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Building Semantic Networks: The Impact of a Vocabulary Intervention on Preschoolers' Depth of Word Knowledge

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ABSTRACT

In this study, the authors examined the impact of a vocabulary intervention designed to support vocabulary depth, or the building of semantic networks, in preschool children (n = 30). The authors further investigated the effect of specific instructional strategies on growth in vocabulary depth. The intervention employed shared book reading and guided play methods to teach words in conceptually linked categories, such as taxonomic and thematic groups. Using a within-subjects design, analyses indicated that the intervention had significant positive effects on children's depth of vocabulary knowledge. Children showed significantly greater growth in vocabulary depth for words taught in taxonomies as compared with words taught in themes. Three types of semantic information were learned more deeply for taxonomy words as compared with theme words: information about category membership, perceptual features, and object function. Results suggest that fostering deep vocabulary knowledge involves not only teaching single word entities but also introducing systems of conceptually related words to build semantic networks.

To make meaning from text, children draw on a wealth of accumulated knowledge about words and the concepts that words signify. Comprehension requires not only that children have broad vocabularies (i.e., a large number of words in their lexicon) but also that those words activate rich, interconnected networks of conceptual knowledge (Anderson & Freebody, 1985; Kintsch, 1998). For example, when reading a passage and coming across the word *sparrow*, a child retrieves not only meaning information for that single word but also all the associated knowledge that he or she has built over time: A sparrow is a bird and therefore has feathers, wings, and a beak and lays eggs. The child may also access words commonly used in context with *sparrow*, such as *robin*, *egg*, *worm*, *nest*, and *fly*, to help him or her interpret the passage. There is growing consensus that this knowledge base that supports word depth is critical for young readers (Hirsch, 2006; Neuman, 2010).

Networks of word knowledge, often referred to as vocabulary depth, play a unique and powerful role in supporting children's understanding of what they read (Ouellette, 2006; Roth, Speece, & Cooper, 2002; Tannenbaum, Torgesen, & Wagner, 2006). The National Early Literacy Panel (2008) found that children's ability to supply definitions for words (a measure of vocabulary depth) was a significantly stronger predictor of later decoding and reading comprehension than receptive vocabulary measures (which typically tap the surface-level

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knowledge of words associated with vocabulary breadth) were. Moreover, vocabulary depth predicts reading comprehension above and beyond the association explained by breadth (Ouellette, 2006). Unlike fast-mapped, shallow knowledge about words, deep word knowledge slowly accumulates over time (Bloom, 2002; Bolger, Balass, Landen, & Perfetti, 2008), and intentional efforts at fostering this knowledge in classrooms should begin early. However, the available literature on supporting depth of vocabulary knowledge in early childhood learners is sparse, with limited information about which features of instruction might support the building of semantic networks.

In the present study, we examined the impact of a vocabulary intervention designed to support depth in preschool children through the reading of informational texts and guided play activities. We further investigated the effect of specific instructional strategies on depth, namely, teaching words in conceptually related categories and in multiple contexts.

Theoretical Framework

The term *vocabulary depth* has been defined as referring to the quality of knowledge about words, rather than the quantity of words known (Anderson & Freebody, 1985). Whereas some perspectives on depth emphasize richness of knowledge for individual lexical representations (e.g., Perfetti, 2007), depth has also been envisioned as the connected networks of semantic knowledge that underpin word labels, with similar concepts linked together by shared semantic relations (Anderson & Freebody, 1985). In this view, word learning is not simply the process by which isolated object–label associations are added to the mental lexicon one by one but also involves the learning of interrelated clusters of concepts, in which the knowledge of one concept supports the learning of another. For example, it is difficult for a child to understand the word *shore* without also knowing *ocean*, and learning the word *mosquito* provides an opportunity to learn the general properties of an insect. These concepts are linked, so the learning of one can help leverage the learning of another, especially if those links are explicitly highlighted for children (Durso & Coggins, 1991).

The idea of semantic networks has a long history in cognitive psychology (Collins & Loftus, 1975; Collins & Quillian, 1969), with a recent renewal of interest with new methodological innovations (Wojcik, 2017). A new line of research applies network science, an approach that draws on graph theory to examine complex systems such as social networks and the internet (Börner, Sanyal, & Vespignani, 2007), to further investigate how knowledge is organized in the mental lexicon. Using tools from network science, word knowledge can be modeled as semantic networks in which words are represented as nodes and semantic relations as connections between those nodes (Hills, Maouene, Maouene, Sheya, & Smith, 2009; Steyvers & Tenenbaum, 2005). These semantic networks have a small-world structure, meaning that there is a relatively small distance between any two words and that words tend to form clusters more than would be expected by chance (Steyvers & Tenenbaum, 2005). Further, semantic networks are scale-free, meaning that only a small number of words are highly connected to other words (especially early acquired words such as *truck*), with many low-frequency words having only a few connections (Hills et al., 2009). These structural properties are believed to support efficient language processing and word retrieval (Borovsky, Ellis, Evans, & Elman, 2016b; Griffiths, Steyvers, & Firl, 2007; Solé, Corominas-Murtra, Valverde, & Steels, 2010; Vitevitch, 2008).

The small-world, scale-free structure of semantic networks likely emerges as children's vocabularies grow, with reorganization and/or expansion of networks occurring as new words are added. Semantic networks expand through the principle of preferential attachment: When new words are added to the semantic network, they are more likely to connect to words that are already highly connected (Sailor, 2013), creating the characteristic scale-free, or clustered, structure. The principle of preferential attachment has important consequences for theories of word-learning: It suggests that new words are added to the semantic network by further differentiating or reorganizing existing networks (Steyvers & Tenenbaum, 2005). Furthermore, it implies that children may be more likely to learn new words that are semantically related to known words than those that are unrelated (Borovsky, Ellis, Evans, & Elman, 2016a). That is, when children encounter a variety of new words in their environment, they may be more likely to acquire and retain the words that have ready-made semantic relations or hooks to existing networks. Borovsky and colleagues found that 2-year-olds were better at recognizing novel words when they knew more about the category to which the words belonged, as opposed to words for which they had only low category knowledge. These findings indicate that dense semantic networks may help leverage word learning because of the knowledge children already have about semantically similar words in the network, effectively giving them a head start in learning the new words.

Dense semantic networks, because of their clustered structure, may also support the quicker processing of related words (Borovsky et al., 2016b). The principle of preferential attachment also helps explain the frequently observed Matthew effect (Stanovich, 1986): Children who already have rich knowledge about words are able to acquire new word knowledge rapidly, whereas those with less extensive vocabularies acquire new words at a slower rate, perhaps because of fewer available hooks for new words. Researchers comparing 15–36-month-old children with faster and slower vocabulary growth trajectories found that there were significant differences in the structure of each group's semantic networks, with the semantic networks of children with slow vocabulary growth showing less cohesive and less efficiently structured networks (Beckage, Smith, & Hills, 2011).

Broadly, then, growth in vocabulary depth can be considered as the increased semantic differentiation and reorganization of semantic networks that occur as new words are added to the lexicon (Steyvers & Tenenbaum, 2005). Words that are known more deeply have a greater number of connections to more words and, thus, have more elaborated, and more differentiated, meanings. Semantic network theory further suggests that growth in depth can be supported by building networks of conceptually linked knowledge so new, semantically similar words can be acquired more readily (Borovsky et al., 2016a). The goal of the present study was to apply these theories in an instructional context, explicitly teaching children to recognize the conceptual relations between words to build deep vocabulary knowledge more efficiently and extensively.

Factors That Support Depth of Knowledge

Repeated Encounters With Words and Explicit Word Meaning Information

Children are able to glean some information about a word from only a single exposure. To do so, they draw on social cues in their environment, an object's or action's perceptual features, syntactic information, and their preexisting word knowledge, which supports the integration of the new word into the semantic network in its proper place (Alt, Plante, & Creusere, 2004; Borovsky, Elman, & Kutas, 2012; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992). A single, initial encounter with a word can result in a fast-mapped lexical representation, consisting of minimal phonological (Graf Estes, Evans, Alibali, & Saffran, 2007; Swingley, 2007) or syntactic (Yuan & Fisher, 2009) information, but typically includes little semantic information. Preschool children's semantic knowledge has been shown to increase with each additional encounter with a word (McGregor, Friedman, Reilly, & Newman, 2002), with multiple contexts that provide cues for meaning expediting the word-learning process (Frishkoff, Perfetti, & Collins-Thompson, 2011). In a study in which students in kindergarten through grade 2 heard a book read four times but were not given any extratextual information about words, students were able to give verbal explanations for 15% of the target words simply from hearing them used repeatedly in the book (Biemiller & Boote, 2006), demonstrating at least surface-level learning from exposure alone.

Providing explicit information about the meanings of words has been shown to support depth of vocabulary knowledge beyond the contribution of repeated encounters alone (Bolger et al., 2008). In Biemiller and Boote's (2006) study, 22% of words were learned when brief definitions were included during the book-reading sessions. Similarly, preschoolers had significantly greater depth in knowledge ($d = 0.41$) for words taught with definitions versus words simply heard during repeated readings of books (Dickinson et al., 2018).

Types of Semantic Information

Learning certain types of information about words may be particularly helpful for building semantic networks. Hills et al. (2009), in modeling the semantic networks of nouns for 2.5-year-olds, found that categorical clusters could be formed on the basis of either shared perceptual features or shared object function information (i.e., what something does or is used for). The authors concluded that perceptual information may provide a gateway to some superordinate categories, with object function information further refining these categories. These findings have instructional implications, suggesting that providing both perceptual and object function information about words might help children form categories on the basis of those overlapping features. Preschool vocabulary interventions that provide explicit information about target words' taxonomies also have had positive effects (Gonzalez et al., 2010; Neuman, Newman, & Dwyer, 2011), indicating that highlighting hierarchical relations between words is also beneficial in supporting vocabulary depth. Combining these types of information—providing a category label and highlighting their common perceptual and functional features—may be even more effective in helping children organize their semantic network effectively in providing a top-down organizational structure.

Activity Settings: Book Reading and Play

Another promising approach for fostering depth is to teach words in more than one activity setting during the school day (i.e., Wasik & Bond, 2001), as this approach builds in frequent encounters with words and allows for connections to be made to a variety of related words. Many successful vocabulary interventions use shared book reading as the main activity setting and typically have moderate effects on vocabulary knowledge (d = 0.60; National Early Literacy Panel, 2008). Informational books are thought to be a particularly rich source for building conceptual knowledge (Duke, Halvorsen, & Knight, 2012). However, there is some concern that book-reading interventions must become more potent to build the deep word knowledge important for later reading comprehension (Beck & McKeown, 2007; Neuman et al., 2011; Roskos & Burstein, 2011).

One approach to boosting the impact of book reading is to pair play (or playful activities) with book-reading sessions (Hadley, Dickinson, Hirsh-Pasek, Golinkoff, & Nesbitt, 2016; Roskos & Burstein, 2011; Weisberg et al., 2015). An emerging line of research has explored the learning possibilities of guided play, a method in which early childhood teachers play with children while scaffolding them toward specific learning aims such as learning new words (K.R. Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Han, Moore, Vukelich, & Buell, 2010; Hirsh-Pasek & Golinkoff, 2011; Weisberg et al., 2015). The children in guided play maintain their agency in actively directing the learning within the more constrained context provided by the teacher.

Pairing book reading and guided play show promise for fostering depth of knowledge, as combining these activity settings builds in repeated encounters with words and explicit semantic information about words. Shared book-reading sessions can serve as a foundation for later play, as children may gain a fast-mapped understanding of a book's new words and a narrative that can serve as the basis of play ideas. Guided play, typically a more responsive and child-led activity than book reading, also provides a space for children to actively process word relations and meanings. Guided play can also be the source of semantic information as new words are indexed to play props (e.g., using a small chair toy to learn *throne*; Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004) or illustrated through play characters' actions and feelings.

Relations Between Words

Semantic network theory suggests that supporting children's knowledge of the semantic relations between words may foster depth because new words are thought to hook into the semantic network more readily when they are related to known words (Borovsky et al., 2016a; Steyvers & Tenenbaum, 2005). One approach to doing so, pioneered and extensively studied by Neuman and colleagues (e.g., Neuman et al., 2011), is to teach words in conceptually related categories, explicitly labeling words' common semantic features and category membership to build semantic networks more efficiently than would otherwise be possible.

The practice of teaching words in categories draws on language research suggesting that improving the quality of word knowledge involves not only adding more information about individual concepts but also changes in how concepts are organized (A.V. Fisher, Godwin, Matlen, & Unger, 2015). The ability to more finely differentiate these categories, and group categories into nested hierarchies, develops as children gain more knowledge about the world around them (A.V. Fisher et al., 2015; Gelman & O'Reilly, 1988; Hills et al., 2009). In particular, research has focused on children's developing understanding of and facility with two types of categories: thematic and taxonomic. Experimental research with 2-year-olds found that children were sensitive to both thematic and taxonomic relations, suggesting that words could be integrated into a semantic network on the basis of either relation type (Arias-Trejo & Plunkett, 2013).

Thematically Related Words

Thematically related words are involved in the same event (e.g., *rain/umbrella*) or are spatially or causally related (e.g., *car/garage*). Thematically related words do not share inherent characteristics and are not things of the same type (Markman, 1989). When children learn about concepts in thematic groups, they gain an understanding of semantic relations between words, such as causal or spatial relations (Markman, 1989). Many early childhood curricula capitalize on the learning possibilities of thematic categories by organizing instruction around themes. For example, a "farm, markets, and food" theme (e.g., as used by Shine Early Learning in their Head Start curriculum) involves instruction about growing, purchasing, and cooking food, thereby building a rich semantic network of words from a variety of form classes that co-occur in the same context.

Previous studies have designed preschool vocabulary instruction around words grouped in thematic categories (Pollard-Durodola et al., 2011; Wasik & Bond, 2001). In their Words of Oral Reading and Language Development (WORLD) intervention, Pollard-Durodola and colleagues presented new words in thematic groups so children could make connections between concepts and build more extended semantic networks. For example, the researchers chose two narrative and two informational texts for a water theme (e.g., *The Snowy Day* by Ezra Jack Keats, *Amazing Water* by Melvin Berger) and then selected lexical sets of thematically related words, such as *raindrop*, *liquid*, *frozen*, and *drain*, for instruction. Children in the WORLD intervention condition showed significantly greater growth in vocabulary depth on researcher-created measures than those in the control condition.

Taxonomically Related Words

Words in taxonomies are hierarchically related, organized in a nested structure so each higher order category is increasingly general. Taxonomies allow for inference making based on perceptual features (e.g., an animal with five digits can be categorized as a primate), which in turn supports inductions that are not perceptually available (e.g., the animal likely sees in color and is warm-blooded; Gelman & Markman, 1987). Taxonomic knowledge therefore provides a shortcut for acquiring information about the world. There is evidence that taxonomic organization and semantic knowledge are reciprocally related, with semantic knowledge supporting children's ability to categorize and, in turn, more differentiated taxonomic organization leveraging children's word learning (A.V. Fisher et al., 2015; Kaefer & Neuman, 2013). Using taxonomies also exhibits features of academic language such as organizing information into a hierarchical structure (Snow & Uccelli, 2009) and is central to academic discourse in disciplines such as science and social studies (Richardson Bruna, Vann, & Perales Escudero, 2007; Wignell, Martin, & Eggins, 1989). Gaining proficiency with this form of conceptual organization, then, can help support students' ability to acquire and communicate knowledge using the language of schooling (Schleppegrell, 2012).

Neuman and colleagues' (Neuman & Dwyer, 2011; Neuman et al., 2011; Neuman, Pinkham, & Kaefer, 2015) World of Words (WOW) intervention was the first to teach words in taxonomies as a way of promoting vocabulary growth in preschoolers from low-income families (Neuman et al., 2011). In a large cluster-randomized trial, 3- and 4-year-olds in the WOW intervention condition learned significantly more words than control children on researcher-created measures (d = 0.62) and could use their knowledge of categories to identify new words (Neuman & Dwyer, 2011). Growth in both vocabulary and category knowledge was sustained at a six-month posttest.

Thematically Versus Taxonomically Related Words

Although interventions such as WOW and WORLD indicate the value of teaching words in both thematically and taxonomically related groups, teaching words in taxonomies may be of particular advantage because instruction can capitalize on their hierarchical nature; that is, once the properties of a category are taught, those properties can be applied to all the exemplars in that category without a great deal of additional instruction (Kaefer & Neuman, 2013). Pinkham, Kaefer, and Neuman (2014) compared two conditions: (1) children who heard target words as part of a researcher-created storybook in which the text provides support for the words' taxonomic category (e.g., "a faroe [type of bird] lays eggs because it is a bird"; p. 3) and (2) children who heard the same target words as part of a traditional, researcher-created storybook in which the text introduces target words as part of a thematic grouping (e.g., "a faroe has a sofa and lives in a house"; p. 4). Children in the taxonomic storybook condition knew significantly more words at posttest than those in the traditional storybook condition.

We add to these findings here by contrasting growth in word knowledge for target words taught in taxonomies versus those taught in thematic categories. We further examine differences in the types of semantic information learned by children for taxonomic versus thematic words, focusing on the semantic information types that are hypothesized to be especially helpful in building extensive semantic networks (Hills et al., 2009; Neuman et al., 2011).

Integrating Knowledge Across Contexts

Another potential tool in building rich semantic networks is to teach words in multiple contexts. (We use *context* here in a linguistic sense, to mean the words or phrases surrounding the word in question.) Research on semantic networks has suggested that one way words are linked to others is simply hearing them used in the same context (e.g., *dog/bone*; Arias-Trejo & Plunkett, 2013). Words that are contextually diverse (i.e., those that co-occur with a greater variety of words in adult speech) are acquired earlier by young children (Hills, Maouene, Riordan, & Smith, 2010), suggesting that words heard frequently in multiple contexts are more quickly integrated into children's semantic networks, as there are more potential points of association to existing knowledge.

Such research has indicated that hearing words used in multiple contexts may be beneficial for word learning. In practice, however, there have been mixed findings about the efficacy of this approach. Some research has indicated that young children learn more about new words, particularly verbs and adjectives, when they are presented consistently in a single context (Goldberg, Casenhiser, & Sethuraman, 2004). For example, preschoolers who learned new words from the same book read three times learned and retained significantly more words than those who learned the same new words encountered in three different books (Horst, Parsons, & Bryan, 2011). Other research has found that diverse contexts, as compared with the same number of exposures in a single context, are helpful for word learning across a range of ages (Bolger et al., 2008; McKeown & Beck, 2014; Suanda, Mugwanya, & Namy, 2014).

Given these conflicting results, we hypothesized that it may be beneficial to give young children substantial experience with words in one context, establishing strong associative links to typically co-occurring words, before building links to additional co-occurring words in additional contexts. In the present study, one set of words was taught in a single unit, through book reading and play focused on either vegetables or flowers, and a second set of words was taught in both units (vegetables and flowers). The learning of these two word sets was then compared, controlling for exposure.

The Present Study

The goals of the present study were to examine the effects of an intervention designed to support preschool children's depth of vocabulary knowledge through informational book reading and play, as well as to examine specific features of instruction that supported vocabulary depth. We explored four research questions:

1. Did children show significant growth in their knowledge of target words on a vocabulary depth measure, as compared with their knowledge of exposure and control words?
2. Did children show significantly greater increases in knowledge for taxonomically related versus thematically related words?
3. Were there differences in children's learning of certain types of semantic information (category, object function, and perceptual information) for taxonomically related words versus thematically related words?
4. Did children show significantly greater increases in knowledge for words taught in two contexts (here defined as units) versus one?

Methods

Research Participants

The participants were 30 children enrolled in three preschool classrooms from a state-funded program for low-income families in a Southeastern U.S. city. The sample comprised only children who did not have an Individualized Education Plan and who understood enough English to follow directions, as reported by their teacher. The average age at pretest was 59.6 months (standard deviation = 3.1 months). The sample was approximately 43% male, and based on teacher reports, 76.7% of the sample children were African American, 6.7% Hispanic, 10% Caucasian, and 6.6% designated as biracial or of another ethnicity. Thirteen percent of the children were English learners. Within each classroom, children were randomly assigned to a mixed-gender playgroup of three children. Children remained in the same playgroup for the duration of the intervention. The first author, an experienced classroom teacher and trained educational researcher, delivered the intervention to the children.

Materials: Book and Word Selection

We chose two commercially available informational texts that contained information about flowers (*Planting a Rainbow* by Lois Ehlert) and vegetables (*Vegetables in the Garden* by Pascale de Bourgoing and Gallimard Jeunesse). Both books include descriptions of the plant-growing process and of different category members, such as types of vegetables or flowers. The texts are comparable in terms of difficulty, as measured by word frequency and sentence length (*Vegetables in the Garden* has a Lexile text score of 600L–700L, and *Planting a Rainbow*'s Lexile score is 700L–800L). All children heard both books, but half of the 10 playgroups were randomly assigned to start with the flowers book and the other half with the vegetables book.

We selected eight target words from each book (16 words total). These words comprise the taxonomy name (vegetables or flowers), five words for taxonomy members (e.g., *artichoke*, *tiger lily*), and two theme words that are thematically, but not taxonomically, related to the category (e.g., *vines* for the vegetables book, *petals* for the flowers book). Therefore, both books include instruction of both taxonomy and theme words. Five additional target words (*stem*, *bulb*, *seeds*, *soil*, and *roots*) were taught from both books, with the intention of helping children integrate the categories of vegetables and flowers into the larger category of growing things, thereby creating a more comprehensive semantic network. We selected three exposure words for each book (six total) that are not explicitly defined in the texts. We also selected eight control words, equivalent in difficulty to the target and exposure words, that do not appear in the books and were not used or taught during the intervention.

To evaluate how comparable study words were in terms of difficulty, we used several metrics. First, we evaluated the relative concreteness of words, as the perceptual accessibility of words has been shown to be a major contributing factor in preschool children's ability to learn those words (Hadley et al., 2016). We obtained concreteness ratings using Brysbaert, Warriner, and Kuperman's (2014) ratings for 40,000 words, for which participants rated words' concreteness on a scale from 1 (*highly abstract*) to 5 (*highly concrete*). The concreteness of the theme and taxonomy words in our study is comparable, as is the concreteness of the target, exposure, and control words and the one- and two-unit words (see Appendix A).

We also used age-of-acquisition (AoA) norms (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012) to compare words. AoA norms represent the average age at which a word is understood. The taxonomy and theme words in our study have comparable average AoA, as do the target, exposure, and control words and the one- and two-unit words. In general, the average AoA for the words used (mean [*M*] = 7.26 years) is older than our sample's average age (*M* = 4.96 years), meaning that participants were unlikely to have extensive knowledge of the study words at pretest (see Appendix A).

As a final metric for evaluating the comparability of words, we evaluated the frequency with which study words appear in written text, using Zeno, Ivens, Millard, and Duvvuri's (1995) corpus of written texts used in schools, including textbooks, literature, and nonfiction. If a word appears more frequently in text, it is assumed to be relatively more common and easier to learn. In Appendix A, we report the standard frequency index (SFI; Zeno et al., 1995) for each word used in this study. This value is a logarithmic transformation of the frequency of type per million tokens, weighted by an index of dispersion of the word across content areas. The range in Zeno et al.'s corpus is from 3.5 (0.0002 frequency per million) to 88.3 (67,500 frequency per million). On average, the taxonomy words in this study appear less frequently in written text (*M* = 39.0) than the theme words (*M* = 52.2). The target, exposure, and control words are comparable in terms of frequency. The one-unit words have a higher SFI (*M* = 41.5) than the two-unit words (*M* = 55.3).

In summary, the words selected for this study are all highly concrete and thus thought to be all relatively easy to learn (Hadley et al., 2016). The average age at which study words are typically acquired is also comparable across our groups of words. However, the taxonomy words, with the exception of *flower* and *vegetable*, appear less frequently in written text used in schools. Taxonomy members are by their nature more specific and less commonly used than theme words, and therefore may be less familiar to children. To control for the possibility that participants may have had more knowledge of our theme words than our taxonomy words at pretest, we included pretest knowledge of words as a covariate in all analyses.

See Appendix A for our complete list of words, along with their concreteness, AoA, and frequency ratings and word-level pretest and posttest means for each vocabulary measure.

Procedures

We conducted the intervention over a two-month period, from February to April 2013. The intervention included one book on vegetables and another on flowers. Activities based on each book lasted for four days each. Mixed-gender playgroups left their classroom to participate in intervention activities in a quiet space. During each of two weeks, children participated in four consecutive days of back-to-back book-reading and play sessions, for a total of eight days of intervention activities. The children read the assigned book first and then engaged in 10 minutes of book-related, adult-guided play. Each book-reading and play session lasted for approximately 20 minutes. Members of the research team pretested and posttested all children individually for knowledge of vocabulary words within one week prior to and following the intervention, respectively.

Book Reading

Before each of the four readings of the informational texts, the properties of each category were discussed using each theme word (e.g., *stem*, *bulb*). We also used pictures of theme words (e.g., *stem*, *bulb*, *petals*) to review parts of plants, and we fit these images together to form a large picture of a plant to help children organize and group these concepts together. Next, children were shown pictures of various plants and other growing things and asked to decide whether the picture was a category member and to explain their answer. Each target word was explained when it occurred in the text. Word meaning explanations consisted of the following:

- Pointing at a corresponding illustration in the book to help support word meaning and also showing a card that depicted a photograph of the word to support conceptual knowledge and ensure that the perceptual features of the object were clear (e.g., "These are *radishes*. Here's another picture of some *radishes* growing in the ground.")
- Definitional information delivered in concise, child-friendly language:
  - Taxonomy membership, when possible (e.g., "Radishes are vegetables.")
  - Taxonomy nonmembership, when possible (e.g., "Radishes don't have seeds, so they're not a fruit.")
  - Information about how the word relates to the larger theme, when possible (e.g., "Some vegetables grow on vines.")
  - Perceptual features (e.g., "Radishes are red on the outside and white on the inside. They taste a little spicy.")
  - Conceptual information (e.g., "Radishes are the root of the plant, so they grow underground.")
  - Object function information (e.g., "People usually eat radishes raw.")

During the first and second readings, children were encouraged to repeat the word to reinforce it phonological representation (e.g., "Can you say *radish*?"), and in the third and fourth readings, children were given a definition and asked to supply the word (e.g., "What is the vegetable that grows underground and is red on the outside and white on the inside?"). This extratextual talk was listed on prompt cards used by the first author during reading to ensure that children in different playgroups received similar information about words.

Play

A 10-minute play session immediately followed each book reading. There was a collection of toys for each book, with props related to target vocabulary. For the vegetables book, this included a farmhouse, farmer figurines, small toy vegetables, seeds, cooking implements, and larger toy vegetables. For the flowers book, the same farmhouse, farmer figurines, and seeds were used, but the collection also included a variety of toy plant beds, clay used to represent dirt, and gardening implements, such as a watering can, hose, rake, and shovel.

During the first two days of play, the first author used an adult-directed method of play, in which each child was each given two or three props, and she instructed children to enact key concepts from the book. For example, after the vegetables book, children were each given farmer figurines and instructed to act out planting seeds in the soil, watering the plants, and harvesting and cooking the vegetables. This make-believe play also involved some sort of threat or conflict to foster a sense of playfulness and fun: animals coming to eat the plants, a tornado ruining the crop, or some other difficulty involving growing conditions. Target vocabulary words were used in each scene, along with a definition. For example, the adult would say, "Let's plant some seeds! Those are a small part of the plant. Let's put them in the soil and water them, and they will grow into flowers." This adult-directed play was intended to serve as a model for children's play, demonstrating ways to use the props and incorporate concepts from the book into their play.

During the second two days of play, a more child-led, guided play method was used, in which the children initiated the play and the first author followed their lead, building on their play ideas and encouraging the other children to join in. The adult also took on one of the character roles (e.g., farmer, chef) during this play and focused on incorporating target words whenever possible, as well as capitalizing on opportunities for developing conceptual knowledge as they arose (e.g., talking about why the seeds will not grow if planted in the farmer's hat). Throughout all four days of play, a checklist ensured that all target words were used during play sessions.

Overall Intensity of Instruction

On average, each child heard each target word 29 times over four days of the intervention. These exposures included, on average, 2.6 uses of the word as part of the book text, 5.1 definitions, and 26.5 visual supports, such as pictures, gestures, and use of a toy representing the word (note that these categories are not mutually exclusive). Similarly robust instruction was provided for each of the subcategories of theme and taxonomy words: On average, each child heard a taxonomy word 30.2 times and a theme word 27.6 times over four days of the intervention and were provided with similar amounts of definitional and visual support for these words (see Appendix A). Variability in exposures was due to the nature of the instruction given, which was designed to be responsive to children's questions about target words and included child-initiated play scenes involving different target words.

Measures and Variables of Interest

Coding for Target Word Use

We coded videos of intervention activities to track and describe all adult uses of target words during book reading and play. We did not code children's use of target words because children were not always visible or audible on the videotapes. All book-reading and play sessions were video recorded, and we selected half of all videos for coding: two videos per book for each playgroup for a total of four videos per playgroup.

We selected the videos from days 2 (more instructional) and 3 (more responsive and interactive) as most representative of the range of instruction used in the intervention. In three instances, we substituted a video from day 1 or 4 because the day 2 or 3 video was missing or incomplete. The average video length was 21.06 minutes (median = 21.75 minutes) and ranged from 12 to 33 minutes.

An education master's student was trained to criterion (90% agreement) and coded the selected videos. The coder recorded each use of a target word by the adult. The coder then filled out a number of fields to describe the supports provided for word meaning. These codes are subsequently described in more detail.

Number of Exposures

Because we designed the book-reading and play sessions to be responsive to children's interests and questions, the intervention procedures were not able to strictly control for the number of times each target word was used. The coding of videos counted each use of the target word by the adult to create a statistical control for analyses comparing groups of target words. Analyses comparing target words (i.e., those performed for research questions 2 and 4) controlled for the number of target word exposures as a way of equalizing intensity of exposure to words of different types. To establish inter-rater reliability, 20% of the videos were double-coded by the first author; inter-rater reliability was high (90%).

Word Supports

Coders selected from six nonexclusive codes to describe the nature of the instruction provided for target words (word supports) during book reading and play:

1. *Definition:* Definitional information is given about the word.
2. *Part of book text:* The word is read aloud as part of the book.
3. *Book picture:* The adult points to a picture in the book to illustrate the word's meaning.
4. *Picture card:* The adult holds up or points at the picture card for the word.
5. *Gesture:* The teacher performs a gesture that illustrates the word's meaning in conjunction with verbal use of the word.
6. *Prop:* The target word is indexed to a toy or prop.

Because codes 3–6 provided similar types of support, we created a composite visual support variable by adding those codes together. Inter-rater reliability was high for this category (96.6%). Information about word supports is provided in Appendix A by word level and for each category to provide additional descriptive information about the intervention, but these variables are not used in the analyses.

Peabody Picture Vocabulary Test, Fourth Edition

To assess general vocabulary breadth and language abilities of the sample children as compared with their age group peers, we administered the fourth edition of the Peabody Picture Vocabulary Test (PPVT–4; Dunn & Dunn, 2007) before the intervention began. For this sample, the mean standard score (97.0) was slightly lower than the normative mean of 100, and the standard deviation (16.05) was slightly higher than the normative standard deviation of 15.

Vocabulary Depth Measure: New Word Definition Test—Modified

To measure children's depth of knowledge of target words, we developed an experimenter-designed measure and administered it at pretest and posttest. We adapted this measure from Blewitt, Rump, Shealy, and Cook's (2009) New Word Definition Test and named our version the New Word Definition Test–Modified to reflect our adaptations, namely, additional categories for gestures and contextual information. This informal definition task allowed for coding of the number of information units that children offered for each word rather than their ability to give conventional, dictionary-style definitions.

Children were asked to define words verbally or by using gestures. They were tested on a representative subset of the total number of target, exposure, and control words on this measure (23 out of 35 words; see Appendix A for words assessed) due to time constraints and the cognitive demand of this task. For each word, children were asked, "What is (a) ___?" and a follow-up question, "Can you show me or tell me anything else about ___?" If a student did not respond to a question, the tester moved on to the next word. Student responses (both verbal and gestural) were transcribed by testers and video recorded. Two forms of the test (A and B) listed words in different orders, and these were counterbalanced.

We developed a coding scheme (adapted from Blewitt et al., 2009) to categorize and score student responses for the number of information units given. Coding was conducted by a research assistant, and 20% of assessments were randomly selected and checked for reliability against a master coder after every four forms were completed. Overall percentage agreement averaged 97.6%, with a mean Cohen's Kappa value of .97. Possible scores on this measure range from 0 to a nearly unlimited number of points, although the maximum total score in this sample was 39 points.

The coding scheme comprised eight information unit categories: category information, perceptual qualities, object function information, part/whole, synonyms, gestures, meaningful context, and basic context. Each information unit was worth 1 point except for basic context, which was worth 0.5 point. We used the first four categories for concrete nouns only. Category information entailed naming a target word's larger taxonomy or, for the target words that were also taxonomy names (i.e., *flower*, *vegetable*), naming a taxonomy member. Perceptual qualities were properties such as how something looks, smells, tastes, feels, or sounds. Object function information pertained to any process, purpose, or use for concrete nouns and answers the question, "What do you do with it?" Part/whole described a distinct part of a target word or the whole that the target word was a part of. The remaining categories were used for all word types. Synonyms were any word or short phrase that was equivalent to the word being explained, and provided decontextualized meaning information. Gestures were gestures or actions that showed knowledge of the word's meaning (e.g., curling up in a ball and then gradually standing up to represent *sprouting*).

We also coded for two types of use in context. Meaningful context entailed responses that showed knowledge of the target word in a typical, meaningful context, along with semantic information. For example, one student said, "Seeds grow. They grow into a red tree." In this example, *grow* was scored for function, and "into a…tree" was scored for meaningful context because the student used an example to illustrate what seeds might grow into, along with semantic information. Basic context, worth only 0.5 point, was a simple association between a target word and a typical context, without any use of semantic information. For example, several children said, "Monkey," for *vines*, a response that does not include semantic information but still contains an association with a typical context in which the target word is used. Incorrect or irrelevant responses received a score of 0. See Appendix B for examples of student responses and scoring.

Psychometric Properties of the Researcher-Created Measure

The vocabulary depth measure demonstrated acceptable internal consistency at pretest (Cronbach's $\alpha = .72$) and posttest (Cronbach's $\alpha = .85$). We also evaluated the validity of the depth measure by comparing the test scores on a concurrent measure of a highly related construct (Cronbach, 1971; Messick, 1989), in this case, the PPVT–4, which measures general vocabulary knowledge. The correlation between the PPVT–4 and the depth measure was statistically significant at pretest ($r = .56$). These two measures are related, indicating that both assess the larger construct of vocabulary, but the strength of the correlation is only moderate, indicating that they measure the different, but closely related, dimensions of vocabulary breadth and depth (for a fuller discussion of the vocabulary depth measure, see Hadley et al., 2016).

Data Analysis

In this study, we used a within-subject design in which children served as their own controls, and we compared their learning of one kind of word with their learning of another (e.g., their learning of taught words versus exposure and control words). A within-subject design has the advantages of controlling for classroom and demographic factors. A power analysis indicated that an effect size of 0.44 or greater for within-subject contrasts would be detected as significant. We used multilevel regression models to account for the nested nature of our data, in which measurement occasions are nested within children and, in turn, children nested within playgroups. The intraclass correlations from an unconditional three-level model for the depth measure indicated that 58.2% of the variance in children's residual gains in vocabulary knowledge was accounted for by within-child differences in word type, 33.3% of the variance was attributed to differences between children, and 8.5% of the variance was due to differences between playgroups.

In our analyses, we examined children's residualized gains (posttest vocabulary knowledge controlling for pretest vocabulary knowledge) in vocabulary knowledge. Unless otherwise noted, we conducted all post hoc pairwise comparisons using Fisher's least significant difference test, and effect sizes are presented as Hedges's *g*.

Results

Table 1 provides mean raw scores and standard deviations for both measures and all word types examined in research questions 1–4 at pretest and posttest.

TABLE 1
Vocabulary Depth Measure Unadjusted Means (and Standard Deviations)

Variable	Pretest	Posttest
Research question 1: Growth in vocabulary depth		
Target words	0.36 (0.23)	1.18 (0.54)
Exposure words	0.17 (0.26)	0.16 (0.31)
Control words	0.17 (0.31)	0.17 (0.32)
Research question 2: Growth in knowledge for taxonomy versus theme words		
Taxonomy words	0.58 (0.36)	1.70 (0.79)
Theme words	0.23 (0.23)	0.87 (0.45)
Research question 3: Growth in semantic information for taxonomy versus theme words		
Taxonomy words		
• Category information	0.14 (0.24)	0.49 (0.46)
• Object function information	0.35 (0.27)	0.61 (0.30)
• Perceptual information	0.07 (0.15)	0.24 (0.21)
Theme words		
• Category information	0.01 (0.02)	0.02 (0.06)
• Object function information	0.10 (0.11)	0.29 (0.22)
• Perceptual information	0.01 (0.05)	0.07 (0.11)
Research question 4: Growth in knowledge for one- versus two-unit words		
One-unit words	0.40 (0.28)	1.23 (0.60)
Two-unit words	0.30 (0.24)	1.15 (0.54)

Note. Depth measure values indicate the average number of information units that children provided for each word.

Growth in Vocabulary Depth

The first research question investigates the main effect of the intervention, examining whether children's learning of target words was greater than that of exposure and control words. In a multilevel regression model, we tested whether vocabulary gains varied by level of instruction (target, exposure, and control words):

$$\begin{aligned}\text{Posttest}_{ij} = \gamma_{00} &+ (\gamma_{10}{*}\text{Exposure}_{ij}) + (\gamma_{20}{*}\text{Control}_{ij}) \\ &+ (\gamma_{30}{*}\text{Pretest}_{ij}) + (\gamma_{01}{*}\text{PPVT}-4_{j}) \\ &+ U_{0j} + e_{ij}\end{aligned} \tag{1}$$

This model accounts for two nesting levels in the data: Level of instruction$_{ij}$ (target, exposure, and control words) is nested within children$_j$ (n = 30). For parsimony, we aggregated the playgroup random effects at the child level, as there were no playgroup-level variables in this analysis. We dummy-coded level of instruction with target words as the reference group, which were contrasted to exposure (γ_{10}) and control (γ_{20}) words. We included PPVT–4 (γ_{01}) as a covariate to control for general vocabulary knowledge at pretest. To look at residualized gains, we also included children's pretest vocabulary scores (γ_{30}) as a covariate.

Results indicated that children learned significantly more about target words than both exposure ($p < .001$, $g = 1.921$) and control words ($p < .001$, $g = 1.628$) and that effect sizes for the differences in learning were large (Cohen, 1988; see Table 2). Controlling for baseline vocabulary knowledge, the score for a target word was estimated to be 0.731 point higher than the score for an exposure word and 0.856 point higher than the score for a control word. Post hoc pairwise comparisons also indicated that there was no significant difference between children's learning of control and exposure words ($p = .088$, $g = 0.392$).

TABLE 2
Parameter Estimates (and Standard Errors) for Growth in Word Knowledge for Vocabulary Depth (Top Panel) and Effect Size Estimates (Bottom Panel)

Parameter	Vocabulary depth
Main effects of the intervention	
Level 1: Level of instruction	
• Intercept (γ_{00})	0.017 (0.251)
• Pretest score (γ_{30})	0.841** (0.132)
• Target versus exposure words (γ_{10})	−0.731** (0.076)
• Target versus control words (γ_{20})	−0.856** (0.076)
Level 2: Child	
• Peabody Picture Vocabulary Test, fourth edition (γ_{01})	0.009** (0.003)
Hedges's g effect sizes and 95% confidence intervals	
Target versus exposure words	1.921** [1.810, 2.033]
Target versus control words	1.628** [1.515, 1.740]

Note. Standard errors adjusted for interdependency of level of instruction nested within children. Target words are the reference group for the comparison (negative estimates indicate that target words had larger covariate-adjusted posttest scores).
**$p < .01$.

Growth in Knowledge for Taxonomy Versus Theme Words

Controlling for the number of exposures, we used a multilevel regression model to determine whether children learned more about taxonomically related than thematically related target words:

$$\begin{aligned}\text{Posttest}_{ijk} = \gamma_{000} &+ (\gamma_{100}{*}\text{Theme}_{ijk}) \\ &+ (\gamma_{200}{*}\text{Pretest}_{ijk}) + (\gamma_{010}{*}\text{PPVT}-4_{jk}) \\ &+ (\gamma_{001}{*}\text{Number}_{k}) + U_{00k} + U_{0jk} + e_{ijk}\end{aligned} \tag{2}$$

This model accounts for three nesting levels in the data: Theme$_{ijk}$ is nested within children$_{ij}$, who are nested in playgroups$_k$. We included number of exposures (γ_{001}), that is, the number of times taxonomy and theme words were each used, as a covariate because of minor variability in the number of exposures for theme versus taxonomy words (see Appendix A). This covariate allowed us to hold exposures constant and isolate the effect of teaching in taxonomies versus themes on word learning. We dummy-coded word type with theme words as the reference group, which was contrasted to taxonomy words (γ_{100}).

Analyses revealed that children learned significantly more about taxonomy words than theme words (see Table 3). The score for a taxonomy word was estimated to be 0.593 point higher than that of a theme word, holding all other variables constant. The effect size for this difference was large ($g = 0.909$; Cohen, 1988). The number of exposures variable was not a significant predictor of vocabulary depth scores.

Growth of Semantic Information Types for Taxonomy Versus Theme Words

We analyzed whether growth in learning was greater for target taxonomy words versus target theme words for category, object function, and perceptual information. We used three separate multilevel regression models, one for each type of semantic information:

$$\begin{aligned}\text{InfoTypePosttest}_{ijk} = \gamma_{000} &+ (\gamma_{100}{*}\text{Theme}_{ijk}) \\ &+ (\gamma_{200}{*}\text{InfoTypePretest}_{ijk}) \\ &+ (\gamma_{010}{*}\text{PPVT}-4_{jk}) \\ &+ (\gamma_{001}{*}\text{Number}_{k}) + U_{00k} \\ &+ U_{0jk} + e_{ijk}\end{aligned} \tag{3}$$

TABLE 3
Parameter Estimates (and Standard Errors) for Effects of Taxonomy Versus Theme Words on Vocabulary Depth (Top Panel) and Effect Size Estimate (Bottom Panel)

Parameter	Vocabulary depth
Effect of taxonomy words	
Level 1: Word type	
• Intercept (γ_{000})	−0.431 (0.712)
• Pretest score (γ_{200})	0.635* (0.235)
• Taxonomy versus theme words (γ_{100})	0.593** (0.131)
Level 2: Child	
• Peabody Picture Vocabulary Test, fourth edition (γ_{010})	0.152* (0.005)
Level 3: Playgroup	
• Number of exposures to theme and taxonomy words (γ_{001})	−0.010 (0.015)
Hedges's g effect size and 95% confidence interval	
Taxonomy versus theme words	0.909** [0.746, 1.072]

Note. Standard errors adjusted for interdependency of word type nested within children and children nested within playgroup. Theme words are the reference group for the comparison (positive estimates indicate that words taught in taxonomy had larger covariate-adjusted posttest scores).
*$p < .05$. **$p < .01$.

This model is similar to equation 2, except the posttest and pretest scores used here were a subtotal of their overall depth score, specifically testing the growth in three types of semantic information (category, object function, and perceptual information) for taxonomy versus theme words.

Analyses revealed that children learned significantly more categorical ($p < .001$, $g = 1.347$), object function ($p < .001$, $g = 1.123$), and perceptual information ($p < .001$, $g = 0.955$) for taxonomy words than theme words (see Table 4). Controlling for baseline vocabulary knowledge, children were predicted to score 0.447 point higher for category information, 0.299 point higher for object function information, and 0.162 point higher for perceptual information for a taxonomy word as compared with a theme word.

Growth in Knowledge for Words Taught in One Versus Two Units

We tested whether vocabulary gains were greater in two book/play units (vegetables and flowers books and play sessions) versus one (vegetables or flowers book and play session), using an equation similar to equations 2 and 3.

This model accounts for three nesting levels in the data: Unit_{ijk} is nested within children_{ij}, who are nested in playgroups_j. We dummy-coded number of units with two units as the reference group, which was contrasted to one unit (γ_{100}). The number of uses variable (γ_{001}) represents the number of times one- and two-unit words were used, respectively, and was included as a covariate so the effect of learning a word in one versus two units was isolated by holding the number of times a word was

TABLE 4
Parameter Estimates (and Standard Errors) for Effect of Taxonomy Versus Theme Words on Category, Object Function, and Perceptual Information (Top Panel) and Effect Size Estimates (Bottom Panel)

Parameter	Category information	Object function information	Perceptual information
Growth in information type for taxonomy versus theme words			
Level 1: Word type			
• Intercept (γ_{000})	−0.417 (0.406)	−0.197 (0.313)	−0.158 (0.213)
• Pretest score (γ_{200})	0.049 (0.247)	0.165 (0.134)	0.099 (0.191)
• Taxonomy versus theme words (γ_{100})	0.447** (0.094)	0.299** (0.056)	0.162** (0.042)
Level 2: Child			
• Peabody Picture Vocabulary Test, fourth edition (γ_{010})	0.002 (0.002)	0.007** (0.002)	0.002 (0.001)
Level 3: Playgroup			
• Number of exposures to theme and taxonomy words (γ_{001})	0.007 (0.010)	−0.007 (0.007)	0.001 (0.005)
Hedges's g effect sizes and 95% confidence intervals			
Taxonomy versus theme words	1.347** [1.264, 1.430]	1.123** [1.057, 1.190]	0.955** [0.912, 0.997]

Note. Standard errors adjusted for interdependency of word type nested within children and children nested within playgroup. Theme words are the reference group for the comparison (positive estimates indicate that words taught in taxonomy had larger covariate-adjusted posttest scores).
**$p < .01$.

heard constant. On average, each child heard a one-unit word 25.7 times and a two-unit word 39.9 times over the course of the intervention.

Results indicated that there was no significant difference between children's learning of words taught in two units versus one ($g = -0.214$; see Table 5).

Discussion

The purpose of this study was twofold: (1) to examine the impact of a vocabulary intervention designed to support preschoolers' depth of vocabulary knowledge through the reading of informational texts and guided play and (2) to investigate specific factors that may contribute to growth in depth, such as teaching words in conceptually related groups and across multiple contexts. The present intervention had significant positive effects on children's depth of vocabulary knowledge, with taxonomy words learned more deeply than theme words. Categorical, object function, and perceptual information were all learned better for taxonomy words than theme words. There were no differences in learning for words taught in two units versus one. In this section, we discuss the implications of these findings in more detail.

TABLE 5
Parameter Estimates (and Standard Errors) for Teaching Words in One Versus Two Units (Top Panel) and Effect Size Estimate (Bottom Panel)

Parameter	Vocabulary depth
Effect of one versus two units	
Level 1: Number of units	
• Intercept (γ_{000})	−0.223 (0.689)
• Pretest score (γ_{200})	0.463^{*} (0.225)
• One versus two units (γ_{100})	−0.123 (0.195)
Level 2: Child	
• Peabody Picture Vocabulary Test, fourth edition (γ_{010})	0.017^{**} (0.005)
Level 3: Playgroup	
• Number of exposures to one- and two-unit words (γ_{001})	−0.011 (0.013)
Hedges's g effect size and 95% confidence interval	
One versus two units	−0.214 [−0.359, −0.070]

Note. Standard errors adjusted for interdependency of context nested within children and children nested within playgroup. Two units is the reference group for the comparison (negative estimates indicate that words taught in two units had larger covariate-adjusted posttest scores).
$^{*}p < .05$. $^{**}p < .01$.

Growth in Vocabulary Depth

The present intervention showed a substantial positive impact on children's growth in depth of vocabulary knowledge (target vs. control words $g = 1.628$). Children showed substantial growth on a demanding measure of vocabulary depth, which asked them to provide semantic and contextual information about words. At pretest, children gave approximately 0.3 information unit for each taught word, whereas at posttest, they gave 1.2 pieces of information for each taught word. (This growth in learning can be exemplified by a child who had no reply for the question, "What is a tiger lily?" at pretest and at posttest said, "It's a flower.")

The growth in vocabulary knowledge shown here is larger than reported by meta-analyses of preschool vocabulary interventions, which have effect sizes of $d = 0.60$ for shared book-reading interventions (National Early Literacy Panel, 2008) and $g = 0.85$ for preschool vocabulary interventions in general (Marulis & Neuman, 2010). Both meta-analyses included researcher-created and standardized measures in the reporting of effect sizes. This study had several features associated with higher effect sizes in meta-analyses: A researcher, rather than teachers or childcare providers, delivered the intervention (Marulis & Neuman, 2010; Mol, Bus, & de Jong, 2009); author-created, rather than standardized, measures were used to assess growth (Marulis & Neuman, 2010); and instruction combined both explicit (e.g., giving definitions) and implicit methods (e.g., embedding target words in guided play; Marulis & Neuman, 2010). The large effect sizes may also be partially driven by our selection of target words, as the concrete nouns taught in the present study are typically learned more quickly than more abstract words such as verbs and adjectives (Hadley et al., 2016; Maguire, Hirsh-Pasek, & Golinkoff, 2006).

We designed the present intervention to include several key features of high-quality instruction: supporting semantic networks by introducing conceptually linked words; providing explicit meaning information about words, such as object function, perceptual, and thematic and taxonomic properties; and encouraging children to repeat words to strengthen phonological representations. Instruction was equally rich for both taxonomy and theme words, exploiting the connected nature of words within categories and themes. Children also had multiple exposures to new words, and opportunities to use these words, in the language-rich contexts of book reading and play. Although we did not parse out the individual contributions of these features in our analyses, it is important to note that the substantial growth in word knowledge occurred within the context of this high-quality instruction.

Fostering depth of vocabulary knowledge, rather than breadth, has sometimes been characterized as a prohibitively time-consuming endeavor, given the large number of words that young children need to learn. Our results indicate that an investment of systematic instructional time helps support vocabulary depth: Children showed no growth in knowledge for exposure words (words simply heard in the book text). However, the preschoolers in this study showed large gains in word knowledge from relatively short daily periods of instruction (20 minutes), with 21 words taught in eight days. This favorably compares with other interventions aimed at supporting extensive word knowledge that taught a similar number of words across a longer time frame (e.g., Beck & McKeown, 2007: 22 words in 10 weeks, $d = 0.96$ on researcher-created measures). The results here suggest that young children are capable of significant improvements in the depth of their word knowledge in a relatively short amount of time, making depth a reasonable instructional goal for preschool classrooms. Moreover, improvements in vocabulary depth indicate that children's actual knowledge base expanded and became more refined, not only that they fast-mapped new words. Such increases in depth may support their later ability to interpret and understand complex text (Anderson & Freebody, 1985) and therefore may be a worthy investment of precious instructional time.

Growth in Knowledge for Taxonomy Versus Theme Words

Children learned taxonomically related words more deeply than theme-related words ($g = 0.909$), although there were increases in learning for both word types. These results are consistent with a preferential attachment theory of word learning (Steyvers & Tenenbaum, 2005), in which new words are learned more quickly and deeply when they are semantically related to known words. These results also support a perspective on fostering depth that emphasizes not only teaching semantic information about single word entities but also expanding semantic networks by teaching words in conceptually related groups. In this view, vocabulary instruction can be considered not only as a one-by-one proposition in which a single word is taught and learned but also as a systems-level approach in which broader networks of related concepts are introduced together to maximize learning. In this case, we introduced not only the larger category of growing things so children would learn the general properties of plants but also information about flowers and vegetables, their properties, what distinguishes each category from the other, and exemplars of each category, with the idea that building larger knowledge systems would in turn leverage knowledge of individual words (Borovsky et al., 2016a).

In particular, the results here indicate that teaching words in taxonomies may be additionally beneficial for deep word learning as compared with teaching words in themes. However, the findings should not be taken to suggest that words should only be taught in taxonomies, not themes, as such an approach is not possible or recommended. Rather, our results indicate that teaching words in conceptually related groups supports depth, with words taught in taxonomies being learned relatively more quickly and deeply than words taught in themes, given similar amounts of instruction. This may mean that words taught in themes may need additional instructional time, as compared with words taught in taxonomies. The extensive support for the higher level taxonomies (vegetables, flowers, and growing things) taught here may have helped leverage children's word learning of the exemplars in each category, meaning that less instructional time for these exemplars was needed. In the following subsection, we discuss in more detail the types of semantic information learned for taxonomy versus theme words.

It is important to note that informational texts were used during book-reading sessions, which were particularly supportive of the concepts underlying the taxonomy words. These results may not generalize to narrative texts if they do not include similar support for taxonomies (in general, thematic relations tend to be more common in narrative texts). Future research should explore whether other types of conceptually linked words, particularly those that are hierarchically related, have similar benefits for word learning in the context of narrative texts.

Currently, many preschool curricula are organized thematically. Although such organization has many benefits (e.g., supporting knowledge of associative relations between concepts), the present study and others (particularly Neuman et al., 2011) have suggested the value of including units that also highlight taxonomic relations for young children. In addition to book reading and guided play, science and social studies activities are other settings in which words could be taught in taxonomies, helping prepare children for the demands of academic language in those content areas. Other research has shown that preschool teachers provide conceptual information more frequently in content areas such as science, math, and social studies than during book reading (Bowne, Yoshikawa, & Snow, 2017), which suggests that these areas are ripe for introducing taxonomic thinking.

Semantic Information Types Learned for Taxonomy Versus Theme Words

To more fully explore the substantial difference in learning of taxonomy versus theme words, we analyzed whether certain types of semantic information were learned better for taxonomy versus theme words. This analysis was exploratory in nature, as the individual types of semantic information are highly correlated with the depth measure as a whole. Prior research has suggested that object function, perceptual, and category information (Hills et al., 2010) may be especially important in promoting the differentiation and growth of semantic networks organized into taxonomies. Our results were in accord with this research: Object function ($g = 1.123$), perceptual ($g = 0.955$), and category information ($g = 1.347$) were learned better for taxonomy words versus theme words.

We hypothesize that the greater growth in perceptual and object function information for taxonomy words was due to the fact that these features are often shared by taxonomy members. For example, the definitional information provided to children emphasized shared object function properties (e.g., flowers are for looking at or smelling; vegetables are for eating and/or cooking) and shared perceptual features (e.g., flowers have a nice smell; vegetables, unlike fruit, typically do not have seeds) of taxonomy members. The commonality of these shared features, and the fact that they were referred to by the same higher order category term (e.g., *flowers*) may have helped link these concepts together into taxonomic networks (Hills et al., 2009; Neuman et al., 2011), and retrieving this information may have also been less cognitively taxing because it had been reiterated often across taxonomy members. In contrast, theme words did not often share object function or perceptual properties (e.g., vines and soil do not serve the same function and do not look alike), so these words did not receive the same boost from shared semantic information.

Children also learned categorical information better for taxonomy words than theme words, which indicates that children were able to identify either the larger taxonomy (e.g., for the word *daffodil*, naming it as a flower) or taxonomy members (e.g., for the word *flower*, naming types of flowers such as daffodils). It is perhaps not surprising that this category showed greater growth for taxonomy versus theme words, as theme words rarely had a superordinate or subordinate category available for naming, but it indicates that children remembered and explicitly named the taxonomy information taught during the intervention and that they had placed a particular concept into a categorical network of related concepts.

Overall, the greater growth in object function, perceptual, and category information suggests that taxonomy words may have been learned more deeply than theme words because children leveraged their knowledge of the larger category (vegetables or flowers) to acquire category members, with shared object function and perceptual information acting as hooks for new words. These findings are consistent with both Steyvers and Tenenbaum's (2005) preferential attachment theory and Borovsky and colleagues' (2016a) findings on leveraged learning, in which 2-year-olds learned words more easily when they had high category knowledge for those words.

Teaching Words in One Versus Two Units

Children did not show significant differences in growth for words learned in two units versus one when exposure was controlled. There was a small, although nonsignificant, effect in favor of two-unit words ($g = -0.214$). Language acquisition research has indicated that teaching words in multiple contexts may be helpful, as words that are heard frequently in different contexts are acquired earlier by young children (Hills et al., 2010). However, further research is needed on the effect of using multiple contexts instructionally, as our result here is not statistically significant, and prior research has been mixed. For example, Horst and colleagues (2011) found that 3-year-olds learned more about novel words when they appeared in a single book context three times rather than in three different books, whereas kindergartners in McKeown and Beck's (2014) study benefited from discussing words in multiple contexts.

Limitations

Future research should address some of the shortcomings of this project. For example, the sample size was relatively small, and the fact that the intervention was implemented by a researcher in small groups of three children may limit the generalization of these results to whole-group classroom settings. Furthermore, subsequent research should include a measure that more directly assesses whether interventions that teach words in taxonomies impact children's ability to successfully categorize objects, such as a picture-sorting task. We also plan to explore the individual affordances of the book-reading and play settings to children's word learning in a later study, as we were not able to gauge the individual contributions of each in the present study. Future research should also improve upon the comparisons made here by using the same words in different conditions to further explore the affordances of teaching words in themes versus taxonomies.

Conclusions

The results of the present study suggest that fostering deep vocabulary knowledge involves not only teaching single-word entities but also teaching words in conceptually linked groups, with particular benefits shown for teaching words in taxonomies. Furthermore, preschool children's knowledge of taxonomies can be supported by sharing information about the shared object function, perceptual, and categorical features of words.

NOTES

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APPENDIX A

Information for Words Used in Intervention

Word	Level of instruction	Taxonomy or theme	Unit(s) taught in	Assessed on depth measure	Mean concreteness rating[a]	Mean age of acquisition[b] (years)	Word frequency[c]	Depth measure[d] unadjusted means (standard deviation)		Instruction provided[e] (per word) for each playgroup			
								Pretest	Posttest	Number of exposures	Word read aloud as part of book text	Number of definitions given	Number of visual supports provided[f]
bulb	Target	Theme	Both	Yes	4.93	6.56	51.8	0.00 (0.00)	0.73 (0.91)	28.3	4.9	6.6	25.8
root	Target	Theme	Both	Yes	4.34	5.94	54.7	0.17 (0.46)	0.77 (0.90)	22.1	4.6	4.8	20.9
seed	Target	Theme	Both	Yes	4.71	4.72	55.1	1.20 (0.93)	2.30 (0.79)	69.9	5.6	5.4	37.4
soil	Target	Theme	Both	Yes	4.87	6.48	61.8	0.03 (0.18)	1.17 (0.79)	46.3	4.8	8.5	44.9
stem	Target	Theme	Both	Yes	4.63	7.26	53.1	0.10 (0.40)	0.80 (0.99)	32.8	4.0	1.7	31.1
flower	Target	Taxonomy	Flowers	Yes	5.00	3.11	56.1	1.67 (1.09)	2.57 (1.19)	91.6	6.1	9.1	75.0
daffodil	Target	Taxonomy	Flowers	No	4.96	5.63	30.6			19.0	0.2	5.8	18.7
iris	Target	Taxonomy	Flowers	Yes	4.54	8.96	46.1	0.00 (0.00)	0.40 (0.68)	13.1	0.2	5.2	12.9
hyacinth	Target	Taxonomy	Flowers	No	4.50	14.56	31.4			14.1	0.2	5.6	14.5
petal	Target	Theme	Flowers	Yes	4.57	6.33	46.7	0.07 (0.25)	0.53 (0.63)	21.1	0.3	1.0	19.7
sprouting	Target	Theme	Flowers	Yes	4.64	9.11	45.1	0.20 (0.55)	1.10 (0.96)	13.0	1.7	4.4	13.6
tiger lily	Target	Taxonomy	Flowers	Yes	4.69	NA	NA	0.03 (0.18)	2.10 (1.19)	9.4	0.2	3.8	9.8
tulip	Target	Taxonomy	Flowers	No	5.00	7.15	42.3			19.2	0.2	5.6	19.9
artichoke	Target	Taxonomy	Vegetables	No	4.63	10.00	29.3			29.0	5.7	5.0	28.7
cauliflower	Target	Taxonomy	Vegetables	Yes	5.00	6.18	36.6	0.17 (0.46)	1.03 (1.30)	26.5	0.3	5.5	25.7
eggplant	Target	Taxonomy	Vegetables	Yes	4.97	8.30	33.3	0.27 (0.58)	1.67 (1.61)	39.2	1.8	8.8	37.7
leek	Target	Taxonomy	Vegetables	No	4.92	11.00	30.9			18.3	3.0	3.8	18.3
radish	Target	Taxonomy	Vegetables	No	4.87	5.25	41.0			24.5	1.9	5.2	24.2
raw	Target	Theme	Vegetables	Yes	3.35	7.17	56.3	0.03 (0.18)	0.03 (0.18)	4.2	1.0	0.6	0.8
vegetable	Target	Taxonomy	Vegetables	Yes	4.89	5.71	51.8	1.37 (0.96)	2.43 (1.48)	58.5	8.5	7.6	44.2
vine	Target	Theme	Vegetables	Yes	4.86	6.95	45.3	0.23 (0.57)	0.43 (0.63)	10.4	1.7	3.6	10.1
blooms	Exposure		Flowers	Yes	4.00	6.84	39.9	0.10 (0.40)	0.10 (0.40)	0.1	0.1		
catalog	Exposure		Flowers	No	4.68	8.55	48.9			1.8	1.8		
pod	Exposure		Vegetables	Yes	4.63	7.95	45.7	0.00 (0.00)	0.00 (0.00)	0.1	0.1		
spade	Exposure		Vegetables	Yes	4.46	8.11	42.8	0.00 (0.00)	0.03 (0.18)	0.7	0.7		
summer	Exposure		Flowers	No	3.64	4.33	62.2			1.6	1.6		
vitamin	Exposure		Vegetables	Yes	4.48	5.42	49.9	0.67 (0.80)	0.50 (0.89)	3.7	1.6		

(*continued*)

Information for Words Used in Intervention (*continued*)

Word	Level of instruction	Taxonomy or theme	Unit(s) taught in	Assessed on depth measure	Mean concreteness rating[a]	Mean age of acquisition[b] (years)	Word frequency[c]	Depth measure[d] unadjusted means (standard deviation)		Instruction provided[e] (per word) for each playgroup			
								Pretest	Posttest	Number of exposures	Word read aloud as part of book text	Number of definitions given	Number of visual supports provided[f]
cavern	Control			No	4.57	8.84	44.2						
frock	Control			Yes	NA	9.65	41.5	0.07 (1.09)	0.07 (0.37)				
platter	Control			No	4.93	8.68	42.5						
scales	Control			No	4.74	6.48	52.2						
spectacles	Control			No	4.56	9.37	44.8						
throne	Control			Yes	4.64	7.28	51.1	0.43 (0.86)	0.63 (1.10)				
valley	Control			Yes	4.72	7.94	59.6	0.13 (0.35)	0.20 (0.48)				
vase	Control			Yes	5.00	7.89	46.1	0.23 (0.68)	0.30 (0.65)				
Target words[g]					4.71	7.32	45.0	0.36 (0.23)	1.18 (0.54)	29.1	2.6	5.1	26.5
Exposure words[g]					4.32	6.87	48.2	0.17 (0.26)	0.16 (0.31)	1.3	1.3		
Control words[g]					4.74	8.26	47.8	0.17 (0.31)	0.17 (0.32)				
Theme words[g]					4.54	6.72	52.2	0.23 (0.23)	0.87 (0.45)	27.6	3.1	4.4	25.4
Taxonomy words[g]					4.83	7.80	39.0	0.58 (0.36)	1.70 (0.79)	30.2	2.4	5.9	27.5
One-unit words[g]					4.71	7.63	41.5	0.40 (0.28)	1.23 (0.60)	25.7	2.0	5.0	23.3
Two-unit words[g]					4.70	6.19	55.3	0.30 (0.24)	1.15 (0.54)	39.9	4.7	5.4	36.9

Note. NA = not applicable.
[a]The mean concreteness rating scale is from 1 to 5, with 1 representing the most abstract words and 5 the most concrete (Brysbaert et al., 2014). [b]Mean age of acquisition is the age at which an average person learned the word in question (Kuperman et al., 2012). [c]Word frequency is expressed as the standard frequency index, a logarithmic transformation of the frequency per million tokens, weighted by the index of dispersion of the words throughout different subject areas; the range of the index in this corpus is from 3.5 to 88.3 (Zeno et al., 1995). [d]Depth measure values indicate the average number of information units that children provided for each word. [e]The numbers for instruction provided represent the average score per word for one playgroup across four days of instruction. [f]The visual support variable represents the sum of times that a picture from the book, an additional image, a gesture, or a toy was used to support the word's meaning. [g]The scores for target, exposure, control, theme, taxonomy, one-unit, and two-unit words are given as ratio scores (number per word).

APPENDIX B

Examples of Student Responses and Codes Assigned

Target word	Student response	Information unit coded
tiger lily	"Kind of flower. They're orange. Have spots on them and leaves. They grow."	Category information Perceptual information Perceptual information Part Function
eggplant	"It's a vegetable, but it's really a fruit."	Category information
vegetable	"You eat them. Eggplant."	Function Category information
soil	"It's dirt. You can dig in it."	Synonym Function
roots	"Grow under the ground to help the flower."	Perceptual information Function