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Morphological analysis skill and academic vocabulary knowledge are malleable through intervention and may contribute to reading comprehension for multilingual adolescents

Amy C. Crosson

Department of Curriculum and Instruction, College of Education, Pennsylvania State University, University Park, State College, Pennsylvania 16802, USA

Margaret G. McKeown

Learning Research and Development Center, University of Pittsburgh, 3939 O'Hara Street, Pittsburgh, Pennsylvania 15260, USA

Puiwa Lei

Department of Educational Psychology, Counseling and Special Education, College of Education, Pennsylvania State University, University Park, State College, Pennsylvania 16802, USA

Hui Zhao

Department of Educational Psychology, Counseling and Special Education, College of Education, Pennsylvania State University, University Park, State College, Pennsylvania 16802, USA

Xinyue Li

Department of Educational Psychology, Counseling and Special Education, College of Education, Pennsylvania State University, University Park, State College, Pennsylvania 16802, USA

Kelly Patrick

College of Education, University of Utah Reading Clinic, 5242 College Drive, Murray, Utah 84123, USA

Kathleen Brown

College of Education, University of Utah Reading Clinic, 5242 College Drive, Murray, Utah 84123, USA

Yaqi Shen

Department of Curriculum and Instruction, College of Education, Pennsylvania State University, University Park, State College, Pennsylvania 16802, USA

Background: Morphological analysis skill is the ability to problem-solve meanings of unfamiliar words by applying knowledge of morphological constituents. For vocabulary words from the academic layer of English, the major, meaning-carrying morphological contituents are Latin roots (*nov* meaning 'new' in *innovative*). The degree to which morphological analysis skill using Latin roots is susceptible to intervention and whether improvements relate to reading comprehension remains unclear.
Methods: We investigated the effects of a morphology intervention designed to promote academic vocabulary learning, morphological analysis and reading comprehension with 140 adolescent, multilingual learners in US schools (intervention $n = 70$; comparison $n = 70$). We estimated direct effects of the intervention on morphological analysis and academic vocabulary knowledge and examined whether they mediate intervention effects on reading comprehension. Academic vocabulary was measured as both definitional and multidimensional knowledge.
Results: We found significant, direct effects of the intervention on morphological analysis skill and academic vocabulary knowledge. Additionally, we found a significant indirect effect on reading comprehension via academic vocabulary and a marginally significant indirect effect via morphological analysis skill. Notably, the indirect effect of academic vocabulary was evident only for multidimensional, not definitional knowledge.
Conclusions: Findings extend current understanding about how morphology intervention promotes vocabulary and reading comprehension improvement for multilingual learners.
(word count = 207)

Keywords: literacy intervention, morphology, multilingual learners, reading comprehension, vocabulary

Highlights

What is already known about this topic

- The ability to figure out word meanings through morphological analysis relates to improvements in vocabulary knowledge. Studies have focused on prefixes and suffixes. However, the main meaning-carrying components of vocabulary words from the academic layer of English are Latin roots (*min* meaning 'small' in *diminish*).
- Much less is known about whether carefully designed interventions focused on Latin roots can affect morphological analysis skill, academic vocabulary knowledge and, in turn, reading comprehension.

What this paper adds

- Intervention can improve multilingual learners' ability to improve vocabulary through analysis of morphological relations using Latin roots (e.g., *min* in *diminish*, *miniscule* and *minor*).

- Intervention may have indirect effects on reading comprehension through morphological analysis and improved academic vocabulary knowledge.
- Both definitional and multidimensional vocabulary knowledge are improved through intervention, but only multidimensional knowledge relates to improvements in comprehension.

Implications for theory, policy or practice

- Morphology intervention benefits multilingual adolescents by promoting vocabulary knowledge and morphological analysis skill.
- Improvements in multidimensional vocabulary knowledge and morphological analysis may contribute to supporting reading comprehension.

Reading comprehension is a notoriously complex and knotty construct. It is influenced by multiple sources of variation at the level of text, activity and purpose for reading (RAND Reading Study Group 2002), as well as by individual skills related to knowledge of the linguistic system, general knowledge and word-level processes (Perfetti & Stafura 2014). Within this complex picture, vocabulary knowledge is recognised as the lynchpin of reading comprehension, the 'central connection point between the word identification system and the comprehension system' (Perfetti & Stafura 2014, p. 24). The critical role of vocabulary knowledge in reading comprehension has been well-documented in studies showing that it is a key determinant of reading comprehension (Cromley & Azevedo 2007; Perfetti 2017).

The role of vocabulary knowledge in reading comprehension is especially consequential for multilingual learners who are learning to read in a second language (L2) in which they are still developing proficiency. While it is clear that multilingualism is an asset associated with economic, social and cognitive benefits (Kroll & Dussias 2016), minoritised multilingual learners often face obstacles in L2 reading development. A major obstacle is L2 vocabulary knowledge (Carlo et al. 2004; Lesaux et al. 2010; Proctor et al. 2005; Reed et al. 2016), which is associated with reading comprehension difficulties (Mancilla-Martínez & Lesaux 2010; Verhoeven et al. 2019). Thus, interventions to accelerate vocabulary learning and improve reading outcomes are urgently needed.

One promising avenue for supporting vocabulary learning to improve reading comprehension is through instruction that incorporates attention to morphological relations. English is a morphologically rich language, comprising inflectional and derivational morphemes, free-standing root or base words and bound Latin roots. Starting in the elementary grades, much growth in word knowledge is driven by understanding derivational relations (Anglin 1993; Berninger et al. 2010), such as the relation between *speak* and *unspeakable*. However, in adolescence, the challenge shifts to learning general academic words that are ubiquitous in secondary school texts across content areas, such as *diminish* or *regulate* (Coxhead 2000; Gardner & Davies 2013). These words are from the Latinate layer of English. Latin-based roots such as *min*, meaning 'small,' and *reg*, meaning 'rule' are the main meaning-carriers for academic words.

In this study, we investigated the effects of an intervention, *English Learners' Robust Academic Vocabulary Encounters* (EL RAVE), on multilingual learners' vocabulary learning, morphological analysis skill and reading comprehension outcomes. We were

interested in direct effects of the intervention on both vocabulary learning and students' ability to use Latin-based morphemes to problem-solve unfamiliar words. The ultimate goal of the intervention was to improve comprehension; thus, we also were interested in direct and indirect effects on reading comprehension.

Theoretical framework

We situate our study within two theoretical perspectives that model how morphology may relate to vocabulary knowledge and reading comprehension. First, our study draws on Schreuder and Baayen's (1995) framework, which suggests a mechanism by which morphological processing leads to vocabulary learning. The model proposes that over the course of multiple encounters, learners develop connections between orthographic strings and their corresponding meanings, forming representations of morphemes in memory. These representations are called 'concept nodes' in the model. Each time a morpheme is encountered, the strength of the representation increases and accumulates additional semantic information. For example, when the morpheme *min* is encountered in multiple words such as *minimise* and *minor*, a concept node for *min* may be created, with its meaning becoming increasingly specified and robust with each encounter. Accordingly, when an unfamiliar morphologically complex word is encountered, the learner may activate relevant concept nodes to hypothesise how morphemes might be combined to infer word meaning.

Second, our study is guided by the Reading Systems Framework articulated by Perfetti and Stafura (2014), which is 'wide-angle view of reading comprehension' (p. 21) that places vocabulary knowledge as the center connection between systems, or sets of processes, for word identification and comprehension. As Deacon et al. (2017) have noted, morphology plays an important role in this complex framework, serving both as a component of vocabulary knowledge and also as one of the linguistic knowledge sources that feeds into the processes of comprehension. Thus, instruction in morphology may affect comprehension indirectly via word-level processes that facilitate the rapid, efficient recognition of individual word form and meaning essential to reading comprehension, and also may support reading comprehension directly as a more general linguistic knowledge source (Perfetti & Stafura 2014; Stafura & Perfetti 2017).

How might morphological interventions support vocabulary and reading comprehension improvement?

It is well known that morphological processing and vocabulary knowledge are highly correlated and convergent evidence shows that morphology intervention can improve vocabulary knowledge. A meta-analysis of 22 morphological intervention studies of students in preschool through eighth grade by Bowers et al. (2010) revealed, on average, a moderate treatment effect on vocabulary. However, these studies were conducted with native English speakers and only three investigated Latin roots as morphological components of interest. Yet multilingual learners clearly stand to benefit from morphology instruction, and a focus on academic vocabulary may be especially beneficial.

Growing evidence points to the potential for instruction that moves beyond awareness of morphological relationships to *morphological analysis* skill for problem-solving meanings of unfamiliar words. Following Nagy et al. (2014), we define morphological analysis as the

use of explicit knowledge about morphemes to infer meanings of new morphologically complex words that contain learned morphemes. It is possible that learners employ morphological analysis without conscious attention to analysing morphological constituents (Kim et al. 2019; Nagy 2007), but some of this effort may be carried out deliberately and explicitly. For instance, a learner may seek familiar morphological constituents to infer meaning of unfamiliar words when reading. Recent evidence suggests that, in the absence of intervention, morphological analysis is associated with reading comprehension (McCutchen & Logan 2011) and has been found to predict reading comprehension improvements among English-speaking students in the upper elementary grades (Levesque et al. 2019). Critically, emerging evidence suggests that instruction about Latin roots may improve vocabulary knowledge for English-speaking monolingual learners (Crosson & McKeown 2016; Bowers & Kirby 2010) and, more importantly, for multilingual learners (Crosson & Moore 2017; Crosso, McKeown, Moore & Ye, 2019; Goodwin 2016; Pacheco & Goodwin 2013). However, whether such interventions affect comprehension outcomes remains unclear.

Definitional versus multidimensional vocabulary knowledge

If morphological analysis is to improve vocabulary knowledge and promote reading comprehension, an important consideration is how 'vocabulary knowledge' is defined. It is clear that breadth and depth of vocabulary knowledge are highly correlated constructs, with skilled comprehenders knowing more words and also knowing more about words in their lexicons (McKeownet al. 2017). However, breadth and depth each explain unique variance in reading comprehension (Swart et al. 2017). There is evidence that knowledge of definitions does not produce the kind of word knowledge to support comprehension. Rather the need is for deep, *multidimensional* knowledge that includes understanding various senses of a word, use in different contexts, associated words and features such as syntax and morphology, compared with surface-level (i.e., *definitional*) knowledge (Li & Kirby 2012; Ouellette 2006). Whether integrated academic vocabulary and morphology instruction leads to such definitional knowledge or deep, multidimensional knowledge (Crosson, McKeown & Ward 2019) will likely hold consequences for reading comprehension.

Effects on reading comprehension

Decades of vocabulary research attest that it is notoriously difficult to show a direct impact on reading comprehension of even relatively long-term literacy interventions. Elleman et al.'s (2009) review of vocabulary interventions found that the average effect size on reading comprehension, as measured by standardised assessments, was small and nonsignificant. This may seem surprising given the strong relationship of vocabulary and reading comprehension. Difficulty in detecting influence involves numerous factors, key among them the kind of word knowledge required to influence comprehension (definitional versus multidimensional), and how evidence of that influence might be manifested. Consensus has developed that word knowledge is complex and that knowledge of words, beyond definitions or use in prototypical contexts, is required for reading comprehension. Morphology is one aspect of language that researchers have suggested adding to instruction. However, for morphology interventions, a similar picture emerges. For example, Goodwin and

Ahn (2013) also reviewed morphology interventions, echoing Bowers et al.'s (2010) earlier finding of no significant impact on reading comprehension.

Regarding how the impact of interventions on reading comprehension is manifested, an immediate, direct impact is possible though unlikely. Underlying issues include the complexity of reading comprehension processes and the number of words that may needed to be mastered for successful comprehension. Thus, one possibility for exploration of impact on reading comprehension may be to examine effects indirectly.

Present study

In this study, we tested the direct effects of a morphology intervention, EL RAVE on vocabulary knowledge and morphological analysis skill. As a secondary goal, we estimated indirect effects of EL RAVE through vocabulary knowledge and morphological analysis on reading comprehension. The research questions were as follows:

1 What are the treatment effects of EL RAVE on multilingual learners' vocabulary knowledge, both definitional and multidimensional, on academic word meanings?
2 What are the treatment effects of EL RAVE on multilingual learners' morphological analysis skill?
3 Do vocabulary knowledge (definitional and multidimensional) and morphological analysis skill mediate the impact of EL RAVE on reading comprehension?

Method

Participants

Participants were 169 multilingual seventh and eighth grade students in one middle school in an urban district in the southwestern United States. We employed a randomised block design with 10 classes by subject (English Language Development or English Language Arts) and teacher. Within blocks, classes were randomly assigned to the intervention (n = 5) or comparison (n = 5) condition. All students who were enrolled in participating classes within the first 8 weeks of school participated in the study. Over the course of the intervention, 29 students moved out of participating classes and, consequently, withdrew from the study.1 In total, 70 students participated in the intervention, and 70 students participated in the comparison condition.

At this school, 88% of students were eligible for free or reduced lunch. Approximately, 84% reported that they were born in the United States, 19% had attended school in another country and 63% could read in their home language (L1). When students were asked to identify L1s spoken at home, 74% reported Spanish. Other languages included Tongan, Bosnian, Karen, Somali, Urdu and Vietnamese.

Intervention

English Learners' Robust Academic Vocabulary Encounters was a long-term, multicomponential intervention in which students received daily 15-minute lessons over the course of the school year (80 lessons). EL RAVE integrated robust vocabulary instruction of general academic words (McKeown et al. 2018) with instruction in morphological analysis using Latin roots. Robust vocabulary instruction was intended to build rich

representations of word meanings and flexible use of words based on active use of words in multiple, varied contexts. Morphological instruction was designed to instill understanding of morphological patterns and to promote the ability to apply patterns of morphological relationships to access word meaning through morphological problem-solving. Thus, instruction targeted development of high-quality representations of individual words and generative aspects of word meaning that promote networks of connections among words.

Word and root selection. Sixty words were selected from the 570 headwords on the Academic Word List (Coxhead 2000) and the Academic Vocabulary List (Gardner & Davies 2013). The Academic Word List and Academic Vocabulary List corpora were selected sources of words that are high frequency in academic texts and dispersed across disciplines. For this study, we sought target words that carried Latin-based morphemes that were high frequency in English (Becker et al. 1980) to ensure that they would be useful for learning semantic-related groups of words sharing the Latin roots. Table 1 presents target words with word statistics in a sample unit.

Instruction. The intervention featured analysis of target academic words in multiple, authentic contexts and active processing of word meanings, such as analysing examples of word use, producing examples, justifying use and discussing nuances of meaning. Interventions that have similarly reflected principles of robust instruction have been associated with positive treatment effects on word learning with multilingual adolescents (Crosson & Moore 2017; Crosso, McKeown, Moore & Ye, 2019; Carlo et al. 2004; Lesaux et al. 2010).

Morphological analysis focused on bound Latin roots, such as *reg*, meaning 'rule,' in *regulate*, as distinct from morphologically complex words that contain root words that are freestanding morphemes (e.g., *use* from *reusable*) or derivations (e.g., *accumulation* from *accumulate*). A Latin root (or, in four cases, a prefix) was taught for all target academic words. Instruction about Latin roots was incorporated into every lesson and emphasised both analysis of relationships between root meaning and the target academic

TABLE 1. Word statistics for target words and roots taught in a sample English Learners' Robust Academic Vocabulary Encounters unit

Word	Word freq	Root	Root meaning	Root freq	Related words analysed during intervention
ac*cum*ulate	47.2	CUM	pile up	6	cumulative, cumbersome
di*min*ish	42	MIN	small/less	17	minuscule, minimal
*grad*ual	48.7	GRAD	step	20	upgrade, degrading
*trans*mit	48.7	TRANS	across	59	transfer, translate
*cap*acity	54.3	CAP	take in	12	captivate, captive
ex*tract*	45.2	TRACT	drag	49	protracted, traction
com*pens*ate	43.8	PENS	weigh	20	pensive, suspense
*reg*ulate	50.9	REG	rule	24	regimen, regime

Word freq = Standard Frequency Index score (log transformation of 'U-score' of frequency and dispersion across written English corpus of over 17 million tokens) from *Educator's Word Frequency Guide* (Zeno et al. 1995); Root freq = frequency of morphograph in Becker's corpus (Becker et al. 1980) based on analysis of the 26,000 highest frequency words in English.

word in which it appeared (e.g., the relation between *reg* and *regulate*) and analysis of relations between root meaning and other 'root-related words' in which it appeared (e.g., *reg* in *regimen*, *regal* and *regime*).

Table 2 presents an example of the sequence of lesson content and activities in a typical instructional unit. Instruction was whole-group and teacher-led. Presentation and usage of target words and roots included both oral and written forms, with instruction to draw students' attention to roots within target word (e.g., 'draw a box around "reg" in regimen and an arrow from the root's meaning to the boxed root'). The intervention was designed to be an 'educative curriculum' such that teacher supports to understand the purpose and recommended enactment of each lesson was built into the materials See Crosson, McKeown, Robbins and Brown (2019) for detailed information about the design principles of the intervention and see website, https://sites.psu.edu/elrave/ for examples of instructional materials.

Fidelity to treatment

Intervention fidelity was estimated though transcript analysis. Following McKeon, Beck and Blake (2009), we analysed transcripts of a sample of 15% of lessons to examine whether the teachers implemented the lessons as designed and to ensure consistency in implementation across teachers and classes. First, we created a set of fidelity of implementation checklists for 13 lessons sampled to represent the beginning, middle and end of the intervention. To create checklists, scripted lesson materials were analysed to identify key instructional components, including teacher questions, explanations and examples related to use of target word or Latin root meanings. Each key instructional component was

TABLE 2. Example sequence of English Learners' Robust Academic Vocabulary Encounters activities during one instructional unit

Lesson	Content
1	Introduce two target words and integrate meanings with multiple contexts that are presented in written form along with a friendly definition; introduce two target roots; analyse relation between root meaning and target word meaning (e.g., if we know the root 'reg' means 'rule,' how does that help us understand the meaning of *regulate*?); use root meaning to analyse new morphologically-related words (e.g., *regime* in a context about a cruel regime that took over by force, students are asked to consider the context and the meaning of the root to infer the meaning of the morphologically-related word.).
2	Introduce two additional target words and roots, following instructional practices similar to Lesson 1.
3	Integrate target word meanings with new, varied contexts. Active processing of target words by contrasting word meanings, generating new examples, etc.; analyse new morphologically related words that share the Latin roots of target words.
4	Analyse contexts with extended passages (e.g., based on content from *New York Times*) that carry all target words; analyse new morphologically-related words that share the target words' Latin roots.
5–8	Follow sequence of instruction from Lessons 1–4, but with four new target words, four new target roots, and multiple morphologically related words for analysis.
9	Analyse similarities of morphologically related words across semantic sets; integrate meaning of target words with new contexts; active processing of all target words; build fluency of access to root meanings; assess knowledge of target words and roots.

included as an item with approximately 40 items per lesson checklist. We report the average percentage of key instructional components from the scripted teacher materials implemented in the intervention group. Overall, fidelity in the five intervention classes ranged from 82.10% to 95.14%. Average fidelity was 90.11%. To check interrater reliability, 12 lessons were coded by two members of the research team yielding 93.86% exact agreement.

Comparison condition

Students in the comparison group received 'business as usual' instruction. All teachers reported at the close of the study that they did not teach Latin or Greek roots in comparison classes. Observations by the research team carried out three times for each class over the course of the study confirmed no instruction about Latin roots. In two classes, teachers reported morphology instruction about prefixes and suffixes but described this instruction as infrequent.

Measures

Measures included researcher-designed and standardised assessments. All tasks unless otherwise noted were administered to whole groups by a research team member.

Definitional vocabulary knowledge. Administered at pretest and posttest, this task assesses surface-level, definitional knowledge of target words. Students matched target words to synonyms or short definitions in sets of eight. The measure exhibited acceptable internal consistency (Cronbach's $\alpha 2 = 0.92$).

Multidimensional vocabulary knowledge. The Evaluation of Academic Vocabulary (Crosson, McKeown & Ward 2019) task was administered at pretest and posttest. This task evaluates multidimensional knowledge of 37 target words by assessing syntactic and semantic aspects of word knowledge. For each target academic word, two pairs of sentences are presented. Each pair presents a plausible and implausible use of the target word; students choose which one makes sense. One pair represents a syntactic violation of word use (e.g., for *priority*: 'Jenna likes to priority when she cleans her room.') and the other a semantic violation (e.g., 'Maria wanted to win top *priority* in the essay contest.'). It exhibited acceptable internal consistency (Cronbach's $\alpha = 0.90$).

Morphological analysis task. Administered at pretest and posttest, morphological analysis task assesses students' ability to use an instructed root to infer the meaning of a novel, unfamiliar word. This task includes 25 rare words that were not taught but contain bound roots that had been taught in the intervention. An example is, 'The stadium was *desolate*.' The target word *isolate* and the root *sol* ('alone') were taught, but the novel word, *desolate*, was not taught. Four choices were presented (empty, locked, dirty and crowded). Students with knowledge of the root meanings and who developed morphological analysis skill can use the root to infer meaning of the novel word and arrive at the correct response ('empty'). Novel words were selected to be unfamiliar to students by consulting the Zeno word frequency list (Zeno et al. 1995). The measure exhibited moderate internal consistency (Cronbach's $\alpha = 0.70$).

Reading comprehension. At pretest, the district administered a standardised task, the Scholastic Reading Inventory (SRI/Scholastic Inc. 2007), which reports Lexile levels. Marginal reliability is reported as a measure of internal consistency at 0.94 (SRI/Scholastic Inc. 2014). At posttest, a researcher-designed measure assessing the same construct was administered. Here, four informational passages of approximately 150 words are were presented, with each passage containing five target words. Multiple choice questions test ability to integrate word meaning with context. Internal consistency was acceptable (Cronbach's $\alpha = 0.79$).

Home language and school experiences survey. This survey was administered at pretest to collect information about students' L1s, other languages spoken, schooling experiences outside the United States and language use preferences.

Analytic approach

Preliminary analysis. All participants were included in the analysis. Independent *t*-tests indicated no significant difference between the EL RAVE and comparison groups at the class level on baseline multidimensional vocabulary ($t = -1.38$, $df = 8$, $p = .23$, $ES3 = 0.33$), definitional vocabulary ($t = -1.16$, $df = 8$, $p = .28$, $ES = 0.30$) and reading comprehension ($t = -0.81$, $df = 8$, $p = .44$, $ES = 0.22$). However, the comparison group scored significantly higher than the EL RAVE group at the class level on pretest of Morphological Analysis ($t = -3.30$, $df = 8$, $p = .01$, $ES = 0.50$). Although these levels of baseline imbalance do not meet What Works Clearinghouse's (https://ies.ed.gov/ncee/wwc/) standard, they were considered acceptable for inclusion in best evidence syntheses of interventions (Cheung et al. 2017; Cheung & Slavin 2016). Pretest differences were adjusted for in the estimates of treatment effects by allowing each of the posttests to regress on all pretests in addition to treatment condition (much like analysis of covariance). As such, coefficients for treatment condition represent adjusted treatment group mean differences with all pretest scores held constant or adjusted to be the same between groups.

Less than 3% of cases were missing for each measure. Results from Little's MCAR Test indicated that missing cases were completely at random ($\chi^2 = 38.265$, $df = 53$, $p = .936$). We used raw scores from all measures except we standardised scores for reading comprehension at pretest and posttest to ensure scale consistency across assessments. Data screening suggested mild deviations from univariate normality ($|\text{skewness}| < 1$ and$|\text{kurtosis}| < 10$) for all measures.

Mediation models. We employed the approach recommended by Cole and Maxwell (2003) to estimate indirect effects from the half-longitudinal design. This half-longitudinal mediation model allows us to estimate direct effects of the intervention on definitional vocabulary knowledge, multidimensional vocabulary knowledge and morphological analysis skill. Our secondary goal was to explore if definitional and multidimensional word knowledge, and morphological analysis skill, mediated the hypothesised relationship between treatment and reading comprehension. An advantage of this model over cross-sectional models is that hypothetical causes always occur before outcomes. By collecting data on more than one occasion, the half longitudinal mediation model can satisfy the time precedence requirement for causal inference and thus provide stronger evidence for a causal relationship;

it also takes prior levels of the outcome into consideration to allow for more rigorous inferences (Cole & Maxwell 2003).

Mplus 8.2 (Muthén & Muthén, 2017) was used to conduct the path analysis of the hypothesised mediation model. Due to mild non-normality and missing data found in the data screening, multiple linear regression was applied because it uses full-information maximum likelihood estimation to deal with missing data and provides robust standard errors (Kline 2016). To take into account the dependence of students nested within teachers, we specified "TYPE = COMPLEX" in the analysis and treated classes as clusters (Muthén & Muthén 2017). This approach with multiple linear regression is expected to provide less biased standard error estimates and χ^2-square test statistics when data are obtained by stratification and cluster sampling (Asparouhov & Muthén 2006).

Results

Table 3 presents the class-level and student-level descriptive statistics for all pretests and posttests for both conditions. Students in the treatment group showed greater gains across

TABLE 3. Descriptive statistics for definitional and multidimensional vocabulary knowledge, morphological analysis and reading comprehension

Variable			Treatment				Comparison		
	Range	*n*	Pretest Mean (*SD*)	*n*	Posttest Mean (*SD*)	*n*	Pretest Mean (*SD*)	*n*	Posttest Mean (*SD*)
Class level									
Multidimensional vocab	0–74	5	45.54 (5.26)	5	56.35 (5.73)	5	48.88 (1.29)	5	56.22 (2.68)
Definitional vocab	0–40	5	12.17 (3.36)	5	19.77 (4.59)	5	14.27 (2.32)	5	17.78 (2.97)
Morphological analysis	0–25	5	8.59 (0.76)	5	11.17 (2.26)	5	10.17 (0.75)	5	11.18 (1.40)
Reading comp		5	−0.10 (0.32)	5	−0.11 (0.33)	5	0.12 (0.50)	5	0.13 (0.49)
Student level									
Multidimensional vocab	0–74	70	44.86 (10.10)	68	56.13 (11.60)	70	48.76 (10.17)	69	56.17 (10.18)
Definitional vocab	0–40	70	12.00 (6.43)	69	19.42 (9.84)	69	14.54 (7.64)	69	18.09 (9.16)
Morphological analysis	0–25	70	8.53 (2.64)	68	11.10 (4.52)	70	10.13 (3.58)	70	11.09 (3.83)
Reading comp		70	−0.14 (0.82)	68	−0.12 (0.95)	69	0.14 (1.15)	70	0.12 (1.04)

[·]Reading comp = reading comprehension; Scholastic Reading Inventory (SRI/Scholastic Inc. 2007) at pretest and researcher-designed test at posttest; *z*-scores (standardised across treatment groups by measure) were used to ensure scale comparability and facilitate interpretation.

TABLE 4. Correlations of pretest and posttest outcomes (N = 140)

Variable	1	2	3	4	5	6	7	8
1. Morphological analysis pre	–							
2. Multidimensional vocab pre	.52**	–						
3. Definitional vocab pre	.53**	.62**	–					
4. Passage comprehension pre	.45**	.51**	.59**	–				
5. Morphological analysis post	.56**	.51**	.53**	.40**	–			
6. Multidimensional vocab post	.45**	.65**	.59**	.65**	.66**	–		
7. Definitional vocab post	.42**	.65**	.67**	.51**	.65**	.77**	–	
8. Passage comprehension post	.46**	.60**	.48**	.64**	.59**	.75**	.59**	–

*$p < .05$, two-tailed.
**$p < .01$, two-tailed.
***$p < .001$, two-tailed.

time for all measures compared with their control group peers. Table 4 presents correlations of all measures. Positive and significant correlations were found between all pairs.

Model evaluation

To control for baseline differences in all measures, we estimated a saturated model in which every exogenous variable at pretest predicted every endogenous variable at posttest (Figure 1). As such, the model had perfect goodness-of-fit statistics. *R*-squares for posttests of morphological analysis (R^2 = 0.44), definitional vocabulary (R^2 = 0.60), multidimensional vocabulary (R^2 = 0.61) and reading comprehension (R^2 = 0.52) were considered large. That is, treatment condition and pretests accounted for 44% to 61% of the total variance in the posttest outcome measures.

Parameter estimates

Table 5 presents results for direct and indirect path coefficients.

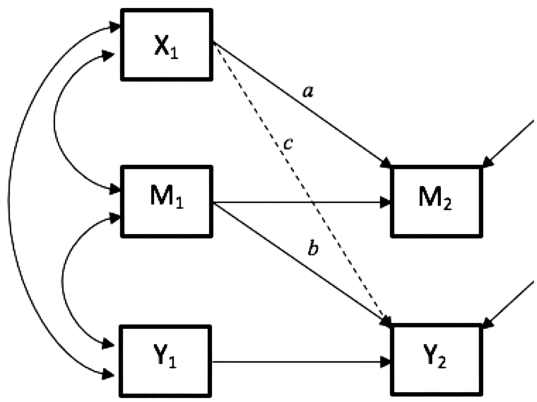

FIGURE 1. Half-longitudinal mediation model (Cole & Maxwell 2003; Kline 2016).

TABLE 5. Parameter estimates of the half-longitudinal mediation model

Parameter	Unstandardised estimate	Standard errors	*p* value	Effect size
Direct effects				
Condition→ Multidimensional vocab post	4.12	1.85	.03	0.41
Condition→ Morphological analysis post	1.48	0.70	.04	0.47
Condition→ Definitional vocab post	4.48	1.39	.001	0.63
Condition→ Reading comprehension post	0.06	0.18	.75	0.06
Multidimensional vocab pre → Reading comprehension post	0.03	0.01	.00	
Morphological analysis pre→ Reading comprehension post	0.04	0.02	.04	
Definitional vocab Pre→ Reading comprehension post	−0.01	0.01	.49	
Indirect effects				
Condition→ Multidimensional vocab→ Reading comprehension post	0.14	0.07	.046	0.14
Condition→ Morphological analysis→ Reading comprehension post	0.05	0.03	.09	0.05
Condition→ Definitional vocab→ Reading comprehension post	−0.04	0.05	.47	−0.04

Effect sizes are measured by Hedges' *g*, calculated by dividing adjusted group mean differences by unadjusted pooled within group student-level standard deviation of pretest scores.

RQ1. English Learners' Robust Academic Vocabulary Encounters effects on multilingual learners' definitional and multidimensional knowledge of target academic word meanings. We found significant, direct effects of the intervention on vocabulary for both definitional (adjusted difference = 4.48, $SE = 1.39$, $p = .001$, $ES = 0.63$) and multidimensional vocabulary knowledge (adjusted difference = 4.12, $SE = 1.85$, $p < .03$, $ES = 0.41$) after controlling for baseline skills. That is, after adjusting for performance differences on all pretests, students who participated in EL RAVE had an average of 4.48 adjusted score points higher on definitional vocabulary and 4.12 adjusted score points higher on multidimensional vocabulary than students in the comparison group. That is, for students who had the same baseline skill levels, those received EL RAVE instruction would have higher vocabulary scores than those who did not. These treatment effects on key outcomes are moderate, per Hedges' *g* criterion (Hedges 1981).

There was a significant direct effect of pretest performance of multidimensional vocabulary ($b = 0.03$, $SE = 0.01$, $p < .01$) on reading comprehension at posttest, controlling for the treatment condition and all other pretests. However, we did not find significant, direct effect of pretest performance of definitional vocabulary ($b = -0.01$, $SE = 0.01$, $p = .49$) on posttest reading comprehension. There was no significant difference between EL RAVE and comparison on adjusted posttest scores on reading comprehension (adjusted difference = 0.06, $SE = 0.18$, $p = .75$, $ES = 0.06$).

RQ2. English Learners' Robust Academic Vocabulary Encounters effects on multilingual learners' morphological analysis skill. We found a significant direct effect of the

intervention on morphological analysis skill (adjusted difference = 1.48, *SE* = 0.70, *p* = .04, *ES* = 0.47). After adjusting for differences on all pretests, students who participated in EL RAVE had an average of 1.48 adjusted score points higher on the assessment of morphological analysis than their control counterparts. The effect size was considered moderate (Hedges 1981). As well, there was a significant direct effect of morphological analysis pretest (*b* = 0.04, *SE* = 0.02, *p* = .04) on reading comprehension posttest, controlling for condition and all other pretests.

RQ3. How do vocabulary knowledge and morphological analysis skill mediate the impact of English Learners' Robust Academic Vocabulary Encounters on reading comprehension. We estimated the indirect effects of EL RAVE on reading comprehension via the competencies targeted in the intervention. The model (Figure 2)suggests that the intervention had a significant indirect effect on posttest reading comprehension via multidimensional vocabulary (adjusted difference = 0.14, *SE* = 0.07, *p* = .046, *ES* = 0.14) and marginally via morphological analysis skill (adjusted difference = 0.05, *SE* = 0.03, *p* = .09, *ES* = 0.05). In other words, students in EL RAVE are predicted to have approximately 0.14 adjusted score points (in *SD* unit) higher than students in the comparison group on reading comprehension via multidimensional vocabulary, after controlling for baseline

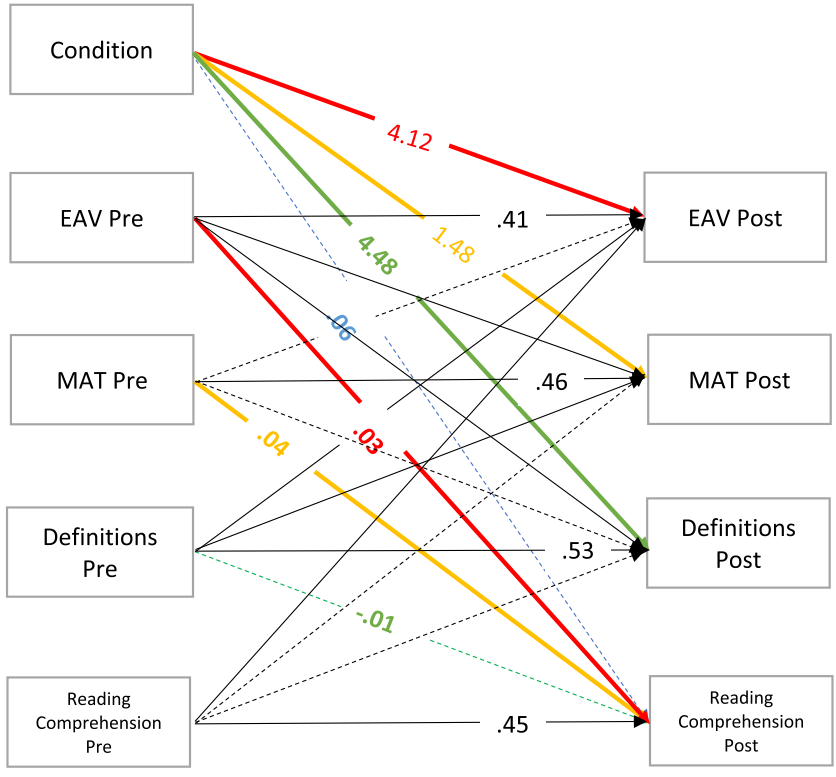

FIGURE 2. Half-longitudinal mediation model with unstandardised parameter estimates. Dashed lines represent insignificant paths. Path coefficients of the same colour are multiplied to calculate indirect effects. Note that covariances among exogenous variables are estimated but not shown in figure for readability. Definitions, definitions task; EAV, evaluation of academic vocabulary; MAT, morphological analysis task.

skills. Although just marginally significant, EL RAVE students are predicted to have 0.05 adjusted score points higher than the comparison group on reading comprehension via morphological analysis skill, after controlling baseline skills. Notably, there was no significant indirect effect of the intervention on posttest score of reading comprehension through definitional vocabulary (adjusted difference = −0.04, $SE = 0.05$, $p = .47$, $ES = -0.04$). Indirect effect sizes are considered small (Hedges 1981). Table 5 present results for unstandardized parameter estimates.

Discussion

In this study, we sought to learn whether multilingual adolescents' vocabulary knowledge and morphological analysis skill could be improved through morphology intervention. Further, we investigated whether vocabulary knowledge and morphological analysis skill mediated the impact of the intervention on students' reading comprehension. We carried out this research with multilingual adolescents, a demographic widely considered among the most vulnerable of learners in US schools, as illustrated by national reports showing wide disparities in reading achievement (National Center for Education Statistics 2017).

We found that, for multilingual adolescents, both vocabulary knowledge and morphological analysis skill are indeed malleable through instruction when that instruction emphasises a problem-solving approach and focuses on the morphological components that are major meaning carriers: Latin roots. Treatment effects on morphological analysis skill, definitional knowledge and multidimensional vocabulary knowledge were moderate.

What about effects of EL RAVE on reading comprehension? In contrast to the direct effects on morphological analysis skill and vocabulary knowledge, the direct effect of EL RAVE on reading comprehension was not significant. Thus, participating in EL RAVE is not enough to boost comprehension immediately, at least as directly measured by our reading comprehension task.

Yet recent evidence suggests that morphological awareness, that is, the insight that words are related through morphological relations, plays an important role in reading comprehension among bilingual learners (Kieffer et al. 2013). Critically, recent evidence also shows that morphological analysis, that is, problem-solving the meanings of unfamiliar words using morphological constituents, predicts reading comprehension improvements among English-speaking children (Levesque et al. 2019). Even so, perhaps the lack of a direct effect on reading comprehension should not be surprising. After all, neither morphology nor vocabulary interventions has shown causal effects on reading comprehension outcomes (Bowers et al. 2010; Elleman et al. 2009; Goodwin & Ahn 2013; Wright & Cervetti 2017).

In light of the promise of morphological analysis instruction, but also tempered by the lack of evidence of literacy interventions on reading comprehension outcomes, we hypothesised that comprehension effects might not be immediately apparent but expected that indirect effects might be estimated. We used the half-longitudinal mediation model described by Cole and Maxwell (2003) to conduct a mediation analysis. Results from this analysis suggested that adolescent multilingual learners, who developed morphological analysis skill through the intervention and who learned the target words deeply, are expected to use that knowledge to boost their reading comprehension. In other words, our results suggest that the intervention's effectiveness at developing morphological analysis skill for inferring new word meanings with bound Latin roots and for building precise

and flexible word knowledge will likely affect reading comprehension in the future. However, the anticipated boosts are small: just 0.05 standard deviations higher for EL RAVE participants via improvements in morphological analysis and 0.14 standard deviations higher for EL RAVE participants via improvements in multidimensional vocabulary knowledge. This is a speculative finding (due to the stationary effect assumption) and requires future replication with larger samples but suggests that the intervention may contribute to the incremental process of improving reading comprehension.

Findings extend current knowledge about morphological analysis and vocabulary in multilinguals' reading comprehension. Our results contribute evidence that multidimensional word knowledge is important for integrating word meaning with context in the service of reading comprehension, in keeping with studies by Li and Kirby (2012) and Ouellette (2006). We also note that Phillips Galloway and Uccelli (2019) tracked the academic language skills and reading comprehension of multilingual adolescents from sixth to seventh grade and found that growth rates in core academic language skills were positively associated with growth in reading comprehension. The knowledge, skills and, perhaps most importantly, the metalinguistic perspective on language emphasised in EL RAVE should improve core skills such as those measured by Phillips Galloway and Uccelli for subsequent impact on reading comprehension.

Limitations and future research

There are several directions for research to address unanswered questions that emerged from this study and to address its limitations. First, our approach to mediation was limited by the two time points in the study's design. When employing the half-longitudinal mediation model (Cole & Maxwell 2003), hypothetical causes always occur before outcomes offering an advantage over cross-sectional models. Still, our estimates of indirect effects on reading comprehension are based on the stationary effect assumption and somewhat speculative. Designs are needed with at least three time points to estimate paths from intervention to morphological analysis and vocabulary knowledge and from these constructs to reading comprehension. We would predict that effects would be greater over time given the generative nature of word learning through morphological analysis.

Another limitation was the relatively large baseline differences between intervention and comparison groups despite random assignment, although the effect sizes (<0.5) were deemed acceptable by other literacy researchers (e.g., Cheung et al. 2017). When interventions are directed at specific types of learners such as multilingual students, matching classrooms of students can be particularly difficult. Limited numbers of such classrooms within a district restrict the extent of matching that can be achieved. Even though we adjusted for pretest differences in our analysis, they might not be completely removed. Hence, findings of this study should be interpreted with caution and verified in future studies with larger samples.

In our case, the intervention group performed more poorly than comparison on all pretests. This might suggest that the intervention group's greater improvements were due to larger capacity for growth. While this might be true for some skills such as basic decoding processes, it is unlikely to be the case for novel learning of academic vocabulary and morphology. In fact, vocabulary growth trajectories are greater for learners who are already advanced in vocabulary (Duff et al. 2015). So higher pretest scores for the comparison group would likely have indicated more potential for vocabulary growth for those students.

In addition, a direction for future work would be to investigate potential influences of students' L1 literacy on reading comprehension. For example, there is evidence that morphological awareness is susceptible to cross-linguistic transfer (Ramirez et al. 2010). The type of morphological knowledge and analysis emphasised in EL RAVE should be affected by L1 literacy skills. Specifically, for multilingual adolescents with some literacy skill in a Latinate L1, relations between L1 and Latin roots might facilitate learning bound Latin roots for analysis of academic words in English (Crosson, McKeown, Moore & Ye 2019).

Implications for theory, policy and practice

This study offers implications for practice. It demonstrates the importance of morphological instruction that emphasises analysis of morphological relationships and flexible application of bound root meanings for inferring word meaning. This is especially important for multilingual learners in US schools and other language minority contexts. Indeed, academic vocabulary knowledge is essential for engagement with challenging concepts and content, and for reading comprehension and production of academic texts. Rapid rates of vocabulary growth are only likely to be achieved if students are learning words not only in derivational families (e.g., *conform*, *conforming* and *nonconforming*, all sharing the base word, *conform*) but also in semantically related clusters (e.g., *conform*, *transform* and *formative*, all sharing the root *form* meaning 'shape').

While we did not directly test the role of morphology in reading comprehension as modelled in the Reading Systems Framework (Perfetti & Stafura 2014), our results seem to offer tentative evidence for a role of morphology in word-level processing. EL RAVE supported morphological analysis with Latin roots, which was positively (though not significantly) associated with reading comprehension. As well, EL RAVE supported multilingual adolescents' multidimensional knowledge of high utility, abstract academic words and multidimensional knowledge was associated with stronger reading comprehension.

Conclusion

In closing, we have shown that morphological analysis skill and vocabulary knowledge are malleable through instruction and may contribute to reading comprehension for multilingual adolescents. We contribute new evidence supporting the important role of morphological analysis and multidimensional vocabulary knowledge in reading comprehension, extending findings to multilingual learners in middle school grades.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Notes

1. Two-tailed *t*-tests comparing group means for pretests of students who stayed for the duration of the study ($n = 140$) versus those who withdrew ($n = 29$) showed no significant differences between groups.
2. All reported alpha coefficients are from posttest.
3. Effect sizes were calculated by standardising class-level mean difference by student-level pooled within group *SD*.

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Amy C. Crosson is assistant professor in the College of Education and faculty affiliate of the Center for Language Science at the Pennsylvania State University, University Park. Her research focuses on literacy interventions to promote word knowledge, comprehension and argumentation skills of multilingual students.

Margaret G. McKeown is Clinical Professor Emerita, School of Education, and Senior Scientist, Learning Research and Development Center, University of Pittsburgh. Her work covers the areas of learning, instruction, and teacher professional development in reading comprehension and vocabulary.

Pui–Wa Lei is a professor in the Department of Educational Psychology, Counseling, and Special Education at Penn State. Her research interests are in methodological issues of multivariate statistical analyses, particularly structural equation modeling and multilevel modeling, and in applications of these modeling techniques and item response theory.

Hui Zhao is a doctoral student in the College of Education at the Pennsylvania State University. Her research interests are text structure strategy, academic self–efficacy, reading comprehension and application of structural equation modeling.

Xinyue Li is a graduate student in the College of Education at the Pennsylvania State University. Her research focuses on educational assessment and item response modeling.

Kelly C. Patrick is the Associate Director for Professional Development and Intervention at the University of Utah Reading Clinic in the College of Education in Salt Lake City. Her scholarly interests relate to spelling and reading research and the application of effective literacy practices in the field.

Kathleen J. Brown is director of the University of Utah Reading Clinic in the College of Education at the University of Utah. Her research focuses on beginning reading instruction and reading intervention for struggling students.

Yaqi Shen is a PhD candidate in Curriculum and Instruction at Penn State University. Her research interests are in morphological awareness and bi–literacy development.

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Address for correspondence: Amy Crosson, Department of Curriculum and Instruction, College of Education, Pennsylvania State University, University Park, State College, PA 16802, USA. E-mail: acc245@psu.edu