; Meyer & Poon, 2001), reviewed the development of children's competency with various genres (Bereiter & Scardamalia, 1987; Englert, Raphael, Anderson, Anthony, & Stevens, 1991; Englert, Stewart, & Hiebert, 1988;

McCutchen, 1987, 2006; Stein & Glenn, 1979), and provided teachers with schematic representations to support student reading and writing activities. We spent less time discussing explicit instruction to develop fluency, although we encouraged teachers to have students read diverse texts, as well as read and write regularly.

We asked teachers to develop lessons based on their experiences with us, specifically lessons focused on word reading, comprehension, and composition. By discussing examples of students' work and teachers' lessons, we attempted to include in our intervention both content knowledge (e.g., knowledge of English phonology, knowledge of discourse genre; knowledge of explicit comprehension instruction) and pedagogical content knowledge (e.g., knowledge of typical development of children's understandings, predicable student errors), as discussed by Shulman and his colleagues (Ball, 1991; Grossman, 1991; Shulman, 1987; Wineburg & Wilson, 1991). We then observed teachers (intervention and control) in their classrooms on three occasions and assessed their students' learning across the year. To minimize disruption of classroom routines, all assessment and observation occasions were prearranged with teachers. (Alerting teachers to the schedules for our classroom visits represented a compromise in ideal experimental design, but was a practical concession that helped secure and maintain teacher cooperation.)

During the school year we reconvened the intervention teachers for three-one-day follow-up sessions in November, February, and May, and we regularly visited their classrooms for ongoing consultation, observation, and student assessment. The content of the three follow-up sessions varied to respond to teachers' needs; however, the general focus was on revisiting themes from the summer institute and brainstorming issues that arose from teachers' application.

Measures

Teachers' linguistic knowledge

Because increasing teachers' linguistic knowledge was a major goal of the summer institutes, we administered alternate forms of the Informal Survey of Linguistic Knowledge developed by Moats (1994; Moats & Lyon, 1996) to intervention teachers both before and after the summer institute (see Appendix). (Teachers in the control condition completed the Moats survey once in the fall, just before the school year began.) The 65-item Moats survey assessed teachers' ability to identify sounds within words (phonemic awareness), and it is generally perceived to be difficult because it pits one's analysis of word sounds against knowledge of spelling. For example, one item asked teachers to recognize that *sung* consists of three phonemes, despite its four letters. The Moats survey also assessed teachers' knowledge of morphemes, syllable structure, and historical aspects of English spelling. These additional levels of language are especially important in helping older children learn to read and spell multi-syllabic words. In a prior study involving the Moats survey, we found internal consistency reliability coefficients ranging from .70 to .84 (McCutchen et al., 2002b).

Teachers' instruction

We observed classroom instruction at three points across the school year (after two, five, and eight months of instruction). Observers took detailed field notes during 15 minutes of literacy instruction, describing varied activities being utilized and indicating time spent on each. Field notes were coded for the *knowledge focus* of the instructional activity (e.g., writing extended text, spelling, comprehension, vocabulary, phonemic awareness), the *context* e.g., (teacher- or student-directed), the *text* involved (extended or isolated text), and the size of instructional *group* (whole class, small group, individual). Observers were graduate students in education who had taken part in the summer institute, most of whom had prior teaching experience. Observers were trained in using the coding scheme, and they took part in regular meetings to discuss and calibrate their use of the codes. The coding scheme was derived from that described by McCutchen, et al. (2002a) but was expanded to account for changes in instruction for older students. For example, we added multiple codes for writing instruction, including narrative, expository, and creative writing, as well as explicit instruction in writing strategies.

During 10% of the classroom observations, two observers took field notes and coded time allocations to provide reliability measures for the coding categories, calculated as the correlations (Pearson's r) between observers on the number of minutes assigned to each code. Reliability estimates for all categories included in the analyses were .74 or higher (ps $< .01$).

Despite our attempts to tailor our observational scheme to upper elementary classrooms, the observational data yielded few systematic differences between intervention and control teachers (discussed in the Results section below), and none that could be linked via compelling theoretical warrants to observed differences between teacher knowledge and student learning. Therefore, observational data are discussed only minimally.

Student assessments

Twice during the school year (during the previously described screening session in the fall after approximately two months of instruction, and again in the spring after approximately eight months of instruction) we administered to all students the comprehension and vocabulary subtests of the *Gates-MacGinitie Reading Tests* (MacGinitie & MacGinitie, 1989), the writing fluency subtest of the *Woodcock-Johnson III* (Woodcock et al., 2001), and a group-administered adaptation of the spelling subtest of the *Wechsler Individual Achievement Test* (Wechsler, 1991). All students also wrote a narrative in response to a picture prompt (Klecan-Aker & Brueggerman, 1991; prompts were counterbalanced across testing sessions). At both time points, the five lowest performing students in each class were also individually assessed on the WRMT-R Word Identification and Word Attack subtests.

Data analysis

A hierarchical linear modeling approach (a form of multi-level modeling) was used as the primary analytic tool for this study since our main focus was to test for teacher effects on student outcomes. As compared with unilevel methods (such as fixed-factor analyses of variance or simple linear regression), the more complex analysis method allowed us to: (a) account for the dependencies within nesting structures, allowing for valid inferences to be drawn about outcomes and predictors without simple linear regression assumption violations; (b) account for the differing levels of the nesting structure, allowing for valid inferences to be drawn about relationships between teacher-level variables and student-level outcomes (cross-level effects); and (c) account for missing data by analyzing all available data instead of only cases for which all data were available. To analyze teachers' instruction over the course of the year, two-level hierarchical growth models were specified (observations nested within teachers, centered at midyear) to provide an estimate of both the average time teachers afforded to instructional content at midyear, as well as the changes to instructional time over the course of the school year. To analyze student outcome data, we also used hierarchical modeling in order to account for variance between classrooms. To determine whether significant group differences existed on students' Time 1 assessments (after two months of instruction), we specified ANOVA-like two-level models with students nested within teachers. Finally, to analyze the impact of teacher-level variables (teacher knowledge, group assignment, grade taught and instructional time allotment) on students' Time 2 outcomes (after eight months of instruction), we specified ANCOVA-like, two-level models in which students assessment scores at Time 1 (after two months of instruction) were explicitly taken into account in comparisons of performance at Time 2.

Although we added additional predictors to our Time 2 models, the general mixed-model equation for an ANCOVA-like model is provided below.

$$\text{Time } 2_{ij} = \gamma_{00} + \gamma_{01} * \text{Group}_j + \gamma_{10} * \text{Time } 1_{ij} + U_{0j} + r_{ij}$$

Interpretation of the general model is as follows: each end-of-year outcome estimated for student *i* in classroom *j* (Time 2) equals: (a) the fixed effect of intercept γ_{00} (Time 2 mean score for all students, holding Time 1 and Group constant), plus (b) the fixed effect of slope γ_{01} (effect of treatment on Time 2, holding Time 1 constant), plus (c) the fixed effect of slope γ_{10} (effect of individual's Time 1 score relative to their group's mean), plus (d) the variance between classrooms U_{0j}, plus (e) the variance within classrooms (or residuals) r_{ij}. *HLM 6.1* (Raudenbush, Bryk, & Congdon, 2004; Raudenbush & Bryk, 2002) was used for all hierarchical modeling analyses.

Results

Teacher variables

Teachers' linguistic knowledge

Although we have anecdotal evidence that teachers deepened many aspects of their knowledge of literacy and literacy instruction as a result of our intervention, we explicitly assessed only their linguistic knowledge. Intervention teachers' pre- and post-institute scores on the Moats survey indicated that teachers significantly increased their linguistic knowledge after their experiences in the summer institute: $F\ (1,\ 15) = 9.2,\ p < .01$ (pre-institute $M = 54.6\%$, $SD = 14.4\%$; post-institute $M = 61.8\%$, $SD = 14.2\%$; Cohen's $d = .50$).

Teachers' instructional practice

Teachers in both conditions engaged their students in a wide range of activities, and because of the variability (and the limited duration of our observations) we were forced to combine some of the more fine-grained codes from our observational field notes into composite categories in order to get categories with non-zero frequencies over a sufficient number of teachers. For example, although our field-note codes distinguished isolated vocabulary instruction from vocabulary instruction embedded in discussions of texts, in the analysis of instructional time both vocabulary codes were combined into a single vocabulary category.

Two-level growth models were specified to analyze teachers' time spent on various areas of literacy instruction across the year (e.g., spelling, comprehension, writing, vocabulary). For these models, the intercept was fixed at the midyear classroom observation; each observation was approximately three months apart. In addition to teachers' group assignment (1 = Intervention, 0 = Control), teachers' grade level taught and scores on the Moats survey (as a proxy for linguistic knowledge) were included in the models, both of which were grand-mean centered in order to maintain dimensionality among predictors and simplify interpretation. All effect sizes were estimated as Cohen's *d*, calculated as the difference between model-implied group means (or between the average score and +1 standard deviation) divided by the pooled standard deviation, which includes between-teacher variance and residuals; Cohen, 1988).

Results of the teacher models revealed that group (Intervention, Control) was a significant unique predictor of midyear time spent on only one instructional activity, vocabulary ($t\ (26) = 2.1,\ p < .05,\ d = .64$), although the overall time allocation for both groups was low. (Control teachers were estimated to average 2 min of 15, and intervention teachers averaged 3.4 min, at midyear observation.) Group assignment was not predictive of change in instructional time allocation across the year, for any category (ps $> .10$). Only mid-year time allocated to vocabulary instruction was included in the student outcomes model, at the classroom level, to allow better estimates of unique effects of condition and teacher knowledge on student learning.

Student outcomes

Table 1 presents the observed means for students in intervention and control conditions on all outcome measures across both assessment occasions (following two and eight months of instruction). Panel A summarizes scores of lower-performing students on all group-administered measures as well as the individual administrations of the WRMT-R Word Identification and Word Attack subtests. Panel B summarizes outcomes across all students on the group-administered measures only.

Student assessments after second month of instruction

For each outcome measure, we specified a two-level hierarchical model (students, Level 1, nested in teachers and classrooms, Level 2) that tested whether group assignment (at the classroom teacher level) had a cross-level effect on students' scores after two months of instruction. Although the observed group means (shown in Table 1) appeared to reflect group differences in lower-performing students' scores at the first testing wave, we found a significant difference in the estimated means only on the WJ Writing Fluency subtest, $t\,(27) = 2.1, p < .05$. The estimated intervention group advantage for lower-performers was 2.3 raw score points ($SE = 1.1$), with lower performing students in intervention classrooms averaging 10.9 points and students in control classrooms averaging 8.6 points. (Note that the scores reported here, and in Tables 2 and 3, are based on parameter estimates from

Table 1 Observed student means (*M*) and standard deviations (*SD*)

Measures	Intervention $n = 80$					Control $n = 60$				
	Time 1		Time 2			Time 1		Time 2		
	M	*(SD)*	*M*	*(SD)*	Gain	*M*	*(SD)*	*M*	*(SD)*	Gain
Panel A: low-performers										
Comprehension	444.0	(56.52)	497.9	(61.03)	53.9	415.1	(69.08)	447.1	(62.34)	32.0
Vocabulary	466.7	(32.01)	498.5	(39.43)	31.8	449.2	(39.59)	467.2	(37.47)	18.0
Composition	3.2	(1.20)	3.9	(1.00)	.7	2.9	(1.19)	2.8	(1.11)	−.1
Spelling	17.8	(4.63)	22.7	(4.76)	4.9	16.2	(5.06)	19.0	(4.17)	2.8
Writing fluency	11.0	(4.14)	17.8	(4.42)	6.8	8.8	(3.95)	13.4	(4.97)	4.7
Word reading	61.6	(8.72)	68.7	(9.02)	7.2	56.9	(11.96)	61.4	(9.75)	4.5
Decoding	25.1	(9.12)	29.3	(7.81)	4.2	22.6	(9.15)	24.8	(7.69)	2.3
Measures	Intervention $n = 389$					Control $n = 329$				
	Time 1		Time 2			Time 1		Time 2		
	M	*(SD)*	*M*	*(SD)*	Gain	*M*	*(SD)*	*M*	*(SD)*	Gain
Panel B: all students										
Comprehension	494.1	(67.48)	542.7	(71.98)	48.7	479.3	(75.74)	511.4	(78.19)	32.1
Vocabulary	495.0	(41.22)	522.9	(43.41)	27.9	478.6	(51.12)	503.7	(52.11)	25.2
Composition	3.6	(1.15)	4.1	(.84)	.6	3.3	(1.24)	3.4	(1.13)	0
Spelling	21.4	(5.10)	25.7	(5.34)	4.3	20.4	(6.33)	23.6	(6.18)	3.2
Writing fluency	12.7	(4.66)	18.8	(4.83)	6.1	12.1	(5.17)	16.5	(6.37)	4.4

Note: Time 1 = two months after instruction began; Time 2 = eight months after instruction began; Comprehension = Gates-MacGinite Comprehension subtest (extended scale score); Vocabulary = Gates-MacGinite Vocabulary subtest (extended scale score); Composition = Narrative Development Composition (quality rating 1–5); Spelling = Weschler Intelligence Aptitude Test Spelling subtest; Writing Fluency = Woodcock-Johnson Writing Fluency subtest; Word Reading = Woodcock Reading Mastery Test-Revised Word Identification subtest (only administered to low-performers); Decoding = Woodcock Reading Mastery Test- Revised Word Attack subtest (only administered to low-performers)

Table 2 Model results for low-performing students' end-of-year (Time 2) outcomes

Fixed effects	Comprehension			Vocabulary			Composition			Spelling			Writing fluency			Word reading			Decoding		
	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*
Students' Time 2 (Endyear) Score, γ_{00}	455.0	(7.8)	58.6***	480.0	(6.9)	69.6***	2.9	(.1)	19.7***	20.2	(.5)	39.6***	14.0	(.5)	26.3***	63.4	(.9)	66.9***	26.0	(1.0)	25.2***
Group, γ_{01}	40.5	(11.0)	3.7***	18.7	(7.9)	2.4*	.9	(.2)	5.0***	2.7	(.6)	4.3***	3.6	(.7)	4.9***	4.8	(1.1)	4.5***	2.9	(1.2)	2.5*
Linguistic KN, γ_{02}	6.2	(7.4)	.8	8.7	(4.0)	2.2*	.5	(.1)	4.4***	1.3	(.3)	4.0***	.2	(.6)	.3	1.5	(.8)	1.8	2.2	(1.0)	2.3*
Grade, γ_{03}	11.0	(7.4)	1.5	−4.2	(4.5)	−.9	−.2	(.1)	−2.6*	−1.7	(.3)	−5.1***	1.1	(.7)	1.7	−.1	(.7)	−.2	−.2	(.8)	−.3
Vocab Instr, γ_{04}	−5.7	(11.9)	−.5	11.9	(5.8)	2.0	.2	(.2)	1.5	2.2	(.5)	4.4***	.4	(.8)	.5	1.5	(1.2)	1.3	1.6	(1.1)	1.4
Students' Time 1 Score, γ_{10}	29.6	(5.4)	5.5***	29.3	(3.7)	7.9***	.2	(.1)	1.9	3.8	(.5)	8.3***	2.1	(.4)	5.3***	8.2	(.6)	14.8***	6.0	(.7)	8.0***
Random effects	Var	(*SD*)	χ^2 (20)	Var	(*SD*)	χ^2 (20)	Var	(*SD*)	χ^2 (15)	Var	(*SD*)	χ^2 (20)	Var	(*SD*)	χ^2 (20)	Var	(*SD*)	χ^2 (20)	Var	(*SD*)	χ^2 (20)
Between-teachers (Endyear), U_0	175.9	(13.3)	31.2	79.1	(8.9)	38.2**	.00	(0)	15.5	.3	(.6)	28.3	1.1	(1.1)	35.2*	2.3	(1.5)	43.1**	2.5	(1.6)	42.4**
Residual, e	2555.9	(50.6)	–	661.8	(25.7)	–	1.0	(1.0)	–	7.6	(2.8)	–	11.2	(3.3)	–	15.2	(3.9)	–	17.4	(4.2)	–

Note: Student sample sizes varied by outcome (although all available data was used for $N = 140$ low-performing students). $N = 29$ teachers had low-performers ($n = 16$ intervention and $n = 13$ control). Students' Time 2 Score = scores after eight months of instruction; Group = teacher's group assignment (1 = Intervention, 0 = Control); Linguistic KN = teacher's end-of-summer-institute/fall linguistic knowledge; Grade = teacher's grade level taught; Vocab Instr = teacher's Empircal Bayes' estimates of midyear minutes spent on Vocabulary instruction; Students' Time 1 Score = scores after two months of instruction. All predictors except Group were group-mean centered prior to analysis. Comprehension = Gates-MacGinite Comprehension subtest (extended scale score); Vocabulary = Gates-MacGinite Vocabulary subtest (extended scale score); Composition = Narrative Development Composition (quality rating 1–5); Spelling = Weschler Intelligence Aptitude Test Spelling subtest; Writing Fluency = Woodcock-Johnson Writing Fluency subtest; Word Reading = Woodcock Reading Mastery Test-Revised Word Identification subtest; Decoding = Woodcock Reading Mastery Test-Revised Word Attack subtest. All t-tests based on 24 degrees of freedom, except Time 1 (degrees of freedom range from 77 to 110)

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3 Model results for all students' end-of-year (Time 2) outcomes

Fixed effects	Comprehension			Vocabulary			Composition			Spelling			Writing fluency		
	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*	Coeff	(*SE*)	*t*
Students' Time 2 (Endyear) Score, γ_{00}	519.0	(3.3)	157.3***	508.1	(3.4)	147.4***	3.4	(.1)	32.6***	24.2	(.5)	53.0***	16.8	(.5)	33.5***
Group, γ_{01}	22.2	(5.8)	3.9***	15.4	(3.8)	4.1***	.6	(.1)	5.0***	1.4	(.5)	2.6*	1.9	(.6)	2.9**
Linguistic KN, γ_{02}	1.4	(4.8)	.3	2.9	(2.7)	1.1	.4	(.1)	2.9**	.6	(.3)	2.1*	.5	(.5)	1.0
Grade, γ_{03}	2.1	(4.4)	.5	.9	(1.9)	.5	−.1	(.1)	−1.2	−.9	(.3)	−2.8**	.6	(.5)	1.3
Vocab Instr, γ_{04}	−2.7	(6.5)	−.4	3.7	(2.7)	1.4	.2	(.1)	1.8	.8	(.4)	2.1*	1.0	(.6)	1.7
Students' Time 1 Score, γ_{10}	55.5	(2.4)	22.7***	37.5	(2.2)	16.7***	.2	(.1)	3.2***	4.4	(.2)	19.1***	3.1	(.2)	14.5
Random effects	Var	(*SD*)	χ^2 (21)	Var	(*SD*)	χ^2 (21)	Var	(*SD*)	χ^2 (16)	Var	(*SD*)	χ^2 (21)	Var	(*SD*)	χ^2 (21)
Between-teachers (Endyear), U_0	94.1	(9.7)	50.9***	37.7	(6.1)	59.6***	.02	(.1)	31.9*	1.1	(1.0)	93.1***	1.5	(1.2)	85.9***
Residual, e	2163.5	(46.5)	–	634.8	(25.2)	–	.8	(.9)	–	9.5	(3.1)	–	14.1	(3.8)	–

Note: Student sample sizes varied by outcome (although all available data was used for $N = 718$ students in $N = 30$ classrooms: $n = 16$ intervention and $n = 14$ control). Students' Time 2 Score = scores after eight months of instruction; Group = teacher's group assignment (1 = Intervention, 0 = Control); Linguistic KN = teacher's end-of-summer-institute/fall linguistic knowledge; Grade = teacher's grade level taught; Vocab Instr = teacher's Empircal Bayes' estimates of midyear minutes spent on Vocabulary instruction; Students' Time 1 Score = scores after two months of instruction. All predictors except Group were group-mean centered prior to analysis. Comprehension = Gates-MacGinite Comprehension subtest (extended scale score); Vocabulary = Gates-MacGinite Vocabulary subtest (extended scale score); Composition = Narrative Development Composition (quality rating 1–5); Spelling = Weschler Intelligence Aptitude Test Spelling subtest; Writing Fluency = Woodcock-Johnson Writing Fluency subtest. All *t*-tests based on 25 degrees of freedom, except Time 1 (degrees of freedom range from 395 to 456)

* $p < .05$,** $p < .01$,*** $p < .001$

the multi-level models and therefore differ slightly from the observed scores reported in Table 1.) When we repeated the Time 1 analyses for all students, we found a significant group difference only for the Gates-MacGinitie Vocabulary subtest, $t\ (28) = 2.1$, $p < .05$. This difference amounted to an estimated intervention group advantage of 19.6 points in the extended scale scores ($SE = 9.2$), with intervention students averaging 493.5 points and control students averaging 473.9 points. No other reliable differences were detected at the Time 1 assessment. (Analyses of the larger sample were substantively the same irrespective of whether the lower performing students were included or excluded.). Finally, results of the analyses revealed reliable variation in student scores between classrooms across all measures, for both lower-performers and across all students (all ps $< .001$), indicating that students were significantly more similar to their classmates than to non-classmates after only two months of instruction (which supports our use of hierarchical modeling over unilevel modeling for these data).

Student assessments after eighth month of instruction

To analyze students' end-of-year (Time 2) assessments, which occurred after approximately eight months of instruction, we employed two-level ANCOVA-like hierarchical models. We used students' respective Time 1 assessment as a covariate to account for any group differences present at Time 1. (Note that inclusion of the Time 1 scores either controls for non-equivalent student abilities between groups prior to instruction, or it diminishes estimates of intervention effects that resulted from two months of instruction.) Teacher-level predictors employed in the student models included teacher group (1 = Intervention, 0 = Control), grade taught (3 through 5), and the two teacher outcomes that were significantly associated with group: linguistic knowledge scores and teachers' midyear vocabulary instruction time (model estimates described previously). We included these two teacher variables in order to test more accurately unique effects of condition and teacher knowledge on students' end-of-year performance. Except for group, all predictors were group-mean centered such that any effects detected would be independent of group. All effect sizes reported make use of Cohen's d, calculated as the difference between model-implied group means (or between the average score and +1 standard deviation) divided by the pooled standard deviation, which includes between-teacher variance and residuals.

Results for the lower-performing students from Time 2 analyses are summarized in Table 2, and results for all students are reported in Table 3. Random effects results show that significant between-classroom variation on lower-performing students' end-of-year scores was significant for many measures (ps $< .05$), and nearly significant (ps $< .10$) for all but one measure (again verifying the need for a multi-level approach). The exception was narrative composition. As was expected, Time 1 scores uniquely predicted end-of-year scores across nearly every outcome (all ps $< .001$), holding teacher group, linguistic knowledge, and vocabulary instruction time constant; the exception was narrative composition, for which there was a trend ($p < .10$).

Although the main focus of the study was lower-performing students, we were interested in whether the relationship between teacher knowledge and student learning generalized to all students. To answer this question, we repeated our ANCOVA-like analyses for all students (note that WRMT-R Word Identification and Word Attack were not administered to all students). Model results for all students, including the lower-performers, are largely consistent with the lower-performer models (see Table 3): Across all measures, students' Time 1 scores were uniquely predictive of end-of-year scores (all other things held constant); and for all measures, we found significant variation in students' end-of-year scores between classrooms (all $ps < .05$).

Unique effects of teacher group

More interestingly, teachers' group assignment uniquely predicted lower-performing students' end-of-year scores across all measures (all $ps < .05$), holding constant students' Time 1 scores and teachers' linguistic knowledge, grade taught, and vocabulary instruction time (see Table 2). Specifically, lower-performing students within intervention classrooms were estimated to have a 40.5-point advantage over peers in control classrooms on Gates-MacGinitie Comprehension ($d = .78$), an 18.5-point advantage on Gates-MacGinitie Vocabulary ($d = .69$), a .9-point

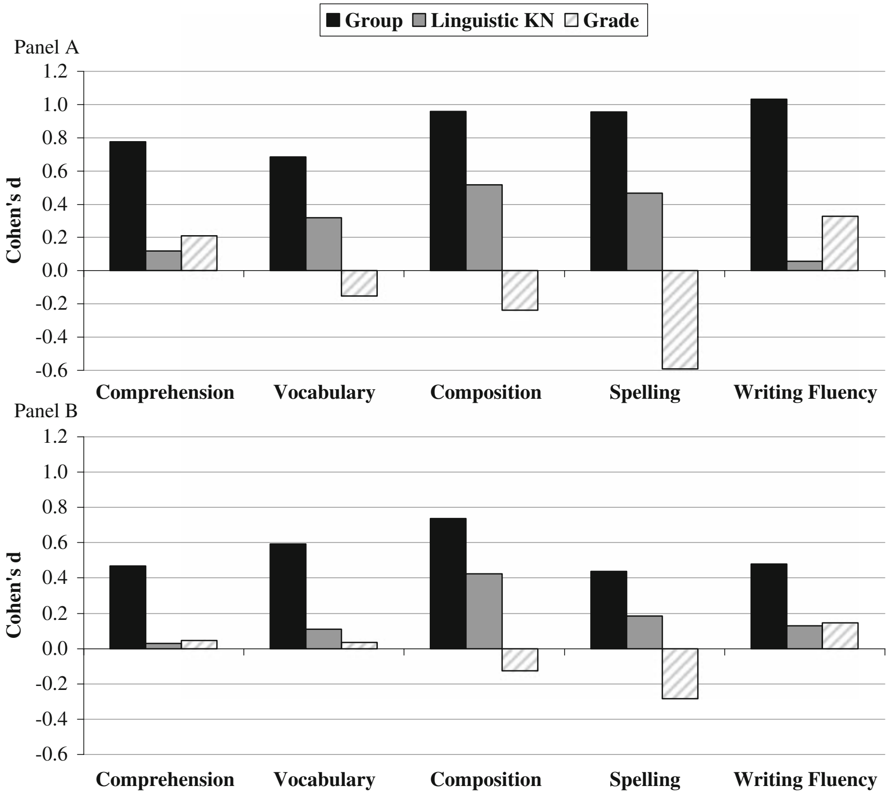

Fig. 1 Model-implied effect sizes (Cohen's d) for predictors, by outcome measure. *Panel A* = lower-performers; *Panel B* = all students

advantage on narrative composition ($d = .96$), a 2.7-point advantage on WIAT Spelling ($d = .96$), a 3.6-point advantage on WJ Writing Fluency ($d = 1.03$), a 4.8-point advantage on WRMT-R Word Identification ($d = 1.15$), and a 2.9-point advantage on WRMT-R Word Attack ($d = .64$). Effect sizes are graphed in Fig. 1, Panel A. (Note that the scores reported in Tables 2 and 3 are based on the model estimates and therefore differ slightly from the observed scores in Table 1.)

In the analysis of all students, we observed reliable, moderate group effects on students' end-of-year scores (all ps $< .05$), favoring students in intervention classes across all outcomes (see Table 3). Specific effect sizes were as follows (holding other variables constant): Gates-MacGinitie Comprehension $d = .47$, Gates-MacGinitie Vocabulary $d = .59$, narrative composition $d = .74$, WIAT Spelling $d = .44$, and WJ Writing Fluency $d = .48$. Effect sizes are graphed in Fig. 1, Panel B. (This pattern of significance was consistent when lower-performing students were removed from the analysis.)

Unique effects of teachers' linguistic knowledge

Holding group, grade, and vocabulary instruction constant, teachers' linguistic knowledge (i.e., teachers' scores on the Moats survey) uniquely predicted lower-performing students' end-of-year scores on Gates-MacGinitie Vocabulary, narrative composition, WIAT Spelling, and WRMT-R Word Attack (ps $< .05$; see Table 2). Specifically, students of teachers with deeper linguistic knowledge (scores one standard deviation above their group mean, regardless of group) were estimated to have an 8.7 point advantage on the Gates-MacGinitie Vocabulary ($d = .32$), compared with students of teachers scoring at their group mean. Likewise, students of teachers with deeper linguistic knowledge had an estimated .5-point advantage on narrative composition ($d = .52$), a 1.3-point advantage on WIAT Spelling ($d = .47$), and a 2.2-point advantage on WRMT-R Word Attack ($d = .50$). In addition, a similar trend was evident for WRMT-R Word Identification ($p < .10$, $d = .36$). No effects of teacher linguistic knowledge were evident for students' end-of-year Gates-MacGinitie Comprehension or WJ Writing Fluency scores.

For all students, the positive benefits of being in classrooms with teachers who had deeper linguistic knowledge (i.e., higher scores on the Moats survey) were consistent with, but smaller than, the benefits observed for lower-performing students on end-of-year narrative composition ($d = .42$) and WIAT Spelling ($d = .19$) scores (see Table 3). However, no positive effects of teachers' linguistic knowledge were evident in all students' end-of-year Gates-MacGinitie comprehension or vocabulary scores, or on WJ Writing fluency. (We note that when lower performing students are removed from the analysis, the effect of linguistic knowledge on spelling becomes non-significant ($d = .12$), although in the same direction.)

Unique effects of grade

Surprisingly, we found two unique negative effects due to grade level among the lower-performing students (see Table 2). After teacher group, linguistic knowledge, and vocabulary instruction time are accounted for, the performance of older students was estimated to be slightly (.2 points on a five point scale) lower than that of younger students on end-of-year narrative composition ($d = -.24$) and 1.7 points lower on the 40 item WIAT Spelling assessment ($d = -.59$). One explanation for this finding may be that reading difficulties develop into larger writing difficulties as children get older and fall further behind their peers.

In the analysis of all students (see Table 3), grade level had a small but significant negative effect on students' end-of-year WIAT Spelling (approximately one fewer word spelled correctly out of 40, $d = -.28$), similar to the finding with lower-performer students. No other effects of grade were significant. (Results are similar when lower-performing students are excluded from the analysis.)

Unique effects of instructional time

Results showed that time spent on vocabulary instruction was uniquely predictive of lower-performing students' end-of-year WIAT spelling only. Specifically, students of teachers who allocated one standard deviation more time to vocabulary instruction were estimated to have an end-of- year performance of 22.4 words spelled correctly compared with 20.2 words for students whose teachers spent an average amount of time on vocabulary (given their group assignment), $d = .76$. (Again, overall allocation of time to vocabulary instruction was low in both groups, and we discuss this variable primarily because it was included in the model.) Teachers' time allotted to vocabulary instruction also had small but positive benefits for all students in end-of-year WIAT spelling scores ($d = .26$), holding other predictors constant; however when lower performing students are removed from the analysis, the effect is non-significant but in the same direction ($d = .15$).

Discussion

Given the current emphasis on accountability, we consider it important that studies of teacher knowledge include outcomes of student learning. In the study described here, we worked with teachers to deepen their knowledge in areas we know are important for effective reading instruction—for example, knowledge of relationships between phonology, orthography, and morphology; knowledge of developmental sequences in children's metalinguistic skills; knowledge of explicit strategy instruction in comprehension and writing—and we continually embedded into our discussions examples of student work and classroom practice. We then followed teachers back to their classrooms and examined student learning across the year.

Despite the fact that we documented no theoretically compelling evidence for a causal relationship between allocation of instructional time and student learning, we did observe a relationship between teacher knowledge and student learning. The model of lower performing students showed significant and sizable group effects (Intervention over Control) for all of the literacy measures (comprehension, vocabulary, word and nonword reading, spelling, and composition, with average effect size $d = .89$) even with Time 1 performance taken into account. Although the average effect size was smaller in the classroom-wide analyses ($d = .54$), students in intervention classrooms again outperformed their peers in control classrooms. Thus, lower-performing students benefited more from their teachers' involvement in our intervention, but the intervention had some positive effects on student outcomes overall.

Moreover, teachers' linguistic knowledge had a specific, measurable effect on the achievement of lower-performing students. Teachers within both the intervention and control groups varied considerably in their linguistic knowledge (as measured by the Moats survey), and regardless of group, lower-performing students in classrooms with higher knowledge teachers significantly outperformed their peers on measures of vocabulary, composition, spelling, and nonword reading, with a similar but non-significant trend evident for real word reading. Such a finding is consistent with the interpretation that deeper linguistic knowledge enables teachers to intervene more effectively with struggling students' decoding and spelling, which may influence other higher-level literacy skills. Certainly, skilled decoding is not sufficient to ensure comprehension, but comprehension is difficult when decoding skills are poor. Similarly, improvements in spelling skill could have contributed to increased composition scores (reflecting more complex texts) in a number of ways, not the least of which being students' willingness to write more. (Correlations between text length and text quality tend to be positive with young children (Bereiter & Scardamalia, 1987).) It is worth noting that writing skill was the area in which we saw negative effects associated with grade, in that older struggling readers performed more poorly on measures of spelling and composition than their younger counterparts. Thus, over time, we might hope that teachers with deeper linguistic knowledge can intervene to prevent reading difficulties from escalating into larger writing difficulties.

Limitations

Although we statistically controlled for Time 1 differences in our analyses of end-of-year student learning outcomes, we did observe some differences between intervention and control classrooms at the initial assessment (Time 1), after only two months of instruction. Such early-appearing differences leave open the question of exactly how, and when, intervention teachers contributed to student learning outcomes. It may be that two months of instruction had already begun to affect student learning in intervention classes, but we cannot identify the specific mechanisms. We did document that the summer institute increased intervention teachers' linguistic knowledge, and we hope we deepened their knowledge of other aspects of literacy instruction. Because most intervention schools housed two or more participating teachers, the summer institute also provided intervention teachers an opportunity to share experiences with colleagues around their literacy instruction and reflect collaboratively on their practice. Thus, we cannot be sure whether the intervention effects on student learning can be attributed solely to information learned during the summer institute by individual teachers, or whether the observed effects are also due in part to a more collaborative climate within intervention schools that focused on the needs of students.

In several instances we compromised features of the experimental design to accommodate the practicalities of long-term classroom-based research. For example, classroom observers were not blind to teachers' group assignment, because they had worked with intervention teachers in the summer institute, in their classrooms and in follow-up sessions, building trust around issues of knowledge and practice. Still, the levels of inter-rater reliability we documented across coders may alleviate concern over rampant coding biases due to personal loyalties. Classrooms visits for assessments, consultations, and observations were also prescheduled with teachers in both conditions, raising the possibilities that the activities we observed were not necessarily typical of daily instruction. Since the observation data played only a minor role in the present analyses, issues of the representativeness of the observation data have little bearing on interpretation of student outcomes. Such compromises are frequently encountered, and are sometimes even part of the design, in work with teachers and classrooms (Brown, 1992).

We must also acknowledge that our observations were limited to brief time periods at only three occasions, and due to their brevity (among other factors) we were unable to make theoretically compelling links between teacher knowledge, instructional practice and student learning. It was heartening to see that students of teachers in our intervention scored higher on all of our literacy measures, but inferences about causal links between teacher knowledge, teacher practice and student learning in the upper elementary grades remain an area for future research. It is already clear, however, that such research will require considerable investment in observational time and precision.

Finally, we should note that teachers volunteered to take part in the present study, as well as in our previous intervention (McCutchen et al., 2002a). Not every teacher may be so willing to welcome university researchers into the classroom for an entire year; thus, results of our intervention may not generalize to teachers for whom similar professional development is mandated.

Conclusions

Our findings add to the mounting evidence indicating that there is a disciplinary knowledge base required for the effective teaching of reading and deeper teacher knowledge is related to improved student learning. However, providing persuasive evidence supporting causal links from teacher knowledge to teacher practice and student learning will require more extensive classroom observations than those entailed in the present study. Despite the limited success of the present study in providing such evidence, we advocate that such evidentiary links should be explored in future teacher-knowledge research. We have considerable work ahead to meet the instructional needs of all students, but skilled and knowledgeable teachers will be some of our best allies in that effort.

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Appendix

Informal Survey of Linguistic Knowledge (from Moats, 1994)

1. From the list below, find an example of each of the following:

   inflected verb ______________________
   compound noun ______________________
   bound root ______________________
   derivational suffix ______________________

   scarecrow nameless terrible phonograph

   impeached tables weakly

2. For each word on the left, determine the number of syllables and the number of morphemes:

   salamander
   crocodile
   attached
   unbelievable
   finger
   pies
   gardener
   psychometrics

3. How many speech sounds are in the following words?

   ox
   boil
   king
   thank
   straight
   shout
   though
   precious

4. What is the third speech sound in each of the following words?

   boyfriend prayer
   thankyou higher
   educate witchcraft
   stood badger

5. Underline the schwa vowels:

   About melody sofa effect difficult definition

6. Underline the consonant blends:

   Doubt known first pumpkin squawk scratch

7. Underline the consonant digraphs:

    wholesale psychic doubt wrap daughter think

8. When is a "ck" used in spelling?
9. What letters signal that a "g" is pronounced /j/?
10. List all the ways you can think of to spell "long a":
11. List all the ways you can think of to spell /k/: *)*
12. What are six common syllable types in English?
13. When adding a suffix to a word ending with "y", what is the rule?
14. How can you recognize a word of Greek origin?
15. Account for the double "m" in *comment* or *commitment*

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