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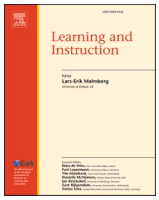

Disciplinary vocabulary and mastery of educational objectives in first-grade

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ABSTRACT

Background: In contrast with general academic words, disciplinary academic words have been less studied, in particular their frequency in educational materials and their contribution to educational outcomes in the early grades; therefore, there are no strong scholarly recommendations about teaching these words to young students. A better understanding of the importance of these words for young learners may complement our understanding of vocabulary's role in education and learning, as well as support the development of more effective interventions.
Aims: To measure the contribution of children's knowledge of science and social studies disciplinary words to their mastery of educational objectives.
Sample: One-hundred-and-seventy-four Chilean first-grade students in 26 schools.
Methods: We identified the general academic and disciplinary vocabulary present in 272 science and social studies materials. Using frequency and pedagogical criteria, we selected a set of science and social studies words, as well as general academic words, and assessed their knowledge in 174 Chilean first graders. Later we administered tests of the children's mastery of educational objectives in the two subjects. Using mixed-effects regression analyses, we examined the contribution of each type of word to mastery of educational goals.
Results: Disciplinary words were frequent in first-grade materials, but only science, not social studies words, had a significant contribution to children's mastery of the educational objectives after controlling for general vocabulary, general academic vocabulary, and working memory.
Conclusions: Disciplinary words are frequent, and science words specifically are relevant for first-grade educational objectives. Vocabulary interventions should include both general academic and disciplinary words.

This study seeks to contribute to our understanding of the role of different types of vocabulary for education. We address three main gaps in extant knowledge about this topic. First, this study focuses on disciplinary vocabulary, a specific kind of vocabulary that has been neglected in most of the literature. Second, the present study extends our knowledge to the role of disciplinary vocabulary in understanding and applying subject matter knowledge, instead of comprehending text, which has been the outcome of most vocabulary studies. Finally, the study examines the importance of disciplinary words for first graders, whereas virtually all previous studies of disciplinary words have been conducted in adolescents or adult learners.

Beyond their importance to our theoretical understanding of the role that vocabulary plays in education, these three issues also have practical implications for the way that different types of words are represented in learning materials, as well as for interventions that teach words to support learning and comprehension in the early grades.

1. Types of vocabulary

The breadth and depth of a person's lexicon is one of the best predictors of their reading comprehension (Binder et al., 2017; Language and Reading Research Consortium et al., 2019), as well as other educational outcomes (for example, standardized math tests, Bleses et al., 2016; oral science examinations, Dale et al., 2023). For several decades, researchers have tried to harness this power of vocabulary to improve students' outcomes, especially reading comprehension (e.g., Coyne et al., 2019; McKeown, 2019). These intervention studies have mostly focused on what scholars call *academic vocabulary*.

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1.1. Academic vocabulary

Academic vocabulary consists of words that are more frequent in academic contexts such as educational institutions and textbooks, than in non-academic contexts such as daily activities and conversations (Beck et al., 2002). According to Nagy and Townsend (2012), these words are necessary for accessing the content of academic texts and academic talk, and for "thinking like" an expert in academic disciplines such as history or science. Knoph et al. (2023) claim that this kind of vocabulary -in contrast to general vocabulary– is used to convey abstract, technical, and nuanced ideas within the context of academic language. Nagy and Townsend (2012) describe several common characteristics of these words: they tend to be more morphologically complex than non-academic words, are likely to have Latin or Greek roots, and are more likely to be abstract nouns and adjectives, than non-academic words. Knoph et al. (2023) conducted a study of the features of words in academic word lists, and further found that they tended to be longer than non-academic words.

Academic words in turn can be classified into *general academic words* and domain-specific, or *disciplinary*, words (Townsend et al., 2012).

1.2. General academic words

General academic words are those used with similar frequency across academic domains (McKeown, 2019). They are not specific to a subject matter such as biology, geography, or history, but are used to convey similar ideas and for similar purposes in different disciplines. For example, the words "process" or "function" are used more frequently in academic contexts than daily life, but they are used in similar ways and with similar frequency in different academic disciplines, such as history, biology, or physics.

1.3. Disciplinary words

The second type of academic vocabulary is "domain-specific" -or *disciplinary*-vocabulary: words that are unique to a discipline or subject matter, such as "habitat" in science, or "treaty" in social studies (Fitzgerald et al., 2020). These words are used in specific disciplines with specific meanings (Nagy & Townsend, 2012). According to Knoph et al. (2023), these words are less lexically ambiguous than general academic words and understanding them is essential to building conceptual knowledge in the disciplines in which they are used.

2. Academic vocabulary and educational outcomes

Many correlational studies have examined the contribution of academic vocabulary to reading comprehension. For example, Lawrence et al. (2019) assessed 5855 middle-school students and found that general academic vocabulary explained significant portions of variance in the Gates-McGinitie Reading Comprehension test. Wood et al. (2021) found that academic word use accounted for 16% of variance in reading comprehension of both English learners and students with language disabilities. Similarly, Meneses et al. (2017) assessed 810 Chilean middle-schoolers and found that academic vocabulary explained 15% unique variance in reading comprehension, after controlling for reading fluency and grade. A similar finding was reported by Romero-Contreras et al. (2021) with 1103 Mexican students: they found that proficiency in general academic vocabulary uniquely explained 11,2% of reading comprehension variance among upper elementary students and 5,3% among middle-school students.

A smaller number of studies have found a significant contribution of general academic vocabulary to other educational outcomes, specifically grades: Schuth et al. (2017), with 173 German fourth graders; Townsend et al. (2012), with 339 7th and 8th-graders; and Townsend et al. (2020), with 310 11th and 12th graders. These studies suggest that the contribution of general academic vocabulary is not limited to reading comprehension, but it extends to other educational outcomes. Because a substantive proportion of school learning occurs through independent reading, it is also likely that vocabulary effects on grades or other educational outcomes are at least partly mediated by reading comprehension.

Consistent with these findings, there is a consensus among scholars that general academic words should be explicitly taught in school (Beck et al., 2002; Snow, 2010), not only because they are frequent in school materials, but also because they are difficult to learn incidentally (Townsend et al., 2012). Thanks to these recommendations, significant experimental evidence has accumulated with regards to the impact of teaching these words on children's reading comprehension (for example, Apthorp et al., 2012; Coyne et al., 2019; McKeown, 2019). However, results from these studies have been similar to those of other vocabulary training evaluations, in that the acquisition of the words taught does not generally transfer into better results in reading comprehension (Stahl & Fairbanks, 1986; Wright & Cervetti, 2017). No intervention studies exist that evaluate the impact of teaching general academic words on students' grades or outcomes other than reading comprehension.

Regarding disciplinary words, although they are hypothesized to contribute to educational outcomes (Nagy & Townsend, 2012; Schleppegrell, 2004), studies that test this hypothesis are scarce. O'Reilly et al. (2019) assessed knowledge of ecology words of 3534 high-school students and found that a small number of words related to ecosystems were critical for students' comprehension of texts on that topic. Another study (Lazaroff & Vlach, 2022) found a unique contribution of science words (measured with a parental report) to science knowledge, measured with the Woodcock-Muñoz science assessment, in 91 children between the ages of three and eleven.

In line with this lack of evidence about disciplinary words and educational outcomes, there are no strong recommendations of teaching these words explicitly to young elementary children. Rather, scholars recommend focusing on teaching general academic words (Beck et al., 2002; Snow, 2010), partly because it is assumed that teachers already focus on their subject matter's vocabulary but neglect general academic words. For example, Snow (2010, p. 452) says "[Science teachers] of course recognize that teaching vocabulary is key, but typically focus on the science vocabulary, often without recognizing that those bolded words are defined with general-purpose academic words that students also do not know (…). Efforts to help students understand science cannot ignore their need to understand the words used to write and talk about science: the all-purpose academic words as well as the discipline-specific ones." Additionally, some scholars suggest that disciplinary words are not as common as general academic words in the early elementary years, and that they only become more frequent in the upper-grade classrooms (Knoph et al., 2023).

However, recent research suggests that disciplinary words may be frequent in educational materials from early on. Fitzgerald et al. (2022) examined a corpus of best-selling science, mathematics, and social studies textbooks used in 2nd, 3rd, 4th and 5th grade, and found that disciplinary vocabulary accounted for about one in twelve words. No similar analyses exist for first-grade materials, but if disciplinary words are also frequent at that level, they may seep into teachers' oral descriptions, explanations, and questions, therefore becoming a factor in children's ability to understand lessons.

3. The role of vocabulary for mastery of educational objectives

Most research on the role of vocabulary in education has focused on text comprehension -oral and written (e.g., Language and Reading Research Consortium et al., 2019). In contrast, curricula for the subject matters -such as science or social studies-is not typically organized around text comprehension, but rather, around the mastery of "educational objectives" that describe what operations or behaviors students are expected to be able to perform using what knowledge (Anderson

et al., 2001; Krathwohl, 2002). For example, an educational objective may be to "Name characteristics of living beings," and another may be "Explain why something is/is not a living being." Both objectives hinge on the same piece of knowledge, but they require different cognitive processes. Given the difference between comprehending a text and mastering an educational objective, it is relevant to ask the question of what role academic words, and disciplinary words in particular, may play in the subject matters.

In reading comprehension models, word knowledge is assumed to serve two main functions. First, knowing the meaning of the words in the text is necessary for accessing the direct meaning of the explicit propositions in it (Kintsch, 1998). Second, knowing the meaning of the words in a text is necessary for making inferences that link the different propositions with each other, allowing the individual to construct a coherent representation of the text (Language and Reading Research Consortium et al., 2019). These processes are similar for written text and for oral explanations or definitions, and in general, whenever a person is using language -oral or written-to construct knowledge about a complex process, concept, or phenomenon. For example, when children who cannot read are trying to master concepts such as "living being," "safety norms", or "healthy eating", they will be exposed to oral definitions, explanations, and descriptions, and they will need to understand the meaning of the propositions in those elements, and link them with each other and with previous knowledge through inferences, in much the same way that a literate person needs to do this to comprehend a text (Koerber & Osterhaus, 2019). This suggests that the role of vocabulary may be similar for comprehension of written text, and for developing concepts conveyed in other ways, such as through conversations, lectures, explanations, or videos.

On the other hand, and in contrast to what happens when a person is reading or listening to an uninterrupted text, a group of children who are having a conversation with a teacher about some concept may benefit from the teacher's scaffolding of word meanings. Thus, it is possible that a child's ignorance of a given word could be neutralized by teaching strategies such as substituting with a synonym, offering a definition, giving a concrete demonstration, or making the necessary connections (Wright & Gotwals, 2017). For example, if the teacher is explaining that a characteristic of living beings is that they all *reproduce,* the teacher may decide to make this knowledge more accessible for students by replacing the word *reproduce* with something like "having babies." Later, if we assess whether children have mastered the objective of "explaining why something is/is not a living being" children who knew the meaning of the word "*to reproduce*" would have no advantage over those who did not. Asked why a robot-dog is not a living being, they could both argue that "it does not have babies," and they would both be correct. For this reason, it is possible that, while knowledge of disciplinary words is relevant for comprehension of texts that are accessed independently, it is not as relevant -or not relevant at all-for understanding and using disciplinary knowledge accessed through the teaching of an adult. Therefore, in the present study we seek to elucidate whether young children's knowledge of disciplinary words does contribute to their attainment of curriculum goals in the subject matters of science and social studies.

4. The present study

The goal of the present study was to estimate the unique contribution of children's knowledge of social studies and science disciplinary words, to their mastery of first-grade social studies and science educational objectives.

Following recent studies about the high frequency of disciplinary words in second to fifth grade materials, and given the relevance of vocabulary to access the direct meaning of propositions and to construct coherent representations of concepts and processes central to the disciplines, we expected that knowledge of disciplinary words would make a significant contribution to first-grade children's mastery of the educational objectives in science and social studies, even after accounting for general vocabulary and for general academic vocabulary, as well as control variables such as age, socioeconomic status, and cognitive skills such as working memory.

Our hypothesis reflects the assumption that knowledge of the meaning of disciplinary words allows children to have access to the explanations, descriptions, demonstrations, and other resources that teachers use to scaffold disciplinary knowledge for children, and therefore, that children who enter first grade knowing more science and social studies words will master educational objectives in those subject matters to a greater degree.

The present study extends our knowledge about the role of academic vocabulary in several ways. First, it focuses on disciplinary words, which have been largely neglected in the literature. Second, it targets young learners, whereas most of the literature on academic vocabulary has evaluated older elementary or high-school students. Finally, it addresses the question of whether knowing these words is relevant not only for children whose main access to the curriculum is mediated by a teacher.

We focus on first grade students to extend current knowledge about disciplinary words to this age group, given the questions highlighted in our literature review about the potential relevance of this vocabulary for students who are not yet accessing text on their own. The two subject matters (science and social studies) were chosen because previous studies with higher grades have shown that these subject matters exhibit a substantial number of words specific to each one (Fitzgerald et al., 2022).

5. Method

5.1. Participants

Participants were 174 first grade students (93 female; average age 6 years 8 months minimum 5years 9 months, maximum 8 years 4 months) from 26 schools in the Metropolitan Region and the Maule Region of Chile. One hundred seventy-seven families provided consent, but 3 students did not participate because they were never present at the school for any testing. Of the 174 participating students, 18 did not complete one or either of the outcome assessments, due to repeated absences or not wanting to connect for more video-assessments. Outcome measures were imputed using multiple imputation in Mplus, with 50 imputed datasets, to take advantage of all data available.

Regarding distribution by type of school, 50.6% attended a public school, 42.5% a voucher school (schools that receive state funding but are privately managed), and 6.9% a private school. This sample has a slight over-representation of public schools: countrywide, 36.5% students attend public schools, 54.4% voucher, and 9.1% private. Only 140 families provided demographic information. Of these, 85.71% of the mothers and 85% of the fathers were Chilean, and the rest had other nationalities such as Haitian, Ecuadorian, Peruvian and Venezuelan. Average years of education for mothers was 11.7 years, and for fathers, 11.9 years, which is slightly lower than the national average (13.4 years). Thirteen children had a diagnosis of specific language disorder, one child had a diagnosis of autistic spectrum disorder, and five children were diagnosed with attention deficit disorder.

5.2. Word identification and selection

Words were extracted from the materials provided by the Chilean Ministry of Education. Chile has a national mandatory curriculum organized around educational objectives for each subject-matter and grade. Educational objectives are statements that describe behaviors that can be observed to assess whether a student can do something with a given knowledge, for example, recall it, comprehend it, apply it, etc. (Krathwohl, 2002). The Ministry classifies the large number of educational objectives in the Chilean curriculum in "basal" and "complementary." We only analyzed the basal educational objectives (six for

science and six for social studies). Appendix A lists the basal educational objectives that were the focus of our word search.

For basal objectives, the Ministry offers many online materials (textbooks, complementary texts, worksheets, games, tests). Teachers rely on these materials heavily in their daily planning (Fundación Chile, 2022). Our word search encompassed all materials provided online by the Ministry for the basal educational objectives for first-grade science and social studies (272 materials). Social Studies materials (N = 109) included four assessments, 29 worksheets, one hands-on activity, 16 games, 31 videos, two textbooks, and 26 informational textbooks. Science materials (N = 163) included six assessments, 21 worksheets, eight hands-on activities, 21 games, 64 informative books, five power point presentations, five textbooks, and 20 videos. The ministry links each material to one educational objective, allowing us to link each instance of each word to a specific educational objective.

Two elementary school teachers with specialization in science and two in social studies were trained to read each material, and to identify and code academic words. Operational definitions were derived from the conceptual definitions elaborated in the introduction; we also used and adapted the operational definitions in Fitzgerald et al. (2020). Table 1 shows operational definitions used for the coding procedure.

The first and third authors conducted the training, consisting of explaining operational definitions and analyzing examples. After training, each pair of coders double-coded a subset of materials to calculate agreement. The total number of words double-coded was 13,551 in Science and 9266 in Social Studies. All were coded as either non-academic, or one of the academic subcategories. An agreement was defined as a word coded by both coders in the same category. Agreements were divided by total number of words in the material. Average percentage of agreement across double-coded materials was 98.5% in Science and 98.0% in Social Studies. Once agreement was calculated, coders coded the remaining materials independently. They recorded each word family, indicating the material from which it came and the educational objective explicitly declared (if not explicit, an inference was made based on topic). A total of 2421 unique academic word families were identified. Table 2 displays the distribution of word types and tokens.

As Table 2 shows, disciplinary words are very common. Excluding exemplars and frequent disciplinary words (which are also frequent in daily language), disciplinary words account for 26.7% of academic word tokens in the Science materials, and 39.7% in the Social Studies materials. General academic words account for 10.5% of academic word tokens in Science and 4.6% of Social Studies materials.

Table 1
Operational definitions of academic words and subtypes used for coding (adapted from Fitzgerald et al., 2020).

Word Type	Definition
General Academic	Words more frequent in academic materials than daily conversations or fiction ("function", "characteristic"), used in different subject matters.
Science Disciplinary	Academic words that refer to the natural world (life sciences, earth sciences, physics, and chemistry) and natural phenomena.
Social Studies Disciplinary	Academic words that refer to the social world, human relations, societies, history, and the study of earth's surface, its societies, regions, and their representation.
Frequent Disciplinary	Science or social studies words also frequent in daily life with the same meaning ("plant", "week").
Polysemous Disciplinary	Words that have different meanings in everyday and academic language (e.g., "diet" refers to a weight-loss regimen or to the foods that an organism eat).
Exemplar Disciplinary	Exemplars of disciplinary categories (e.g., names of mammals such as "panda"; names of geographical accidents such as "valley").
Compound disc. terms	Disciplinary terms with more than one word, with a meaning different from that of each word ("life cycle", "common good").

Word frequency was aggregated by word family and by educational objective. Appendix B presents the 30 most common academic words in each subject matter (excluding disciplinary exemplars and frequent disciplinary terms), with frequencies.

Next, we selected a subset of words to be assessed. Selection was conducted by the four authors (two psychologists with PhDs in educational psychology, one language teacher with a PhD in linguistics, and one primary teacher). We first generated a list of the most frequent words per educational objective, and added words with low frequency, but critical for the educational objectives. From this preliminary list, we selected five to eight words per objective, attending to the following criteria: the word is NOT frequent in everyday language of 5-to-7-year-old Chilean first-graders[1]; and the word is relevant for the pedagogical approach declared in the curricular documents. For selecting general academic words, we used the additional criterion that the words must have a high frequency *across* educational objectives. To validate the selection, an elementary teacher was asked to select a limited number of words from the preliminary list based on the same criteria. Kappa coefficients between our team's selection and the teacher's selection were $k = 0.645$ for science ($p = .000$); $k = 0.745$ for social studies ($p = .000$) and $k = 0.656$ for general academic words ($p = .000$).

5.3. Measures and instruments

5.3.1. Knowledge of general and disciplinary academic vocabulary

In this study, we define "knowing a word" as knowing its meaning (semantics) as well as how it is used in language (what part of speech it is and what role it may play in a sentence) (Miller, 1999). In research, knowledge of a word usually refers to being able to perform certain tasks such as identifying a visual representation of the word, defining it, recognizing situations where it can be used, or using it in a sentence. In the present study, we used two tasks to measure word knowledge: pointing to a picture representing the word or defining it.

Once words were selected, instruments to assess children's knowledge were constructed, submitted to expert judges, and piloted with a sample of 41 first graders that did not participate in the final study. The assessment modality of each word was chosen depending on how concrete or abstract they were. Concrete words that could be represented unambiguously with an illustration were assessed with a pointing task (child must point to the correct picture), and abstract words were assessed with a definitional task (what does *X* mean). For example, the word "city" (ciudad) was assessed with a pointing task, while the verb "to respect" (respetar) was assessed with a definitional task.

Although there are other ways of assessing abstract words -for example, choosing a sentence where the word is correctly used, or using the word in a sentence-definitional tasks have been shown to be valid measures of vocabulary knowledge and are widely used with children as young as four (Hadley et al., 2016; Marinellie & Chan, 2006). Because general academic words in this study were all abstract (reflecting the general high frequency of abstract words in academic lexicon) they were all evaluated via the definitional task.

To build the pointing questions, we created illustrations for correct responses and distractors, maintaining the syntactic category of the target word (i.e. verbs, nouns, adjectives). For in-person assessments the assessor named the word and asked the child to point to the correct picture. For online testing, each image was assigned a colored frame, and children were asked "what color is [word]." Children adapted readily to this procedure. The definitional task followed the format "Tell

[1] There is no searchable digital corpus of non-academic materials relevant to the population of Chilean, or Latin America, first-grade children. The frequency of the words in "daily non-academic language" was estimated based on the experience of the researchers, considering that the chosen words would undergo further screening through pilot testing before being included in the regression study.

Table 2
Word types and tokens coded by subject matter.

Type of Word	Science		Social Studies		Total	
	Types	Tokens	Types	Tokens	Types	Tokens
General Academic	121 (12.2%)	589 (10.5%)	47 (3.3%)	255 (4.6%)	168 (6.9%)	844 (7.5%)
Disciplinary: Standard	193 (19.4%)	1295 (23.1%)	168 (11.8%)	1734 (31.0%)	361 (14.9%)	3029 (27.0%)
Disciplinary: Polysemous	42 (4.2%)	411 (7.3%)	24 (1.7%)	235 (4.2%)	66 (2.7%)	646 (5.8%)
Disciplinary: Compound	73 (7.3%)	369 (6.6%)	52 (3.6%)	261 (4.7%)	125 (5.2%)	630 (5.6%)
Disciplinary: Frequent	158 (15.9%)	1786 (31.8%)	40 (2.8%)	803 (14.4%)	198 (8.2%)	2589 (23.1%)
Disciplinary: Exemplar	407 (40.8%)	1160 (20.7%)	1096 (76.8%)	2306 (41.2%)	1503 (62.0%)	3466 (30.9%)
Total	994 (100%)	5610 (100%)	1427 (100%)	5594 (100%)	2421 (100%)	11,204 (100%)

me what X means …" or "What is X". The questions were submitted to experts (four first-grade teachers with at least three years of classroom experience), who judged each item in terms of difficulty, relevance to the curriculum, and in the case of pointing tasks, the clarity of illustrations and adequacy of distractors.

Based on expert judges' opinions, modifications were made to construct a pilot test. Three psychology students were trained, and they administered the pilot tests in two sessions to 41 first-grade students online. The pointing tasks were scored zero or one. Definitional questions were assigned zero points if response did not show knowledge of meaning or was a formulaic phrase (e.g. "respect your elders"); one point if it demonstrated generic knowledge that could also be applied to other words (e.g. "behavior is that you can behave well or badly"); or two points if it demonstrated specific knowledge (e.g. "benefit is something that does you good"). Score was not penalized for not using formal definitions. For example, if instead of defining the word "norm" the child said "in our classroom there is a norm that you raise your hand before speaking," they would receive full credit.

Three coders were trained in four rounds of 10 cases each. After each round, disagreements were reconciled, and modifications made to the manual. In round four, all coders had achieved at least 90% of agreement (maximum one disagreement in one round) with the master coder. Based on item difficulty and item-test correlations, some items were eliminated, and the final tests were constructed.

General Academic Vocabulary Test. Consisting of 15 definitional questions ("function", "identify", "obtain", "organize", "allow", "record", "select", "transform", "feature", "discover", "classify", "compare", "instruction", "consequence", and "describe"). Maximum is 30 and minimum is 0. Internal consistency (Cronbach's Alpha) was 0.803.

Science Disciplinary Vocabulary. Consisting of 27 questions, 11 definitional and 16 pointing tasks. Words are "material", "opaque", "texture", "transparent", "fabric", "sound", "vision", "sense organ", "hearing", "smell", "perceive", "need", "living being", "reproduction", "animal covering", "species", "araucaria", "cactus", "condor", "copihue", "pudú", "hygiene", "physical activity", "balanced", "self-care", "sugar", and "healthy habit". The 11 definitional questions were scored 0–2 (maximum 22 points) and the 16 pointing questions were scored 0–1 (maximum 16 points). The scale has a maximum of 38 and minimum of 0 points. Internal consistency is 0.810.

Social Studies Disciplinary Vocabulary. Consisting of 25 items, 11 definitional questions and 14 pointing questions. The words are "month", "week", "year", "capital", "city", "limit", "map", "ocean", "country", "region", "coast", "landscape", "vegetation", "community", "Australia", "Africa", "norms", "respect", "protect", "coexistence", "security", "behavior", "municipality", "carabineros [the Chilean police force]", "benefit". The 11 definitional questions were scored 0–2 (maximum 22 points) and the 14 pointing questions were scored 0–1 (maximum 14 points). The total scale has a maximum of 36 and minimum of zero. Internal consistency is 0.693.

5.3.2. *Mastery of educational objectives*

To evaluate students' mastery of the Science and Social Studies educational objectives, we analyzed each basal educational objective, and constructed, validated, and piloted questions for each.

Breakdown of Educational Objectives into Indicators and Questions. To construct the educational objectives test, we broke down each objective into indicators (specific observable behaviors). The 12 educational objectives were broken down into 61 indicators. An elementary teacher with experience in test construction coded all indicators, and the second author of the paper coded 20% (13 indicators) to assess agreement, and they agreed on 11 of the 13 (85% agreement). Then the four authors translated each indicator into test items with a question, stimulus (e.g., pictures, a fictional scenario), and scoring rubric. Some questions had sub-questions, for example, a yes-no question may be followed-up with a request for justification or examples.

None of the questions nor the rubrics included the words tested in the vocabulary tests. For instance, a question could be "Is this volcano alive? Why/why not?" avoiding the use of the words "need" or "reproduction". Children would get credit for answering with or without disciplinary words. For example, the child could say "because it can't have babies" or "because it does not eat/sleep," and would get the same credit as if they said "because it cannot *reproduce*" or "it does not have a *need* for food."

Questions were submitted to expert judgment by four experienced first-grade teachers who evaluated their difficulty and relevance for each educational objective. A pilot test with 34 questions was built for each subject matter and administered to 30 students. Two coders were trained to determine inter-coder agreement. Agreement was calculated with 11 cases using Intra Class Correlation (ICC). Of the 81 science sub-questions, five had ICCs between 0.7 and 0.79, 13 between 0.8 and 0.9, 25 between 0.9 and 0.99, and 38 questions had perfect agreement. Of the 48 Social Studies sub-questions, six had an ICC between 0.7 and 0.79, four between 0.8 and 0.89, six between 0.9 and 0.99, and the remaining 32 sub-questions had perfect agreement. Internal consistency (with Cronbach's alpha) and difficulty (with percentage correct) were calculated, and some items were altered to create the final tests.

Science Test. The Science test had 81 sub-questions scored between zero and five points. Maximum is 137 and minimum is zero. Internal consistency is 0.889.

Social Studies Test. The Social Studies test had 48 sub-questions, scored between zero and two points. Maximum is 47 and minimum is 0. Internal consistency is 0.825.

5.3.3. *Control variables*

General Vocabulary. General vocabulary was measured with the vocabulary scale of the Chilean version of the Wechsler Intelligence scale for children (WISC-V, Rosas et al., 2022). Internal consistency reported by authors is 0.701; in our data, it was 0.709. Raw score was used. Maximum is 25 points.

Working Memory. Working memory is a predictor of achievement (Kim et al., 2021; Waters et al., 2021), as well as a predictor of vocabulary growth in young children (Gathercole et al., 1992; Gray et al., 2022). Because students' working memory can at the same time

contribute to their knowledge of disciplinary words and their attainment of educational objectives, causing a spurious association, it is important to control for it in our analyses, to isolate the contribution of disciplinary words. We administered the digit-retention scale of the Chilean version of the Wechsler Intelligence scale for children (WISC-V, Rosas et al., 2022). Internal consistency reported by authors is 0.77; in our data, it was 0.720. The sum of the raw score of the three tasks that make up this test was used. Maximum is 27 points.

Days Between Testing. Days between administration of vocabulary measures and of educational objectives measures varied, especially between the two cohorts. Because children who waited more days between both measures may have had more opportunity to acquire subject matter knowledge, we controlled for this measure in all regression analyses.

Age. Children's age in months at the time of testing was calculated from birth dates provided by their school or parents.

Cohort. Cohort (2021-online vs 2022-in-person) was significantly related to all measures, so we entered it as a control in all regression variables. Because different schools were recruited during different cohorts, this was a school-level variable.

School Vulnerability Index. The school vulnerability index is the percentage of students classified as "vulnerable". A student is classified as vulnerable depending on the home per capita income, educational level of adults, and health data. This is a school-level measure. It was used as a proxy for individual SES, because individual demographic data was not available. Given that the Chilean school system is socioeconomically segregated, students' SES is typically homogeneous inside schools, so the school's percentage of students with a family income below the 40th percentile is widely used when an individual measure of socio-economic status is not available (Valenzuela et al., 2014). This was entered in models as a level-2, or school, variable.

5.4. Testing procedures

This study was initiated during the COVID-19 school closures. Chilean schools remained completely closed between March 15th and October 1st, 2020. After that, some private schools opened with half-schedules, and most public and voucher schools remained closed all of 2020. In 2021 schools were very strict about external personnel entering, so our 2021 assessments were conducted online. In 2022 we added a second, in-person cohort to boost our sample size. A total of 89 children (51.7%) were assessed online (2021 cohort), and 96 (55.8%) were assessed in-person (2022 cohort). All procedures were approved by the ethics review board of INSTITUTION BLINDED.

Because during 2021 (online cohort) children entered the study individually as they signed up, vocabulary and control assessments were administered between June and September 2021. The educational objectives assessments took place for that cohort between November 2021 and March 2022 (approximately six months later for each child). Due to school closures, we were not able to reach the desired number of participants, so an extension from the funding agency was obtained and an in-person cohort was added in March 2022. In this cohort, it was not possible to maintain six months between vocabulary and educational objectives assessments, because funding constraints required that all research activities cease in August. Thus, in the second cohort, vocabulary was tested between April and May 2022, and educational objectives in July. Because of the different times between the two assessments, we added the number of days between the two assessments as a control variable.

5.5. Analysis

To estimate the unique contribution of disciplinary vocabulary to mastery of educational objectives in Science and Social Studies in first grade, two regression analyses were conducted, one for each subject matter, controlling for relevant covariates. Multilevel modelling in MPlus was used to account for clustering at the school. Multilevel multiple imputation with 50 datasets was conducted before the multilevel regression analysis.

6. Results

Table 3 reports descriptive statistics for all variables in the regression study. As shown in the table, the general academic vocabulary scale was difficult for students: mean score is 4.21 out of 30. Several students scored zero points, even though 10 high-difficulty words were removed after the pilot.

Table 4 reports correlations between all variables in the study. The in-person cohort had significantly lower scores in all vocabulary and educational objectives variables, perhaps because they were younger (they were tested at the beginning of the school year). Days between vocabulary and objectives tests have a positive and significant correlation with the outcomes. All vocabulary measures correlate significantly and positively with each other, even the general academic vocabulary test, despite its difficulty.

Table 5 shows results of regression models. As expected, working memory and general vocabulary make significant contributions to children's mastery of educational objectives in both subjects. Aside from that, only science words were a significant predictor of the educational objectives test scores in that subject matter ($B = 0.417$, $B/SE = 5.724$, $p = .000$). Contrary to our hypothesis, knowledge of Social Studies words did not make a significant contribution to students' attainment of educational objectives in that discipline ($B = 0.068$, $B/SE = 1.030$, $p > .05$).

Also contrary to our hypothesis, the contribution of the general academic vocabulary score to the subject matter tests was not significant for either of the two subjects (for Science: $B = 0.042$, $B/SE = 0.510$, $p > .05$; for Social Studies: $B = 0.074$, $B/SE = 0.806$, $p > .420$). This may have been due to the restricted range in the test, caused by its extreme difficulty for children.

Because the disciplinary vocabulary tests included both definitional and pointing questions, but the general academic tests only included definitional questions, this may have caused a confound, since performance in each test may be influenced not only by word knowledge, but also by assessment modality. To address this issue, we ran a second analysis using only definitional questions of science and social studies words. Table 6 shows that, when we use only definitional questions for estimating children's knowledge of science and social studies words, the model results are essentially identical to the original analysis.

Finally, to estimate the schools' contribution to children's attainment of educational objectives, we calculated variance explained by schools after all predictors had been entered. For the full-scale models, this was 3% for science and 1.9% for social studies, and for the

Table 3
Descriptive statistics.

Variable	Min	Max	Mean	SD	Skew	Kurtosis
Age (months)	69	100	81.45	5.726	0.737	1.080
Working Memory	0	25	12.14	5.308	−0.135	−0.595
General Vocabulary	0	23	10.88	4.219	0.077	−0.155
General Academic Vocabulary	0	20	4.21	3.878	1.231	1.487
Science Disc. Vocabulary	5	26	15.56	5.429	0.001	−1.067
Social Studies Disc. Vocabulary	5	28	15.68	4.961	0.193	−0.770
Days Science Voc.-Ed. objectives	45	182	92.24	45.963	0.637	−1.016
Days Social Studies Voc.-Ed.objectives	45	184	92.65	43.536	0.635	−1.034
Science Ed.Objectives	18	94	58.21	15.445	−0.010	−0.598
Social Studies Ed. Objectives	3	35.50	19.37	6.983	0.019	−0.321

Note.Descriptives before multiple imputation.

Table 4
Bivariate correlations.

	1	2	3	4	5	6	7	8	9	10	11	12
1.Age in months	1											
2.School Vulnerability Index	−0.349**	1										
3.Cohort (1 = Online)	0.396 **	−0.757**	1									
4.Working Memory	0.264**	−0.486**	0.591**	1								
5.General Vocabulary	0.175	−0.301**	0.375**	0.498**	1							
6.General Academic Vocabulary	0.365 **	−0.560**	0.560**	0.585**	0.465**	1						
7.Science Vocabulary	0.357**	−0.649**	0.721**	0.691**	0.541**	0.724**	1					
8.Social Studies Vocabulary	0.384 **	−0.554**	0.625**	0.616**	0.484**	0.674**	0.746**	1				
9.Days Science voc.- Ed.Objectives	0.122	−0.605**	0.734**	0.453**	0.376**	0.397**	0.529**	0.436**	1			
10.Days Social Studies Voc-Ed. Objectives	0.155	−0.619**	0.756**	0.456**	0.372**	0.443**	0.563**	0.473**	0.965**	1		
11.Science Ed.Objectives	0.263**	−0.626**	0.691**	0.704**	0.546**	0.620**	0.791**	0.691**	0.569**	0.585**	1	
12.Social Studies Ed.Objectives	0.244 *	−0.547**	0.628**	0.662**	0.544**	0.550**	0.712**	0.587**	0.587**	0.609**	0.798**	1

Note.*p < .05 * p < .01.
Correlations before multiple imputation.

Table 5
Multilevel regression models with random intercepts for explaining mastery of science and social studies educational objectives (standardized).

	Science				Social Studies			
	B	SE	B/SE	p	B	SE	B/SE	p
School Vulnerability Index	−0.769	0.285	−2.700**	0.007	−0.675	0.577	−1.169	0.242
Cohort (0 = in-person)	0.408	0.289	1.414	0.157	0.519	0.638	0.813	0.416
Age (months)	−0.129	0.099	−1.307	0.191	−0.123	0.096	−1.286	0.198
Working memory	0.266	0.062	4.304**	0.000	0.313	0.064	4.903**	0.000
General vocabulary	0.151	0.082	1.839	0.066	0.208	0.072	2.883	0.004
Days Vocab-Ed.Objectives	0.039	0.101	0.389	0.697	0.223	0.105	2.124*	0.034
General Academic Voc.	0.042	0.083	0.510	0.610	0.074	0.092	0.806	0.420
Science Vocabulary	0.417	0.073	5.724**	0.000	–	–	–	–
Social Studies Vocabulary	–	–	–	–	0.068	0.066	1.030	0.303

Note. *p < .05 **p < .01.
Imputed data (multiple imputations with 50 datasets using MPlus).

Table 6
Multilevel regression models explaining mastery of science and social studies educational objectives (standardized), using only *definitional questions* for science and social studies vocabulary.

	Science				Social Studies			
	B	SE	B/SE	*p*	B	SE	B/SE	*p*
School Vulnerability Index	−0.792	0.311	−2.546*	0.011	−0.736	0.541	−1.361	0.174
Cohort (0 = in-person)	0.379	0.258	1.471	0.141	0.443	0.662	0.669	0.503
Age (months)	−0.117	0.086	−1.363	0.173	−0.121	0.088	−1.385	0.166
Working memory	0.320	0.066	4.854**	0.000	0.316	0.062	5.113**	0.000
General vocabulary	0.186	0.083	2.228*	0.026	0.205	0.072	2.871**	0.004
Days Vocab-Ed.Objectives	0.070	0.110	0.638	0.524	0.245	0.101	2.412*	0.016
General Academic Voc.	0.050	0.087	0.579	0.563	0.055	0.100	0.550	0.583
Science Vocabulary (only definitional)	0.313	0.088	3.549**	0.000	–	–	–	–
Social Studies Vocab. (only definitional)	–	–	–	–	0.095	0.086	1.105	0.269

Note. *p < .05 **p < .01.
Imputed data (multiple imputations with 50 datasets using MPlus).

definitional-scale models, variance explained by schools was 5.8% and 1.9% respectively. This suggests that schools contribute little to students' attainment of educational goals beyond their socio-economic composition, which is entered in the model as the school's vulnerability index.

7. Discussion

This study sought to estimate the contribution of first grade children's knowledge of disciplinary vocabulary associated with the Chilean curriculum to their mastery of the curriculum's science and social studies educational objectives.

To achieve our goals, we identified the frequency of disciplinary words in the Chilean curriculum materials for first-grade science and social studies, selected a set of words, assessed their knowledge among a sample of first graders, and tested the contribution of this knowledge to the students' mastery of the curriculum's educational objectives. Our curriculum analysis revealed that disciplinary words are very frequent in the first-grade curriculum materials. Regression analysis showed that children who knew the meaning of more science words at the beginning of the study achieved better mastery of science educational objectives at the end of the study. This, however, was not true for social studies words, the knowledge of which did not predict the attainment of social studies objectives.

A closer analysis of the social studies words that were extracted suggests that they exhibit more overlap than science words with daily-use words (compare science words such as "reproduce", "oxygen," or "habitat," with social studies words such as "norm", "behavior", or

"respect"). Thus, it is possible that the absence of effect of social studies words may reflect the inability of our social studies word test to effectively separate this construct from general word knowledge. Although our selection method required excluding words that were judged to be common in children's daily lives, many social studies words that were critical to a topic (e.g. "norms" and "respect" for the topic of social norms), were words that children probably do hear outside of school. Future work should determine whether this peculiarity of social studies disciplinary words is applicable to the higher grades, or if social studies words become increasingly "technical."

Conceptually, results about the important contribution of science words to science objectives complement our knowledge about the relation between disciplinary vocabulary and reading comprehension in older learners, extending it to younger children as well as to a different educational outcome: the mastery of disciplinary educational objectives. The fact that young children who cannot read independently benefited from entering first grade knowing more science words means that this vocabulary is an important support for understanding, recalling, and applying science knowledge, even when children are doing this construction with the scaffolding of a teacher. When explaining complex concepts, teachers may paraphrase or substitute disciplinary words with more familiar vocabulary to facilitate children's understanding (Meneses et al., 2016), and they may expect that this reduces the disadvantage of children who come to school knowing fewer specialized words. Our results suggest that individual differences in science vocabulary knowledge are relevant for learning, and that teachers would do well in taking the time to teach the meaning of disciplinary words while explaining complex concepts, instead of substituting or paraphrasing them.

Many scholars have recommended teaching general academic words explicitly to preschool and young elementary children (Beck et al., 2002; Snow, 2010), but the present results support the idea that vocabulary instruction programs for early elementary children should include primarily disciplinary vocabulary. This recommendation is consistent with recent approaches that propose integrating the teaching of reading, disciplinary vocabulary, and domain knowledge (Cabell & Hwang, 2020; Hwang et al., 2023). One central component of these programs is providing children with ample opportunities to encounter disciplinary words through wide reading of expository books (J. S. Kim, Burkhauser, et al., 2021).

In addition to showing that children benefit from knowing more disciplinary words in the field of science, the results of the regression analysis grant validity to the method used to select the words. Identifying relevant words to teach is critical for any vocabulary instruction program, especially considering systematic reviews that show that instructed words have an effect only when they appear in reading materials (Stahl & Fairbanks, 1986; Wright & Cervetti, 2017). Thus, for vocabulary instruction to impact students' educational outcomes, it is critical to choose words that appear in the materials that the students will confront. Studies show that selection of words for teaching in both naturalistic and research settings is not evidence-based or systematic (Hadley & Mendez, 2021; Wright & Neuman, 2014). Our word selection method, based on the words' frequency by educational objective, as well as their conceptual relation with those objectives, produced a list of science words the knowledge of which was highly predictive of children's performance in that discipline. This selection method may be used to create word lists relevant to any given curriculum, or it could be directly transferred to teachers to create their own lists. The same cannot be said, however, of the relevant social studies words, since in this study, knowledge of the social studies words we selected did not prove relevant for attainment of educational objectives.

The outcome measure of the study consisted of tests assessing children's mastery of the curriculum's educational objectives. Because the disciplinary words we assessed were taken from materials associated to those same educational objectives, it may be argued that both tests measure the same construct. However, educational objectives are descriptions of observable behaviors that account for students being able to do specific things with a given piece of knowledge. For example, the social studies objective "Explain and use some coexistence and safety norms at home, school, and in public" requires recall, comprehension, and application. In contrast, the vocabulary tests we constructed measured only whether children could show a picture representing the word or define it. A child may be able to define the word "norm" or use it meaningfully (for example, recite a norm such as "raise your hand before you speak"), and yet not be able to "explain" their appropriate use or function. Additionally, because neither the questions nor the rubrics of the educational objectives tests used the specific words, we believe the association between disciplinary word knowledge and mastery of educational objectives does not represent a mere methodological artifact.

One unexpected result of our study was that knowledge of general academic words did not make a significant contribution to children's mastery of educational objectives. A possible explanation is that there was a confound, because the test of general academic vocabulary included only definitional questions and the disciplinary tests included both pointing and definitional questions. Because definitional questions are more difficult than pointing ones, it is possible that this difficulty masked children's actual knowledge of the general academic words. However, several considerations suggest that assessment modality was not a factor in this result. First, in the definitional task children received credit for any relevant information about a word, eliminating demands associated with formal definitions. Most importantly, when we replicated the regression analysis using only the definitional questions of the disciplinary words, results were identical to the ones using both definitional and pointing tasks, which shows that there is something about the knowledge of the general academic words themselves -not their assessment modality-that is limiting their contribution to mastery of science and social studies objectives in this young sample. We noticed that in our corpus, general academic words such as "to identify" or "feature" tend to appear mostly in worksheets and assessments (e.g. "identify the living being" or "circle a feature of living beings"). Perhaps these words are not used so much during lessons and learning tasks, and therefore lack of knowledge of these words is not detrimental to children's learning.

However, the difficulty of the general academic word test does highlight a challenge for how to measure these words. Definitional questions of disciplinary words such as "species" or "behavior" were easier than those for general academic words, such as "function" or "characteristic". It is possible that such definitional tasks are not appropriate for very abstract words. A definitional task may be pertinent for intermediate abstraction words such as "need" or "norm", but the same may not be true for metalinguistic or epistemic terms such as "represent," "identify," or "compare." In the future, a more contextual task, such as selecting a sentence where the word is correctly used (Schuth et al., 2017), may better capture children's knowledge of these words.

We do not interpret these results to mean that general academic words should not be taught explicitly; on the contrary, these low scores underline the relevance of teaching these words, since they appeared frequently in the learning materials, and therefore children will have to eventually deal with them on a regular basis. Nagy and Townsend (2012) highlight that the teaching of highly abstract words such as these require multiple opportunities to use them in multiple contexts, more than simply defining them for children. In that sense, approaches that expose children to a large amount of academic language through wide reading may be essential for difficult vocabulary.

Another important limitation of this study is that the composition of the sample was not as originally planned, due to school closures caused by the COVID-19 pandemic. While we had planned a sample of over 300 students nested in 30 classrooms, the final sample was made up of 174 students distributed in 26 schools, limiting both the study's statistical power and the generalizability of results. Furthermore, the school

closures forced us to conduct part of our recruitment online. Finally, once we were able to go back to in-person testing, funding restrictions demanded that we finish the study in a period of four months, forcing us to shorten the time between vocabulary assessments and educational objectives tests, contrary to our original design, which required six months to allow children ample opportunity to receive instruction on the curriculum's educational objectives. Thus, not all children had the same learning opportunities. These factors not only created an unbalanced sample, but also introduced additional confounds. Although we strived to control for these issues in the statistical analyses, it is impossible to know the extent to which they may have influenced the results. Perhaps in the future a direct measure of students' learning opportunities should be planned and implemented, with the goal of accounting for potential impact of differences in exposure to instruction.

Another limitation is that, although we took words from the online materials offered by the Ministry, we have a "black box" of what children did in schools, as we did not measure whether and how much teachers used the materials in class, or whether children had access to the materials. Although we did calculate that schools contributed little variance to children's outcomes after accounting for all variables in our models, in a strict sense we can only make inferences regarding the contribution of children's word knowledge to their attainment of educational objectives, and not about the role of the schools in this process.

A final limitation of the study is its correlational nature, which prevents us from drawing causal inferences. A well-designed experiment is necessary to establish whether teaching disciplinary words will have an impact on children's ability to achieve the educational objectives of the curriculum in science and social studies. Most studies of word teaching have been conducted with general academic language; future intervention research should also examine the impact of teaching disciplinary vocabulary on different outcomes such as subject matter learning and reading comprehension.

This study's results show that disciplinary words are ubiquitous in learning materials from an early age, and that children who exhibit more knowledge of science words will go on to demonstrated better attainment of the national curriculum's science educational objectives. These findings highlight the role of this type of vocabulary -in addition to general academic vocabulary-for supporting learning in specific academic subjects.

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CRediT authorship contribution statement

Katherine Strasser: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Alejandra Meneses:** Writing – review & editing, Investigation, Conceptualization. **Carolina Iturra:** Writing – review & editing, Investigation, Conceptualization. **Anneliese Marín:** Writing – review & editing, Project administration, Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.learninstruc.2024.102000.

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