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Structural relations of language and cognitive skills, and topic knowledge to written composition: A test of the direct and indirect effects model of writing

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Background. Writing involves multiple processes, drawing on a number of language, cognitive, and print-related skills, and knowledge. According to the Direct and Indirect Effects model of Writing (DIEW; Kim & Park, 2019, *Reading and Writing*, 32, 1319), these multiple factors have hierarchical, interactive, and dynamic relations.

Aims. I examined the hierarchical relations of language and cognitive skills to written composition as well as the relation of topic knowledge to written composition, using DIEW as a theoretical framework.

Sample. One hundred thirty-two English-speaking students in Grade 4 were assessed on written composition, topic knowledge, oral language (vocabulary, grammatical knowledge, discourse-level oral production), higher order cognitions (inference, perspective taking [theory of mind], monitoring), domain-general cognitions (working memory and attention), and transcription skills (spelling and handwriting fluency).

Methods. Structural equation modelling was used to compare hierarchical relations models with a direct or flat relations model.

Results. The hierarchical relations model was supported. Discourse oral language skills and transcription skills completely mediated the relations of the other component skills to written composition, and the included component skills explained 82% of variance in written composition. Substantial total effects were found for discourse language, transcription, attention, working memory, vocabulary, theory of mind, and grammatical knowledge. Topic knowledge was moderately related to writing, but this relation became weak once the other skills were accounted for.

Conclusions. Component skills have hierarchical structural relations and make direct and indirect contributions to written composition. Furthermore, the role of topic knowledge in written composition appears constrained by language and transcription skills for developing writers.

Component skills of developmental writing and the nature of their relations

Expressing one's ideas effectively in writing is a necessary skill in our modern, information-driven society. Yet, writing (written composition) is one of the most challenging skills to acquire. To generate coherent written composition, writers have to deal with multiple aspects such as content generation, handwriting (or keyboarding),

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spelling, punctuation, word choice, sentence construction, structural organization, textual connections and coherence, purpose, and audience (Bereiter & Scardamalia, 1987). According to an integrative theoretical model of developmental writing called DIEW (Kim & Park, 2019; Kim & Schatschneider, 2017; see Figure 1), written composition draws on the following skills and knowledge: transcription skills (spelling and handwriting or keyboarding fluency; and their component skills such as knowledge of phonology, semantics, and orthography), discourse oral language (oral composition), vocabulary, morphosynatic and syntactic knowledge (i.e., grammatical knowledge), discourse knowledge (knowledge about various discourse forms including genre, procedures, and strategies in instantiation of these schemata; McCutchen, 1986), content or topic knowledge, higher order cognitive skills and regulation such as inferencing and perspective taking (including audience awareness), reading, socio-emotions, and domain-general cognitions (e.g., working memory, attention). These skills and knowledge (component skills hereafter because writing and its development rely on a constellation of related but distinctive contributing, component skills) are employed during the various processes of writing (e.g., drafting, revising) within limited cognitive resources, interacting with environments (e.g., tasks, home environment, instruction).

Direct and indirect effects model of writing integrates and extends extant theoretical models of developmental writing. The simple view of writing (Juel, Griffith, & Gough, 1986) states that children's written composition skill is a function of ideation (idea generation and translation into oral language) and transcription skills (spelling and handwriting fluency). The not-so-simple view of writing further includes self-regulation (which includes attentional control and self-regulatory processes) and working memory, in addition to ideation and transcription skills (Berninger & Winn, 2006). DIEW extends these models in two important ways. First, DIEW explicitly includes component skills beyond those specified in the simple view and not-so-simple view of writing, such as knowledge (topic and discourse knowledge), higher order cognitive skills, reading skills, and socio-emotional aspects (e.g., motivation and attitude).

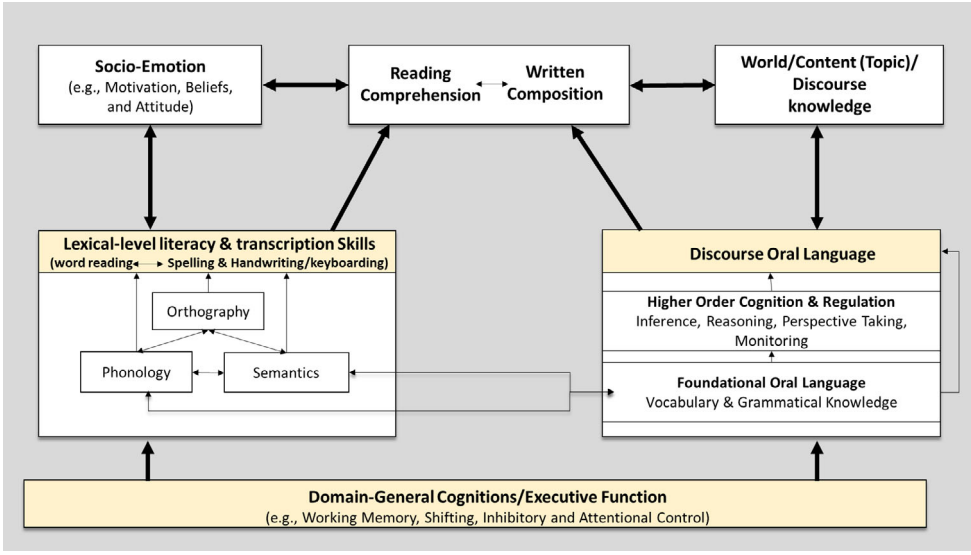

Figure 1. A modified schematic representation of the Direct and Indirect Effects model of Writing (DIEW; Kim & Park, 2019; printed with permission).

The second way DIEW extends previous theoretical models of developmental writing is by specifying the nature of relations among component skills (i.e., hierarchical, interactive, and dynamic relations; see Kim & Park, 2019, for details). The central idea of the hierarchical relations hypothesis is that numerous component skills of writing have hierarchical relations where higher order skills mediate the relations of lower level skills to written composition (see Figure 1). At the upper tier, written composition is largely a function of discourse oral language and transcription skills[1] (see Juel *et al.*, 1986). Discourse oral language captures an oral composition skill – the ability to generate ideas and translate and organize them into oral language (Berninger, Fuller, & Whitaker, 1996); and draw on higher order cognitions (e.g., reasoning) and foundational oral language skills (vocabulary and grammatical knowledge), which are supported by domain-general cognitions such as working memory and attentional control. Transcription skills are necessary for encoding translated ideas into written text or print and require visual-motor integration (Berninger *et al.*, 1992). Furthermore, transcription skills draw on one's phonological, orthographic, and semantic knowledge, which is supported by domain-general cognitions (see Figure 1).

The hierarchical relations specified in DIEW are based on literature and evidence from various lines of work (see Kim & Park, 2019, for a review of empirical evidence) and explain pathways by which component factors influence written composition. In other words, the hierarchical relations entail a chain of mediated relations among component skills such that not all skills make direct contributions to written composition. For example, the upper tier skill, discourse oral language is supported by higher order cognitions and regulation (e.g., Kendeou, Bohn-Gettler, White, & van den Broek, 2008; Kim & Phillips, 2014; Tompkins, Guo, & Justice, 2013), vocabulary and grammatical knowledge (e.g., Kim, 2015, 2017; Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012), and domain-general cognitions (e.g., Daneman & Merikle, 1996; Kim, 2015, 2016; Peng *et al.*, 2018). Furthermore, higher order cognitions are supported by vocabulary and grammatical knowledge (Currie & Cain, 2015; Hughes, 1998; Ruffman, Slade, Rowlandson, Rumsey, & Garnham, 2003) as well as domain-general cognitions (Mutter, Alcorn, & Welsh, 2006; Valle, Massaro, Castelli, & Marchetti, 2015); and vocabulary and grammatical knowledge are supported by domain-general cognitions (Gathercole, Tiffany, Briscoe, Thorn, & ALSPAC team, 2005; Kim, 2016). Thus, the following chain of mediated relations can be hypothesized in this example: domain-general cognitions → vocabulary and grammatical knowledge → higher order cognitions → discourse oral language. Furthermore, the relations of language and cognitive skills to written composition are posited to be wholly mediated by discourse oral language and transcription skills to the extent that discourse oral language is measured approximating an oral composition skill.

Hierarchical relations among the component skills are not expected to change with development. However, the relative contributions of component skills to written composition are posited to change with development (i.e., the dynamic relations hypothesis as a function of development) such that with development, the constraining role of transcription skills decreases as transcription skills become automatized, whereas the roles of oral language and higher order cognitive skills are expected to increase. When

[1] *The term, upper tier, is not the same as 'high order'. Specifically, transcription skills are not higher order skills, but are referred to as an upper tier because of their constraining roles, acting as a bottleneck. On the other hand, discourse oral language is a higher order, discourse-level language skill, as compared to lexical-level (e.g., vocabulary) or sublexical-level language (e.g., morphemes, phonemes).*

transcription skills are not automatized, the writer's mental resources such as working memory and attention are not available for the ideation process, constraining the roles of skills that contribute to the ideation process (Berninger & Winn, 2006; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997). Furthermore, the relations of component skills to written composition are also posited to differ depending on the focal aspects of written composition evaluated (e.g., writing quality, productivity; dynamic relations as a function of writing dimensions; see Kim & Park, 2019 for details).

Finally, DIEW also hypothesizes interactive relations among component skills (see Kim & Park, 2019 for details). For example, content/topic knowledge and writing are expected to have reciprocal relations, particularly at advanced stages (e.g., knowledge-transforming and knowledge-crafting stages) because at the beginning phase, writers primarily rely on a knowledge-telling approach (Bereiter & Scardamalia, 1987; Kellogg, 2008).

The hierarchical relations hypothesis of DIEW, the focal hypothesis examined in this study, has been recently examined and supported for students in primary grades. Kim and Schatschneider (2017) found that working memory, vocabulary, and grammatical knowledge were indirectly related to written composition via discourse oral language and transcription skills for English-speaking first graders. In the present study, I aim to extend these findings by replicating the hierarchical relations hypothesis for children in an upper elementary grade, Grade 4. Furthermore, the relative contributions of component skills might differ in Grade 1 versus Grade 4 (see the dynamic relations hypothesis above). Children in Grade 1 are, on average, at the very initial phase of writing development, particularly in transcription skills, whereas children in Grade 4 are still at the beginning phase, but certainly more advanced than in Grade 1.

The contribution of content/topic knowledge to writing

As a production task, writing requires the generation of content or ideas, for which topic knowledge is necessary. Topic knowledge plays a particularly central role for novice writers because writing for beginning writers is essentially a knowledge retrieval process where writers retrieve readily available content or ideas from memory and encode them in print (Bereiter & Scardamalia, 1987). Thus, those who have greater knowledge about a given topic are likely to include more details and elaborations on the topic (Langer, 1984). Greater topic knowledge is also hypothesized to allow rapid access to the content, which releases cognitive resources (e.g., working memory and attention) that can be used for other processes such as organizing ideas, which then influences the quality of written composition (Kellogg, 1987).

Previous empirical investigations have supported the role of topic knowledge in writing. In one line of studies, students with greater knowledge on a given topic produced higher quality and more coherent writing than those with low knowledge (e.g., Benton, Corkill, Sharp, Downey, & Khramtsova, 1995; Langer, 1984; McCutchen, 1986). In another line of work involving multivariate approaches, topic knowledge was found to make an independent contribution to writing. Olinghouse *et al.* (2015) found that fifth graders' topic knowledge was related to their writing quality in three genres (narrative, opinion, and informative texts) after accounting for writing length, transcription skills, and discourse knowledge. Similarly, Graham *et al.* (2019) reported a unique contribution of topic knowledge to writing quality and writing length for fifth graders, after controlling for variables such as attitude, self-efficacy, and spelling error.

While informative, previous conceptualization and empirical work have not sufficiently considered the nature of the relation of topic knowledge to written

composition in relation to other skills. Although topic knowledge is key to generating ideas, it must undergo translation (into oral language) and transcription (into print) processes. Then, oral language and transcription skills may place a limit on or have constraining roles in the extent to which topic knowledge influences writing. This may be particularly the case in the beginning phase of writing development when children's oral language and transcription skills are developing at a rapid rate, and therefore, the unique or independent role of topic knowledge over and above oral language and transcription skills would likely be found after one reaches a certain proficiency level in oral language and transcription skills. In this study, I examined the independent relation of topic knowledge to writing over and above the other component skills (discourse oral language, transcription, inference, perspective taking, monitoring, vocabulary, grammatical knowledge, working memory, and attention) for children in Grade 4.

Present study

Two primary goals guided the present study. First, I investigated the hierarchical relations hypothesis of DIEW where component skills have a chain of mediated relations to written composition such that lower order skills have cascading indirect relations to written composition via higher order skills. Additionally, I examined whether discourse oral language and transcription skills (spelling and handwriting fluency) completely or partially mediate the relations of inference, perspective taking, monitoring, vocabulary, grammatical knowledge, working memory, and attention to written composition. Second, I examined the relation of topic knowledge to written composition after controlling for transcription and other language and cognitive skills. Specific research questions were as follows.

1. Is the hierarchical relations hypothesis of DIEW supported for children in an upper elementary grade, Grade 4? If so, do discourse oral language and transcription skills (spelling and handwriting fluency) completely or partially mediate the relations of the other component skills (i.e., inference, perspective taking, monitoring, vocabulary, grammatical knowledge, working memory, and attention) to written composition?
2. Is topic knowledge uniquely and independently related to written composition after accounting for discourse oral language and transcription skills as well as their component skills (i.e., inference, perspective taking, monitoring, vocabulary, grammatical knowledge, working memory, and attention)?

The first research question was addressed by comparing a flat or direct relations model (Figure 2a) with four alternative models of a hierarchical or direct and indirect relations model to examine whether language and cognitive skills have direct relations to written composition over and above discourse oral language and transcription skills (see Figure 2b–e). DIEW does not posit that the hierarchical relations vary as a function of development, and therefore, the hierarchical structural relations were expected to be supported for fourth graders in this study similar to a study with first graders (Kim & Schatschneider, 2017). In addition, discourse oral language and transcription skills were expected to completely mediate the relations of the other component skills (i.e., inference, perspective taking, monitoring, vocabulary, grammatical knowledge, working memory, and attention) to written composition, consistent with results from a previous study (Kim & Schatschneider, 2017). As for the relation of topic knowledge to writing, I expected a moderate relation between topic knowledge and written composition in a

zero-order correlation based on previous studies (e.g., Graham *et al.*, 2019; Olinghouse *et al.*, 2015). However, a weaker relation was expected in a multivariate model accounting for the other skills (e.g., language, transcription skills).

Method

Participants

One hundred thirty-two students (50% female; mean age = 9.39 years, *SD* = 0.59) in Grade 4 from five schools in the south-eastern United States participated in the study. The racial and ethnic composition of the sample was as follows: 58% Caucasian, 32% African American, 5% Hispanic, 3% multiracial, and 2% Asian. Two students had identified learning disabilities, and one student had limited English proficiency. Approximately 67% of the students were eligible for the free and reduced-price lunch programme, a proxy for poverty status in the United States. All students were included in the data analysis.

Measures

Reliability estimates are reported in Table 1.

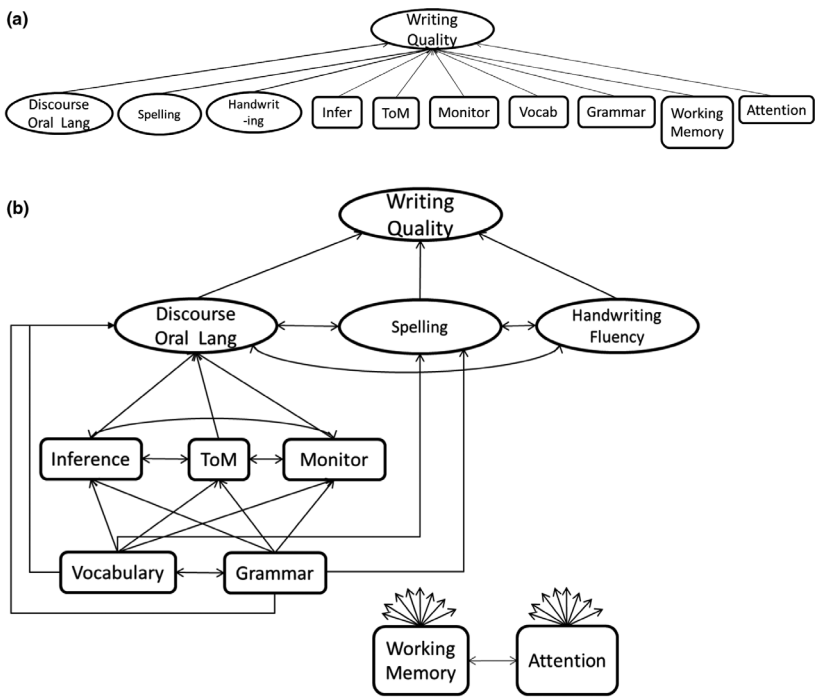

Figure 2. Models fit to examine the nature of the relations of component skills to writing. (a) is a direct or flat relations model, and (b)–(e) are variations of DIEW. In (b–e), working memory and attention were allowed to predict all the component skills (vocabulary, grammatical knowledge, inference, theory of mind (perspective taking), monitoring, discourse oral language, spelling, and handwriting fluency. However, these paths are not shown fully to reduce visual complexity. Grammar = Grammatical knowledge; Handwriting = Handwriting fluency; Lang = Language; Monitor = Monitoring; ToM = Theory of Mind; Vocab = Vocabulary.

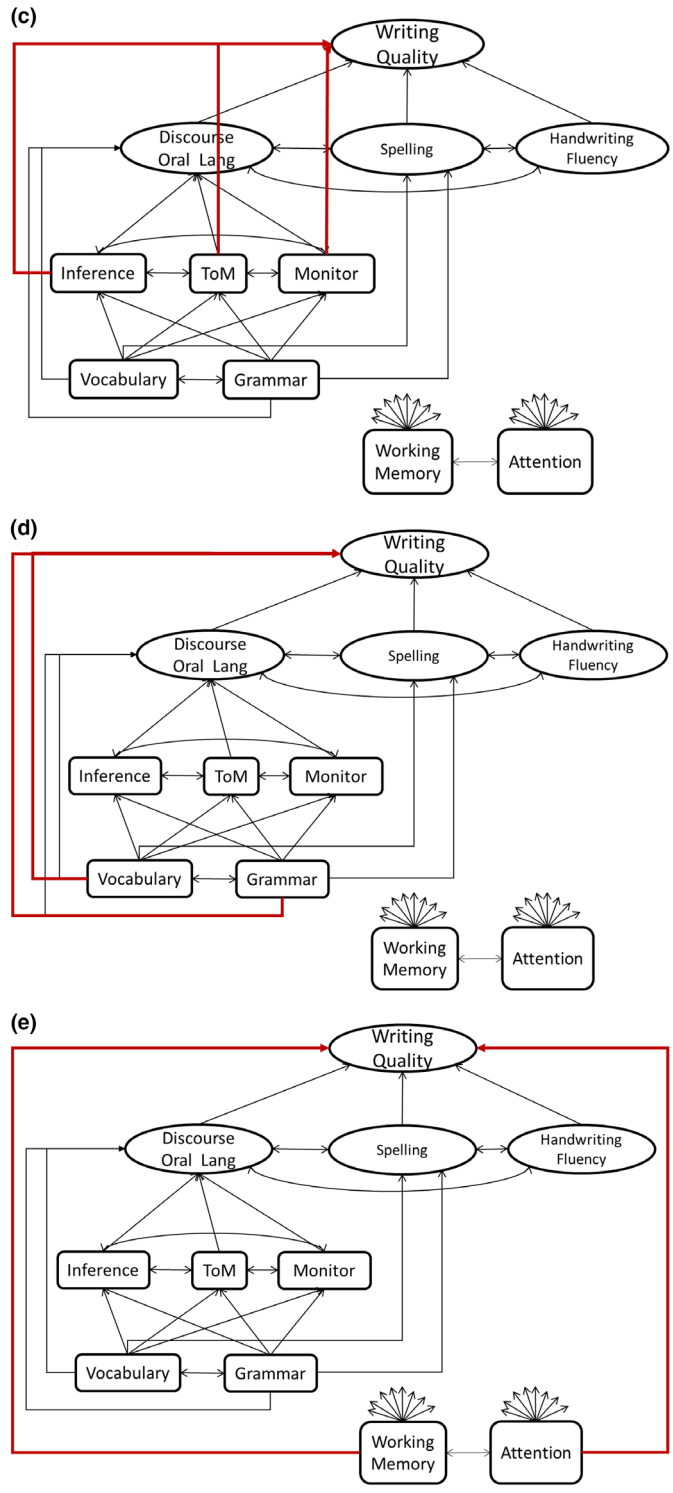

Figure 2. Continued.

Written composition

To capture one's general or overall skill in written composition across genres (i.e., narrative and expository) and format (writing upon prompt and writing in response to source materials), the following three writing tasks were used: The Test of Early Written Language-Third Edition (TEWL; Hresko, Herron, Peak, & Hicks, 2012), the Essay subtest of the Wechsler Individual Achievement Test-Third Edition (WIAT; Wechsler, 2009), and an experimental task called Beaver. In TEWL, the student was presented with an illustration and was asked to write a story that goes with the illustration. In the WIAT Essay task, the student was asked to write about his or her favourite game and three reasons for it. The Beaver task was a source-based writing task in which the student was provided with a passage about beavers (297 words; adapted from the Qualitative Reading Inventory [QRI]; Leslie & Caldwell, 2011). The original Beaver text did not include any illustrations, but I used three accompanying illustrations to aid comprehension of the text, using publicly available images. The assessor read the passage aloud while the student read along silently. Then, the student was asked to write about what beavers do and how they do it and was given access to the beaver text while composing. Each of these writing tasks was administered in different sessions. Students were given 15 min to write, following previous studies (Graham, Harris, & Chorzempa, 2002; Kim, Al Otaiba, Wanzek, & Gatlin, 2015; Olinghouse, 2008).

Written compositions were coded for quality based on the extent to which their ideas were developed and presented in an organized manner, on a rating scale of 1 to 10 (for a similar approach, see Graham *et al.*, 2019; Hooper, Swartz, Wakely, de Kruif, & Montgomery, 2002). Compositions with clearer ideas, greater relevant rich details, and more logical arrangement of ideas (both globally and locally) received higher scores.

Topic knowledge

Topic knowledge was assessed only for the Beaver task because the task involved specific informational content. Before the Beaver passage was presented, the student was asked to list everything he or she knew about beavers (see Graham *et al.*, 2019, for a similar approach). As a practice item, students were given an example on dogs, in which the assessor listed things related to dogs. Using the student-generated list about beavers, the number of valid, relevant ideas was counted without penalizing spelling and punctuation errors (see Graham *et al.*, 2019). For example, '*They swim they make dam they chop woods they live in water*' was counted as four valid ideas and was given a score of four.

Discourse oral language

Two tasks were used: the Test of Narrative Language (TNL; Gillam & Pearson, 2004) and an experimental task using informational texts. There were three tasks in the TNL – in the first two tasks, the student heard a narrative story and was asked to retell the story; in the third task, the student was provided with an illustration and was asked to produce a story that goes with the illustration. In the experimental task, the student heard three Grade 4 informational texts from QRI (Leslie & Caldwell, 2011) and was asked to retell them after hearing each. Note that retell captures one's ability to recall and organize ideas based on the listener's mental model, and oral retell ability and oral production ability were found to be best described as a single construct (Gillam & Pearson, 2004).

Table 1. Descriptive statistics

Variable	Reliability	Mean	*SD*	Min	Max	Skewness	Kurtosis
Working memory	.74	11.26	4.36	0	26	0.15	0.97
SWAN attention	.99	125.28	37.19	30	210	0.32	−0.01
WJ Picture Vocabulary	.65	23.08	2.74	16	30	0.00	−0.12
WJ Picture Vocabulary SS	–	95.84	9.55	69	120	−0.07	0.25
CASL Grammaticality	.95	43.55	13.75	10	84	0.06	0.36
CASL Grammaticality SS	–	94.53	15.89	54	159	0.52	2.18
CASL Inference	.92	17.89	8.74	0	40	−0.04	−0.76
CASL Inference SS	–	91.52	17.08	40	132	−0.37	0.07
Comprehension monitoring	.78	8.27	2.98	2	18	0.38	0.40
Theory of mind	.81	10.23	3.97	0	17	−0.30	−0.62
TNL retell	.90- to .92[a]	41.35	10.82	0	57	−1.55	3.36
QRI retell	.90 to .92[a]	15.34	9.29	0	38	0.43	−0.62
WJ Spelling Raw	.90	33.31	6.14	18	45	−0.23	−0.55
WJ Spelling SS	–	99.35	16.41	54	131	−0.43	0.03
Spelling: Experimental	.90	14.37	5.19	1	23	−0.34	−0.57
Sentence copying 1	.90 to .95[b]	67.41	21.29	0	113	−0.30	0.07
Sentence copying 2	.90 to .95[b]	68.06	21.47	9	130	−0.09	−0.14
Sentence copying 3	.90 to .95[b]	75.82	21.21	14	128	−0.13	0.34
TEWL writing quality	.81[c]	4.48	1.47	0	10	0.21	1.43
WIAT writing quality	.90[c]	4.13	1.59	0	9	0.37	0.51
Beaver writing quality	.96[c]	3.70	1.19	0	7	−0.04	1.53
Beaver topic knowledge	.93[d]	2.92	1.42	0	8	0.37	0.33

CASL = Comprehensive Assessment of Spoken Language; QRI = Qualitative Reading Inventory; SS = standard score; SWAN = Strengths and Weaknesses of ADHD Symptoms and Normal Behavior; TEWL = Test of Early Written Language; TNL = Test of Narrative Language; WIAT = Wechsler Individual Achievement Test; WJ = Woodcock-Johnson. Unless otherwise noted, scores are raw values. Reliability estimates are Cronbach's alpha except for the following.

[a]Two graduate students who had extensive experience in coding students' retell were trained rigorously. Reliability estimates (per cent agreement) ranged from 90 to 92%, using 50 samples per story or text. After reaching these reliabilities, the two coders scored all the retells together, and differences in scores were resolved after discussion.

[b]Exact per cent agreement.

[c]Cohen's kappa. Two graduate students with extensive experiences in coding elementary grade students' written compositions were trained rigorously. Reliabilities (Cohen's kappa) were .81, .90, and .96 for the TEWL, WIAT, and Beaver tasks, respectively, using 40 written samples per task.

[d]Exact per cent agreement using 50 student responses.

Students' retell and production were digitally recorded and transcribed verbatim following the Systematic Analysis of Language Transcripts guidelines (Miller & Iglesias, 2006) and were evaluated for quality in terms of the extent to which key ideas and details were included in logical order. For TNL, this included key narrative elements such as the introduction, main characters, setting, mainline events, problem, resolution, and closing as well as logical sequence of these ideas (e.g., Barnes, Kim, & Phillips, 2014; Scott & Windsor, 2000). For informational texts, the extent to which main ideas and key details were included was evaluated (see Kim & Schatschneider, 2017; Wagner *et al.*, 2011).

Spelling

The Spelling subtest of the Woodcock-Johnson III (WJ; Woodcock, McGrew, & Mather, 2001) and an experimental task were used. Both were dictation tasks in which students heard a target word, a sentence with the target word, and then the target word again. The experimental task included 24 items of developmentally appropriate words and spelling patterns that are relevant for students in upper elementary grades (e.g., *island*, *fortunate*).

Handwriting fluency

Three sentence-copying tasks were used (e.g., Wagner *et al.*, 2011). The sentences included a pangram, 'The quick brown fox jumps over the lazy dog', as well as two experimental sentences, 'My dog jumps and runs when I tell him to jump and run', and 'My mom put the lid on the pan to cook the food'. The student was presented with each sentence and was asked to copy it as many times as possible in 1 min. The number of correctly copied letters was counted.

Inference

Students' ability to make knowledge-based inferences was measured by the Inference task of the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999). In this task, the student heard a short scenario with one to three sentences and was asked a question that required inference drawing on background knowledge (e.g., 'Before Jim left for work, he put on a heavy coat. What was the weather like?').

Perspective taking

A theory of mind task, specifically a false belief task, was used to assess perspective taking (Kim, 2016; Wellman, Cross, & Watson, 2001). Considering the students' developmental phase, three second-order scenarios, which require the student to infer a story character's mistaken belief about another character's knowledge, were used (Arslan, Hohenberger, & Verbrugge, 2017). The student heard each scenario and was asked questions related to understanding characters' mental states. A series of illustrations were presented for each scenario. There were 18 questions (six per scenario).

Monitoring

An inconsistency detection task (Baker, 1984; Cain, Oakhill, & Bryant, 2004) was used. The student heard a short story and was asked whether the story made sense; if the child stated that the story did not make sense, then he or she was asked to provide a brief explanation and to fix the story so that it made sense. Consistent and inconsistent stories were presented in random order following two practice items (one consistent and one inconsistent). Test items included three consistent and six inconsistent stories. Accuracy of the student's answer about whether a story was consistent or inconsistent was dichotomously scored. For the six inconsistent stories, the accuracy of children's explanation and repair of the story were also each dichotomously scored.

Vocabulary

The Picture Vocabulary of the Woodcock-Johnson III (WJ; Woodcock *et al.*, 2001) was used. This was an expressive vocabulary task where the student was asked to identify pictured objects or provide synonyms.

Grammatical knowledge

The Grammaticality Judgement task of the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999) was used. The student heard a sentence (e.g., *The boy were funny*) and was asked whether the sentence was grammatically correct; if the sentence was grammatically incorrect, the child was also asked to correct the sentence. Following the CASL manual, children were given credit for a correct response about grammaticality of a sentence as well as an accurate correction of an incorrect sentence.

Working memory

A listening span task was used (Cain *et al.*, 2004; Kim, 2016). In this task, the student was presented with a sentence (e.g., *Apples are blue*) and asked to identify whether the heard sentence was correct or not. After hearing two to five sentences, the student was asked to recall the last word of each of the sentences in order. There were four practice items and 14 test items. The maximum possible total score was 28 (14×2): A score of 2 was given when the last words for an item were in correct order, a score of 1 was given when the last words were accurate but in incorrect order, and a score of 0 was given when the last words were inaccurate. The students' responses regarding the veracity of the statements (yes/no responses) were not scored.

Attention

Student's attentiveness was measured by the Strengths and Weaknesses of ADHD Symptoms and Normal Behavior (SWAN; Swanson *et al.*, 2006). SWAN includes 30 items on children's behaviours related to attention and hyperactivity on a 7-point scale (1 = *far below average*; 7 = *far above average*). Teachers of the participating children completed the SWAN checklist.

Procedures

Research assistants were rigorously trained and worked with students in a quiet space in the school. The assessment batteries were administered to students individually, except for the writing, spelling, and handwriting fluency tasks, which were administered in small groups of three to four children.

Data analysis strategy

Confirmatory factor analysis and structural equation modelling were employed using MPLUS 7.4 software (Muthén & Muthén, 2013) with full information maximum-likelihood estimation. Latent variables were created for writing, discourse oral language, spelling, and handwriting fluency. For the other constructs, observed variables were used.

The first research question was addressed by fitting structural equation models in Figure 2. Two sets of models were fitted. The first was a direct relations model where all the component skills were hypothesized to be directly related to writing (Figure 2a). Alternatively, hierarchical relations per DIEW were examined by fitting four alternative models. In the complete mediation model (Figure 2b), writing quality was directly predicted by discourse oral language, spelling, and handwriting fluency, which completely mediated the relations of the other skills to writing. Three alternative *partial* mediation models (Figures 2c–e) were also fitted where higher order cognitions (Figure 2c), vocabulary and grammatical knowledge (Figure 2d), and working memory and attentional control (Figure 2e) were, respectively, hypothesized to directly relate to writing over and above discourse oral language and transcription skills. Note that for the direct relations model versus the four alternative models examining DIEW (Figures 2b–e), the goal was not to compare model fit as they were not nested, and all of them were expected to fit the data well. Rather, the goal was to show differences in informativeness. For the alternative DIEW models (Figures 2b–e), which were nested, model fit was compared using the chi-square difference test.

The second research question was addressed by fitting the model shown in Figure 4 in which topic knowledge was added as a predictor of writing in addition to the other variables. Because topic knowledge was assessed only for the Beaver writing task, writing quality on the Beaver task was used as the outcome.

Model fit was evaluated by the chi-square statistic, comparative fit index (CFI; $> .90$ as acceptable), Tucker–Lewis index (TLI; $> .90$ as acceptable), root–mean-square error of approximation (RMSEA; $< .10$ as acceptable), and standardized root-mean-square residuals (SRMR; $< .08$ as acceptable).

Results

Descriptive statistics and preliminary analyses

Table 1 displays descriptive statistics. Students' mean performance on normed tasks (e.g., Vocabulary, Inference, WJ Spelling) ranged from 91.52 (low average) to 99.35 (average). Students' mean performance on the writing tasks ranged from 3.70 in the Beaver task to 4.48 in the TEWL task. For topic knowledge about beavers, children knew, on average, three pieces of information. There was sufficient variation around the means on all the tasks, and distributional properties as indicated by skewness (≤ 2) and kurtosis (<7) were in the acceptable ranges (West, Finch, & Curran, 1995). Subsequent analyses were conducted using raw scores.

Bivariate correlations are displayed in Table 2 and were in expected directions. The language and cognitive skills were moderately related to discourse oral language ($.31 \leq r\text{s} \leq .48$) and weakly to moderately related to writing quality ($.24 \leq r\text{s} \leq .45$). Discourse oral language was moderately related to writing quality ($.32 \leq r\text{s} \leq .46$), and transcription skills were weakly to moderately related to writing ($.27 \leq r\text{s} \leq .54$). Topic knowledge about beavers was moderately related to writing quality on the Beaver task ($r = .36$).

Confirmatory factor analysis was conducted to create latent variables for writing quality, discourse oral language, spelling, and handwriting fluency. As shown in Table 3, loadings were strong to very strong ($.67 \leq \lambda\text{s} \leq .95$, $p\text{s} < .001$). Bivariate correlations between latent variables and Beaver topic knowledge were in the moderate range ($.29 \leq r\text{s} \leq .53$; see Table 4).

Table 2. Correlations between variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Working memory	–																
2. SWAN attention	.30	–															
3. WJ Picture vocabulary	.26	.15	–														
4. CASL Grammaticality	.35	.31	.50	–													
5. CASL Inference	.36	.27	.55	.60	–												
6. Theory of mind	.37	.29	.30	.31	.47	–											
7. Comprehension monitoring	.21	.34	.31	.34	.43	.41	–										
8. TNL retell	.32	.33	.43	.41	.47	.35	.48	–									
9. QRI retell	.31	.47	.45	.40	.44	.38	.41	.59	–								
10. WJ Spelling	.30	.42	.39	.49	.33	.24	.19	.41	.45	–							
11. Spelling: Experimental	.28	.48	.37	.46	.26	.25	.16	.39	.42	.90	–						
12. Sentence copying 1	.15	.29	−.07	.11	.07	−.01	.09	.21	.14	.30	.35	–					
13. Sentence copying 2	.15	.30	−.09	.15	.11	−.03	−.02	.20	.16	.29	.29	.60	–				
14. Sentence copying 3	.18	.30	−.15	.09	−.02	−.09	−.03	.09	−.01	.21	.26	.65	.63	–			
15. TEWL writing quality	.32	.42	.24	.30	.40	.24	.29	.38	.46	.39	.34	.36	.42	.29	–		
16. WIAT writing quality	.29	.44	.27	.39	.29	.25	.28	.38	.46	.51	.54	.35	.31	.31	.43	–	
17. Beaver writing quality	.37	.45	.29	.37	.35	.29	.32	.32	.45	.53	.53	.33	.39	.27	.55	.59	–
18. Beaver topic knowledge	.15	.26	.25	.27	.28	.19	.24	.27	.35	.38	.37	.22	.28	.19	.43	.34	.36

CASL = Comprehensive Assessment of Spoken Language; QRI = Qualitative Reading Inventory; SWAN = Strengths and Weaknesses of ADHD Symptoms and Normal Behavior; TEWL = Test of Early Written Language; TNL = Test of Narrative Language; WIAT = Wechsler Individual Achievement Test; WJ = Woodcock-Johnson.
Coefficients ≤.16 are not statistically significant at the $p < .05$ level.

Research Question 1: Hierarchical structural relations

The direct relations model and four variations of DIEW (Figure 2) were fitted to the data. The direct relations model had a good fit: χ^2 (71) = 71.56, p = .46, CFI = 1.00, TLI = 1.00, RMSEA = .008 [0.00 to 0.051], SRMR = .034. However, as shown in Figure 3a, only spelling (.27, p = .01) and handwriting fluency (.36, p < .001) were independently related to writing quality whereas the other variables were not (ps ≥ .24), most likely due to multicollinearity (Table 2 shows that language and cognitive skills were moderately to fairly strongly related). The four alternative DIEW models fit the data very well, and the model fits did not differ from each other (see Table 5). Therefore, the most parsimonious complete mediation model (Figure 2b) was selected as the final model – that is, discourse oral language and transcription skills completely mediated the relations of the other component skills (i.e., inference, perspective taking, monitoring, vocabulary, grammatical knowledge, working memory, and attention) to written composition.

Standardized coefficients of the complete mediation model are displayed in Figure 3b. Discourse oral language (.54, p < .001), spelling (.22, p = .03), and handwriting fluency (.36, p < .001) were positively related to writing quality. Theory of mind (.28, p < .001), vocabulary (.32, p < .001), and attention (.31, p < .001) were positively related to discourse oral language after accounting for the other variables in the model. Vocabulary was also related to inference (.32, p < .001), monitoring (.18, p = .04), and spelling (.26, p = .001), whereas grammatical knowledge predicted inference (.37, p < .001) and spelling (.26, p = .002). Working memory was related to vocabulary (.24, p = .005), grammatical knowledge (.30, p < .001), and theory of mind (.26, p = .002), while attention was related to monitoring (.22, p = .01), spelling (.32, p < .001), and handwriting fluency (.34, p < .001).

Table 6 shows direct, indirect, and total effects (standardized regression weights) of the component skills on writing quality. Attention had the largest indirect effect (.45), followed by vocabulary (.29), working memory (.25), theory of mind (.15), and grammatical knowledge (.14). Total variance explained was as follows: .82 in writing quality, .72 in discourse oral language, .40 in spelling, and .14 in handwriting fluency.

Research Question 2: The relation of topic knowledge to written composition

The model in Figure 4 fit the data very well, χ^2 (62) = 69.25, p = .25, CFI = .99, TLI = .98, RMSEA = .03 [0.00 to 0.06], SRMR = .05. Discourse oral language (.32, p < .001),

Table 3. Loadings of indicators to latent variables

Latent variable	Indicator	Loading, *p* Value
Writing quality	Test of early written language	.68, <.001
	WIAT Essay composition	.72, <.001
	Experimental: Beaver	.77, <.001
Discourse oral language	Test of narrative language	.67, <.001
	Qualitative reading inventory	.87, <.001
Spelling	Woodcock-Johnson spelling	.95, <.001
	Spelling: Experimental	.95, <.001
Handwriting fluency	Sentence copying 1	.79, <.001
	Sentence copying 2	.80, <.001
	Sentence copying 3	.78, <.001

WIAT = Wechsler Individual Achievement Test.

Table 4. Bivariate correlations between latent variables and Beaver topic knowledge

Variable	1	2	3	4
1. Discourse oral language	–			
2. Spelling	.55	–		
3. Handwriting fluency	.18	.38	–	
4. Writing quality	.71	.70	.57	–
5. Beaver: Topic knowledge	.41	.40	.29	.53

All coefficients are statistically significant at the $p < .05$ level.

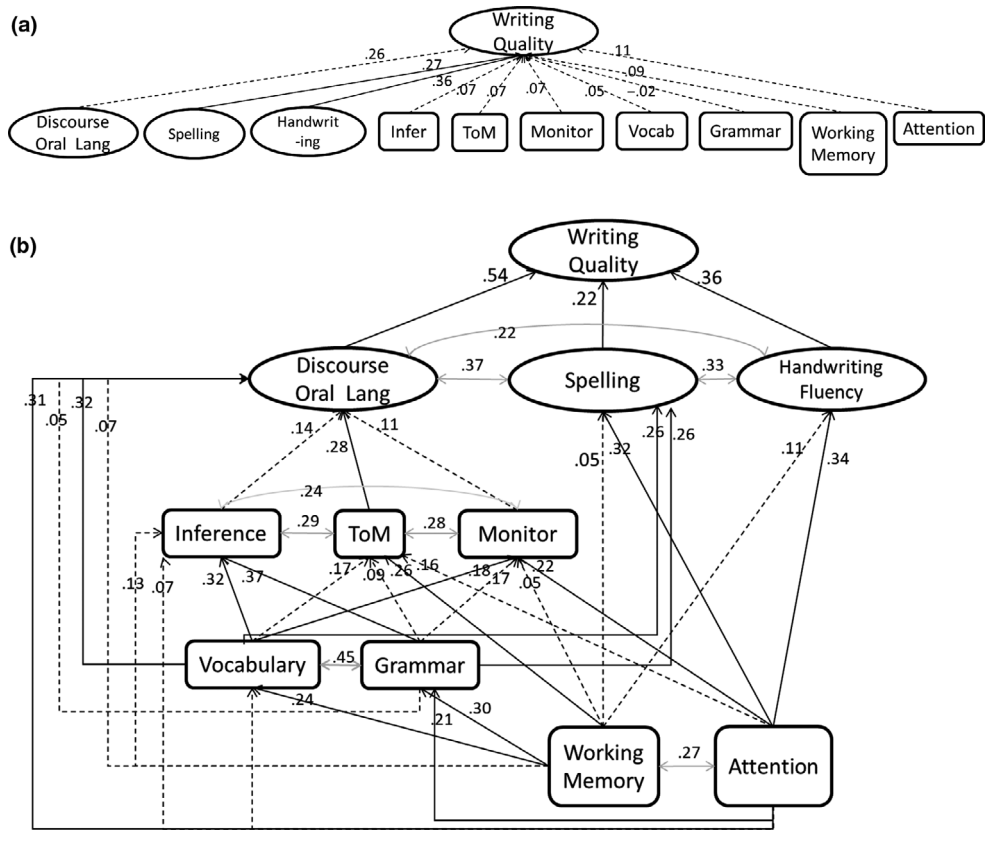

Figure 3. Standardized coefficients in the (a) direct relations model and (b) Direct and Indirect Effects model of Writing (DIEW). Solid lines represent statistically significant relations ($p < .05$), whereas dashed lines represent non-significant relations. Grammar = Grammatical knowledge; Handwriting = Handwriting fluency; Lang = Language; Monitor = Monitoring; ToM = Theory of Mind; Vocab = Vocabulary.

spelling (.22, $p = .02$), and handwriting fluency (.21, $p = .01$) were positively related to Beaver writing quality, after accounting for all the other variables in the model. Topic knowledge about beavers was weakly related to writing quality (.14, $p = .07$), barely missing the conventional statistical significance level of .05, after accounting for all the other variables in the model. Interestingly, the language and cognitive component skills

Table 5. Model fit comparisons

Figure	χ^2 (*df*), *p* Value	CFI (TLI)	RMSEA [90% CI], (SRMR)	Model comparison: $\Delta\chi^2$ (Δdf, *p* Value)
Figure 2b	90.95 (86), .34	1.00 (.99)	.01 [0.00 to 0.053], (.056)	
Figure 2c	89.60 (83), .29	.99 (.99)	.025 [0.00 to 0.055], (.057)	1a vs. 1b: 1.35 (3, .71)
Figure 2d	90.68 (84), .29	.99 (.99)	.025 [0.00 to 0.055], (.055)	1a vs. 1c: 0.27 (2, .87)
Figure 2e	88.84 (84), .34	1.00 (.99)	.021 [0.00 to 0.053], (.054)	1a vs. 1d: 2.11 (2, .35)

Table 6. Direct, indirect, and total effects (standardized coefficients and associated standard errors in parentheses) of language and cognitive component skills on writing quality

	Writing quality		
Variable	Direct effect	Indirect effect	Total effect
Discourse oral language	.54 (.10)	–	.54 (.10)
Spelling	.22 (.10)	–	.22 (.10)
Handwriting fluency	.36 (.08)	–	.36 (.08)
Theory of mind	–	.15 (.05)	.15 (.05)
Inference	–	.08 (.05)	.08 (.05)
Comprehension monitor		.06 (.04)	.06 (.04)
Vocabulary	–	.29 (.06)	.29 (.06)
Grammatical knowledge	–	.14 (.06)	.14 (.06)
Working memory	–	.25 (.07)	.25 (.07)
Attention	–	.45 (.07)	.45 (.07)

were not related to topic knowledge about beavers (see Appendix) after accounting for their relations to discourse oral language and transcription skills. A total of 48% of variance in Beaver writing quality was explained by the included predictors.

Discussion

The results overall supported the hierarchical relations hypothesis. Although both the direct relations model and the direct and indirect relations models fit the data well, in the direct relations model, only transcription skills were independently related to written composition due to multicollinearity. In contrast, the hierarchical structural relations model according to DIEW revealed that discourse oral language and transcription skills completely mediated the relations of the other component skills (working memory, attention, vocabulary, grammatical knowledge, inference, perspective taking, and monitoring) to written composition. An important corollary of hierarchical relations is direct *and* indirect relations. In the vast majority of previous studies where the focus was on isolating 'unique' or direct predictors (e.g., using regression models similar to that shown in Figure 2a), indirect effects were masked and not recognized. Explicit specification of structural relations and associated recognition of indirect effects in theoretical models is important as they describe pathways by which component skills make contributions to written composition, a critical aspect missing in previous theoretical models of developmental writing (Kim & Park, 2019; Kim & Schatschneider,

2017). In addition, not recognizing indirect effects can mislead or confuse the field if indirect or mediated effects are inadvertently interpreted as absence of relations. The indirect relations were substantial for the majority of skills, including perspective taking (as measured by theory of mind), vocabulary, grammatical knowledge, working memory, and attention. These results are in line with previous investigations with primary-grade children (Kim & Park, 2019; Kim & Schatschneider, 2017) and lend support for the hierarchical relations of DIEW for children in upper elementary grades.

Although not a focal research question in this study, comparison of the present findings to similar studies with younger children might illuminate a potential developmental pattern. As stated above, DIEW posits differential contributions of component skills as a function of development. This hypothesis appears to be partially supported. Specifically, the comparison of standardized regression weights in Table 6 in the present study with those in Kim and Schatschneider (2017; Table 3) which included a similar set of skills for first graders revealed that the contributions of discourse oral language, vocabulary, and handwriting fluency were larger by .08, .10, .19, respectively, in the present study whereas those of spelling and working memory were smaller by .15 and .18, respectively. The larger contribution of oral language and decreased contribution of spelling in fourth graders are in line with the dynamic relations hypothesis of DIEW. However, the larger contribution of handwriting fluency in Grade 4, although somewhat

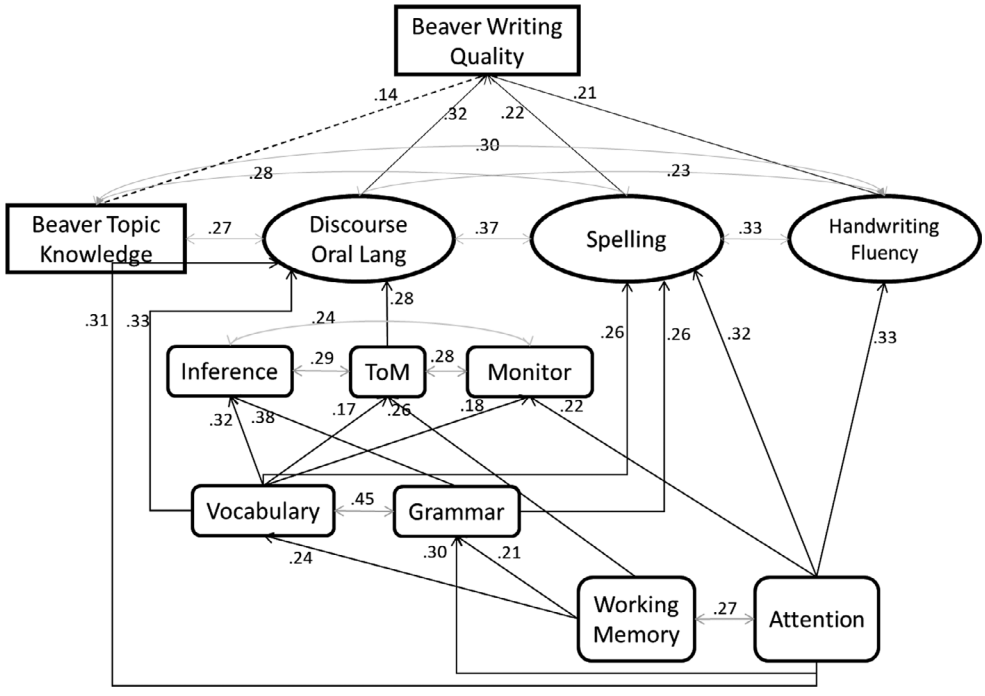

Figure 4. Standardized coefficients for DIEW with topic knowledge on beavers predicting writing quality on the Beaver task. Solid lines represent statistically significant relations ($p < .05$), whereas the dashed line from topic knowledge to writing quality represents a non-significant relation. Note that all other non-significant relations are not shown to reduce clutter. Grammar = Grammatical knowledge; Lang = Language; Monitor = Monitoring; ToM = Theory of Mind.

unexpected, was also reported in Wagner *et al.* (2011). Taken together, these results suggest an increasing role of fluency or automaticity in written composition at least up to a certain point of development. Once handwriting fluency is automatized, other skills such as oral language and higher order cognitive skills may exert greater influence on writing quality (Graham *et al.*, 1997; Kim & Park, 2019). Lastly, the smaller relative contribution of working memory to writing in this study may be due to the inclusion of attention in the present study as working memory and attention are related (see Fougnie, 2008 for a theoretical account) and their relations to writing are shared.

I hypothesized that the relation of topic knowledge may be constrained by oral language and transcription skills for developing writers. As expected, in a bivariate correlation, topic knowledge about beavers was moderately related with writing quality on the Beaver task (r = .36; but r = .53 with the latent variable of writing quality that includes other writing tasks – see Table 4), which is convergent with previous studies (e.g., Graham *et al.*, 2019; Olinghouse *et al.*, 2015). Topic knowledge was moderately related with language and transcription skills (e.g., r = .41 with discourse oral language; r = .40 with spelling), and once the other skills in Figure 4 were accounted for, the relation became weak (.14) and did not reach conventional statistical significance. It is important here to point out that lack of statistical significance of topic knowledge to written composition does not discount or deny the role of topic knowledge in writing. Given that statistical significance is largely a function of sample size, the relation would have reached conventional statistical significance with a somewhat larger sample size. What the present study indicates is the nature of its relation – the magnitude is reduced when accounting for language, cognitive, and transcription skills likely because they constrain the extent to which topic knowledge can contribute to writing. The constraining roles would be particularly germane to beginning writers as they develop oral language and transcription skills. For more advanced writers for whom transcription skills have been automatized and translation processes are proficient with sufficient language development, oral language and transcription skills are not likely to play as large of a constraining role, and, thus, topic knowledge may make a greater contribution to writing. Future longitudinal studies and/or cross-sectional studies with students at different developmental phases of writing will be informative.

Limitations, future directions, and educational implications

Several limitations and associated future directions are worth noting. First of all, although the present study measured writing skill using three tasks, topic knowledge was measured by a single task because the other tasks did not readily render measurement of topic knowledge, and it was practically difficult to administer more than three writing tasks (i.e., a larger assessment battery) in school contexts. Thus, observed variables were used instead of latent variables in addressing the question about the relation of topic knowledge to writing. Latent variables are preferred to reduce measurement error, and this was apparent in the amount of variance explained. In Figure 3b where a latent variable was used for written composition, the included variables explained 82% of its variance. In Figure 4, in contrast, 48% of variance was explained in the observed variable, Beaver writing quality. Therefore, it would be ideal to measure topic knowledge and associated writing quality using multiple tasks in future studies. The use of latent variables is preferred for other constructs as well, including attention, which was measured by the SWAN behavioural checklist in the present study. The attentional control construct in DIEW includes both cognitive (or inhibitory) control and

behavioural control. The SWAN checklist used in this study largely measures behavioural attentional control, and therefore, a useful future direction is to include multiple measures of attentional control (i.e., direct cognitive measures as well as behavioural ratings).

Second, a future replication with a larger sample size is warranted. For example, the relation of topic knowledge to writing did not reach conventional statistical significance; therefore, future replications with larger samples would be needed. Our speculation, together with previous studies, is that topic knowledge would be related to written composition, but its unique, independent contribution may be relatively small in the beginning phase of development because its relation is likely largely constrained by discourse oral language and transcription skills. However, the relative contributions may change over time with writing development such that after reaching a certain threshold in discourse oral language and transcription skills, topic knowledge may exert greater independent influence. Future cross-sectional studies with students in various developmental phases of writing as well as longitudinal studies are needed.

Given the correlational nature of the present study, causal educational implications are limited. However, together with extant empirical evidence, the present findings suggest that to promote development of children's writing skills, instruction needs to target multiple skills, including language, cognitive, print-related skills, and knowledge (e.g., topic knowledge). Moreover, the multiple chains of direct and indirect relations in DIEW indicate a need for a systematic approach in instruction. For example, to support development of transcription skills, explicit instruction is needed on phonology, orthography, and semantics (e.g., morphology; see Figure 1). To support discourse oral language (or oral composition), children need be to taught vocabulary and sentence structures as well as higher order cognitive skills and regulation. Although the relative or unique importance of language and higher order cognitive skills as well as content and topic knowledge may emerge after children have achieved a certain level of transcription skills, they require sustained instruction to develop. Therefore, early explicit and sustained instructional attention on these skills, in addition to transcription skills, is necessary.

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Appendix :

Standardized coefficients of language and cognitive skills to topic knowledge based on Figure 4

Variable	Coefficient (*SE*)	*p* value
Inference	.08 (.11)	.48
Theory of mind	.11 (.09)	.26
Monitoring	.05 (.09)	.60
Vocabulary	.16 (.10)	.11
Grammatical knowledge	.08 (.10)	.43
Working memory	−.04 (.09)	.66
Attention	.12 (.09)	.19

None of the language and cognitive component skills were related to topic knowledge after accounting for their contributions to discourse oral language and transcription skills. However, this does not indicate absence of their relations to topic knowledge. As shown in Tables 2 and 4, topic knowledge was weakly to moderately related to the language, cognitive, and print-related component skills (e.g., $.15 \leq rs \leq .38$ in Table 2 and $.29 \leq rs \leq .41$ in Table 4). Therefore, the lack of independent contributions of the language and cognitive skills to topic knowledge appears to be attributed to shared variance among them.‘