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PARENT-CHILD CONVERSATIONS ABOUT BIOLOGICAL KINDS AS A POTENTIAL CONTRIBUTOR TO THE VARIABILITY IN BIOLOGICAL KNOWLEDGE

There is a growing body of research on variability in the early development of biological knowledge. Most of the studies focus on the variability related to culture and direct exposure to nature, however, there is also data suggesting that parental input plays an important role. In children's first years of life, parents play a key role in scaffolding development. It is therefore very important to provide a detailed account of how parents contribute to children's understanding of living things, and how they convey biological knowledge through everyday conversations. The present article provides a review of the literature on variability in biological knowledge and parent-child conversations about biological kinds. It also presents original data from parent-child interactions while viewing picture books. Eighteen parent-child dyads who differed in the level of parental expertise within biology, talked while viewing books containing 24 photographs of animals and plants. The speech analysis specified labeling, perceptual and conceptual descriptions, relational, and mentalistic talk. Parents also completed a questionnaire on the child's interests. The results showed that biology expert families produced more content overall, and a higher proportion of relational content than lay families. The findings help elucidate the specific role parents have in shaping children's early biological understanding. In particular, I discuss the role of relational language in shaping children's ontological commitments.

Keywords: naive biology, parent-child conversations, expertise

Introduction

The onset of the scientific study of the development of biological reasoning can be traced back to Jean Piaget's analysis of childhood animism (1926/1951).

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Based on structured interviews, Piaget presented evidence for a stage-like development of the concept of *life*, which aligned with his general framework of developmental stages. Piaget's key claim was that the mature biological understanding of the concept of *life* is a late achievement, preceded by a succession of stages during which life is attributed to all objects that undergo any activity, all moving objects, objects capable of spontaneous movement, animals, and, finally, to all and only living things.

About 30 years ago, with the dawn of domain specificity theorizing (Hirschfeld & Gelman, 1994), the study of the development of naive biology was born as a distinct field of inquiry. Its path to maturity can be described as unfolding in three overlapping waves, marked by distinct focus and research methods.

The hallmark of the first wave in the development of research on naive biology was the discovery of astonishing, early competence in biological reasoning. Preschool children were shown to rely on abstract domain-specific expectations about living kinds, which could not be explained by perceptual experience alone. Young children displayed the ability to distinguish living things as a function of growth (Rosengren, Gelman, Kalish, & McCormick, 1991) or regrowth (Backscheider, Shatz, & Gelman, 1993), differentiate mental and physiological processes (Inagaki & Hatano, 1993), realize that properties of living kinds are independent of human action or intention (Gelman & Kremer, 1991), pay attention to animal insides and origins rather than surface features when determining category membership (Gelman & Wellman, 1991; Keil, 1989), rely on categories rather than looks when making inductive inferences within natural kinds (Gelman & Markman, 1986), and construe inheritance in biology-specific way (Springer & Keil, 1989). All these data established important links between child and adult understanding, suggesting continuity in the development of biological knowledge. At the same time, another set of findings showed stark developmental discontinuities. For example, in contrast to adult biological thought, children's projections of biological features were portrayed as anthropocentric, relying on comparison to humans, rather than being constrained by taxonomic relatedness (Carey, 1985). Children's reasoning was described as promiscuously teleological because they assumed living things, like artifacts, are designed for a purpose (Kelemen, 1999). Moreover, children's understanding of inheritance, rather than being biological, was characterized as social (Solomon, Johnson, Zaitchik, & Carey, 1996).

During the first wave of naive biology research, the main focus was on finding universal principles that govern the development of biological knowledge. Three main frameworks were proposed. The intentionality view argued that the foundation of biological knowledge is rooted in naive psychology (Carey, 1999), children's reasoning about living things is anthropocentric, that is, humans serve as a prototype of the living thing category which only includes kinds that, like humans, display intentionality. The vitalism view argued that vital force is the key explanatory construct for biological reasoning (Inagaki & Hatano, 2002). Finally, the essentialism view (Gelman, 2003; Medin & Atran, 2004) assumed that children construe natural or living kinds as organized around central, internal, and unobservable characteristics that causally determine all category-specific features.

The common thread to all these accounts is the claim that young children implicitly partition the world into ontological kinds. Ontological kinds are large superordinate categories such as animal, living thing, artifact, etc. that enjoy a special status in people's naive taxonomies. They are singled out by large clusters of predicates and terms (Carey, 1985). For example, all animals are alive, breathe, have babies, can die, can fall ill, etc. There is a linguistic test that offers an intuitive measure regarding the ontological status of a category distinction. If a predicate is inappropriately applied across the ontological boundary, it generates a category mistake, that is, a statement which, rather than being simply false, is outright nonsensical, for example, "a car has babies, a rock is ill" (Carey, 1985). What makes such statements absurd is a complete misalignment between the feature and the core properties of the category upon which the feature was predicated. Unlike simple category representation, which may be described as a list of unrelated features, each of which being potentially true or false, ontological commitments are based on a system of abstract, causally interrelated properties that are central to the identity of each of the members of the kind. The three major accounts of the development of biological knowledge propose different boundaries to ontological divisions represented by children. According to vitalism (Inagaki & Hatano, 2002) and the essentialist proposal by Medin and Atran (2004), very young children represent an ontological domain that overlaps with the mature representation of living things, that is, includes animals as well as plants and possibly fungi. Carey (1999) proposes a narrower grouping that only includes intentional beings, while Gelman (2003) proposes that children essentialize all natural kinds.

As the field of research on naive biology matured, its focus shifted from universals to variability. This second wave of naive biology research was sparked by adult research showing great variability in biological reasoning across cultures and levels of expertise (see Medin and Atran, 2004 for a review). Developmental studies that followed provided data showing that variability due to culture, language and direct experience with nature seriously constrains or invalidates initial claims about universal patterns of development within biological reasoning. The anthropocentric pattern of inductive inferences was shown to be constrained to urban Western culture children. Children with rich experiences and cultural input about biology relied on biological groupings, either taxonomic or ecological, when extending new knowledge about biological beings (Medin, Waxman, Woodring,

& Washinawatok, 2010; Ross, Medin, Coley, & Atran, 2003 ; Tarłowski, 2006;). Understanding inheritance was shown to be related to cultural views (Astuti, Solomon, Carey, Ingold, & Miller, 2004; Waxman, Medin, & Ross, 2007), and the construal of living kinds was shown to depend on linguistic structure (Anggoro, Waxman, & Medin, 2008).

The discovery of variability naturally provokes questions about its causes. Consequently, the third wave of studies into naive biology is marked by the search for specific factors that contribute to variability in biological knowledge. Rather than relying on group comparisons aimed at specific aspects of children's reasoning, these studies employ experimental and correlational designs, as well as qualitative analyses of parent-child interactions, in order to pinpoint specific factors that potentially contribute to the development of biological concepts. For example, Opfer and Siegler (2004) showed that teaching children about teleological motion in plants makes those children aware that plants are alive, thus experimentally establishing the role of teleological motion as a key foundation to understanding life. Waxman, Herrmann, Woodring and Medin (2014) showed that anthropocentric pattern of induction is displayed by children who were exposed to a storybook anthropomorphizing animals and not to a book featuring realistic photos of animals. Coley (2012) conducted an extensive correlational study among rural and urban children obtaining information about children's out-of-school activities and testing children's reliance on ecological knowledge in induction. He showed that the tendency to make ecological inferences was predicted by whether children spent unsupervised time in nature. Tarłowski (2017) showed that children's tendency to rely on an inclusive concept of a living thing in induction is linked to their exposure to the natural world and the size of their receptive vocabulary. These studies show that the variability in children's reasoning about living kinds can be linked to factors that vary in specificity, such as knowing that plants move toward a goal, being exposed to an anthropocentric description of animals, spending time in nature, having rich vocabulary, etc. A single factor that must be treated with special attention is parental input.

Any account of the sources of biological knowledge should provide a qualitative description of parental input because parents play a central role in children's early development. Parents provide the first foundation for language development, joint attention, social referencing, natural pedagogy, and they offer the scaffolding for development. On the one hand, parental input can be described as a set of universal practices that contribute equally to each child's development. These include inherent attributes of caregiving, historical convergences in parenting or practices promoted through the unifying forces of globalization. Moreover, some of the mechanisms of parental transmission of knowledge and attitudes may also be universal (Bornstein, 2012). On the other hand, cultural and individual variability in parental attitudes, activities, level of expertise, could project to variability in children's knowledge. One of the ways of studying parental contribution to cognitive development is through the analysis of parent-child conversations.

The attempts to establish social roots of naive biological reasoning through the analysis of parent-child conversations draw from the rich tradition of related qualitative research analyzing speech produced by children. Piaget's (1951) data was based on qualitative analysis of children's responses in structured interviews. Significant methodological and theoretical advances came from Gobbo and Chi (1986) who studied the structure of children's expert knowledge within the domain of dinosaurs. Although much of naive biology research relies on quantitative measures, such as children's responses to categorization or induction probes, it is customary to also obtain justifications to those responses and subject these justifications to a qualitative analysis. There is a very rich tradition of qualitative analysis in biology education research, a recent example is an extensive study of children's individual concepts by Rybska (2017). Children's conversations have been extensively studied by Barbara Bokus with the aim to inform and complement general theories of cognitive development. For example, Bokus (2000) provides a thorough analysis of the development of the theory of mind through children's conversations about picture books.

There is also rich tradition of the analysis of parent-child conversations within the field of science education and visitor studies, looking at informal science learning (Crowley & Jacobs, 2002; Crowley, et al., 2001; Fender & Crowley, 2007; Palmquist & Crowley, 2007; Tare, French, Frazier, Diamond, & Evans, 2011; Valle & Callanan, 2006). For example, Palmquist and Crowley (2007) studied conversations between parents and children who were either dinosaur experts or not.

Naive biology is closely linked to other domains of knowledge. It is therefore very unlikely to find an analysis of parent-child conversations that is constrained to the biological domain alone. With this in mind, I will review the studies for which the reasoning about the domain of living kinds forms a central focus.

The prevailing approach in this research is to look at conversations in contexts that are distributed across or around ontological boundaries. For example, Gelman et al. (1998) compared conversations on picture books depicting animals and artifacts. Jipson and Callanan (2003) compared conversations about living and nonliving things. Rigney and Callanan (2011) as well as Geerdts, Van de Walle and LoBue (2015) contrasted parent-child talk about typical and atypical animates, where typicality is understood as the salience of cues to intentionality. Finally, Cameron-Faulkner, Macdonald, Serratrice, Melville and Gattis (2017) studied conversations while the families experienced nature directly (in a botanical garden) or indirectly (in an indoor visitor center devoted to nature). With one exception (Cameron-Faulkner et al., 2017) each of these studies employed a unique set of coding categories that highlight conceptual content potentially distinguishing the domains under comparison. The most prevalent goal was to examine the extent to which parents provide input facilitating the development of children's early ontology.

Gelman et al. (1998) wanted to know whether parental talk contributes to children's tendency to essentialize natural kinds. Because natural kinds are perceived as coherent categories with rich internal structure unified by a central cause, Gelman et al. (1998) examined relational contents, in which two or more items are linked taxonomically or thematically, generic statements (e.g., Dogs Bark, A giraffe is an animal) "which refer to a category as an abstract whole rather than referring to a specific individual" (p. 12), and talk about either nonobvious or readily accessible properties of categories. The results showed that parental use of relational statements was dependent on the context and domain. Parents were most likely to make taxonomic relation statements in the context of two animals representing the same category. The authors also found that parents readily produced generic statements, and that the use of generics was significantly more frequent in relation to animals than to artifacts. They also found that parents rarely conveyed information about nonobvious properties (kinship, origins, teleology), focusing instead on immediately available properties (object use and self-initiated movement). Gelman et al. (1998) concluded that parental input might contribute to the formation of essentialist construal of natural kinds. However, this contribution is not through explicit information, but through an implicit focus on generics and taxonomic relationships.

Jipson and Callanan (2003) focused on the understanding of growth as one of the key concepts distinguishing the living domain. They presented parents and children with a picture book containing images of instances of growth in the living and nonliving domain. They wanted to see whether children and parents talk about growth differently, so they coded all instances of the use of the term growth and whether growth was construed as having an organic, human or other cause (which included intentions). They showed that parents differentiated the domains, and that they mentioned growth overwhelmingly more frequently when referring to increases in size within the biological than within artifact domain.

Rigney and Callanan (2011) as well as Geerdts et al. (2015) were interested in social transmission within the family interacting with a life zoo exhibit as a potential source of children's anthropocentric construal of animates. Consequently, they coded parental talk about intentional characteristics as well as the use of animate and inanimate pronouns. Apart from these categories, Rigney and Callanan (2011) coded biological and physical characteristics and Greedts et al. (2015) included perceptual, conceptual, biological, and connecting content. By connecting content, they meant statements that related the viewed exhibit to existing knowledge or prior experience. Rigney and Callanan (2011) found more intentional talk and more personal pronouns in relation to typical (e.g., fish) than atypical (e.g., sea cucumber) animals. Geerdts et al. (2015) reported more intentional content (which they construed more broadly as social content) as well as more animate pronoun use for typical animals (penguins) than atypical animals (insects). Typical animals also elicited more conceptual and biological content while atypical animals elicited more connecting talk. Both Rigney and Callanan (2011) and Geerdts et al. (2015) concluded that parents may reinforce anthropocentric organization of children's biological knowledge by using more mental and social language in reference to animals that are more closely related to humans in terms of salient clues to intentionality.

In contrast, Cameron-Faulkner et al.'s (2017) approach was more quantitative. They found that the frequency of nature-related words in family conversations was greater in the natural than in the artificial environment, despite the fact that the artificial environment contained materials purposefully designed to foster science learning.

Overall, the studies reviewed above show support to the view that parental speech reflects the ontological divides that children were shown to represent, thus being a likely contributor to their formation. It is not clear though, whether the characteristics of parental input described in those studies are universal or particular to the studied populations. Because the above studies made no distinctions between families in terms of individual or cultural differences, they do not provide any account of variability in parental input. In order to understand the nature of parental contribution to children's biological knowledge, it is necessary to examine the range of variability in parental transmission.

Very few analyses were aimed to identify stable individual or cultural differences that would be displayed in the patterns of parent-child conversation. Leddon, Waxman and Medin (2011) compared records of parent-child conversations from Childes database by Indonesian and American families with the focus on the use of the term *alive*. Their finding suggests that in either linguistic environment parental input does little to support the development of mature, inclusive representation of living things. The study by Gelman, Ware, Kleinberg, Manczak and Stilwell (2014) deserves special attention. Despite the fact that their claims are domain-general, their approach is particularly useful for the study of origins of children's biological knowledge. Gelman et al. (2014) were interested in individual differences in the use of generics. They looked at conversations while viewing picture books containing drawings of a variety of objects. They tested parent and child speech in three interpersonal contexts, i.e., parent-child, parent-researcher, and child-researcher, in two sessions spaced 3-4 weeks apart and they probed three different conceptual domains, i.e., animals, foods, and people. Apart from conversational data, they collected measures of parental tendency to essentialize traits, that is, construe traits such as shy, outgoing, intelligent as stable, immutable, and richly structured. On the one hand, Gelman et al.'s (2014) results showed very high variability across families in the use of generics, on the other hand, there was high consistency across time, conceptual content, interpersonal setting and family. Importantly, when talking with each other, parents and children displayed matching rates of the use of generics, and children's use of generics was related to parental belief in the stability of features. These results offer an important insight into how stable conceptual attitudes are transmitted across generations through the patterns of language use. This research should be extended by looking at a wider range of individual differences.

Parental expertise is an important individual difference factor that has not been studied in the context of parent-child conversations within biology. Studies including the variable of expertise targeted expert and lay children rather than parents (Gobbo & Chi 1986; Palmquist and Crowley, 2007). There is no doubt that there are qualitative differences in how biology experts and laypeople construe living kinds (Bailenson, Shum, Atran, Medin, & Coley, 2002; Medin, Lynch, Coley, & Atran, 1997; Shafto & Coley, 2003). One study shows that children of biology experts reason about animals than children of laypeople (Tarłowski, 2006). Given that conceptual attitudes are transmitted across generations, the level of expertise marks important qualitative differences in the organization of biological knowledge, and parental expertise has been linked to variability in children's representation of living kinds, it is of vital importance to study the role of parental expertise in the transmission of biological knowledge. No extant literature addresses this topic.

The aims of the present study

Past research has established that even very young children rely on ontological commitments when reasoning about biological entities. It has also been shown that there is large variability in how children represent biological categories and that this variability may be related to direct access to nature and parental input. For example, Tarłowski (2006) studied children growing up in an urban environment and in the vicinity of national parks. Those children's parents were or were not biology experts. Only the children of biology experts who had access to rich nature reliably based their inductive inferences of biological features on the category *animal*. Similarly, Tarłowski (2017) showed that access to nature and the size of receptive vocabulary predicted children's reliance on the inclusive category *living thing* in induction. Both these studies suggest that children's experiences play a vital role in how they represent ontological boundaries and how they apply these boundaries in reasoning. The aim of the present study is to see whether parents who vary in biological expertise provide their children with the kind of input that may facilitate the development of the robust and mature ontological distinction separating living things from other kinds of beings. What are the factors that could specifically contribute to the robustness of children's ontological commitments within the biological domain (which means that they are reliably applied in a broad range of contexts) and their alignment with mature ontology (which means that they overlap with the mature extent of the category living thing)? Ontological kinds are large superordinates. One of the reasons that superordinate distinctions are not universally grasped by young children is that, unlike basic level categories, which rely on salient perceptual properties, superordinates are based upon abstract, functional properties (Murphy, 2004). The strengthening of superordinate categorization may be achieved by explicit learning about abstract, functional properties and by analogical reasoning.

The case of explicit learning comes from the research of Opfer and Siegler (2004), who show that early understanding that plants are alive rests on the awareness that plants engage in teleological motion. Children, who learned that plants move towards goals, included plants in the category living thing. Parents could foster children's ontological representations through providing such specific conceptual information.

The acquisition of superordinate abstract groupings is also fostered by comparison or analogical reasoning. According to Gentner's (1983) structure-mapping theory, comparison promotes deep learning, it highlights commonalities between compared items and helps extract common, higher-order relational structure. Therefore, structure mapping facilitates categorization (Namy & Gentner, 2002) and within the categories, based on intrinsic features, the impact of comparison should be most pronounced for higher order groupings, which are based on deep, abstract commonalities.

Research with adult and children experts suggests that their knowledge is distinguished by the level of interrelatedness. Gobbo and Chi (1986) showed that expert children produced more statements comparing and contrasting dinosaurs than their lay counterparts. Shafto and Coley (2003), who compared experts and novices within the biological domain, concluded that "expertise appears to involve knowledge of multiple relations among entities and context-sensitive application of those relations" (p. 641). It can, therefore, be expected that one of the ways in which expert parents facilitate the development of children's superordinate level representations of living things is through promoting thinking that involves comparisons.

In order to test this hypothesis, I asked parents who were either biology experts or did not have expertise in the domain of biology to talk with their children about a picture book containing photographs of nature. The picture book was designed in a way that invited relational talk. I compared various types of information that children and parents produced while viewing the picture book. The coding categories included category labels, references to perceptible features, references to conceptual content, mentalistic talk, and, most importantly, engaging in relational talk. The choice of coding categories was motivated by past research and the specificity of the expert-lay comparison motivating the present study.

Labels. Labeling is the most basic and fundamental form of information regarding category structure (Gelman & Markman, 1986). Data presented by Gelman et al. (1998) showed that both parents' and children's utterances contained labels twice as often than they contained information beyond labeling. Labels are indispensable in a conversation as they establish its focus and serve as pegs onto which additional information can be attached. I expected that labels would be equally prevalent in expert and laypeople's families talk.

Perceptual and conceptual content. The distinction between perceptual and conceptual properties draws from Gobbo and Chi's (1986) work. They defined explicit propositions as relying on observable features visible in the pictures and the implicit propositions as the ones that cannot be directly observed or inferred from the picture. Gobbo and Chi showed that expert children produced more implicit propositions than novice children, while there were no differences in explicit propositions between the two groups. Also, Gelman et al. (1998) and Geerdts et al. (2015) distinguished and coded perceptual and conceptual content, although each of these studies placed the category boundaries somewhat differently. Based on Gobbo and Chi's (1986) data comparing lay and expert children's references to perceptual and conceptual content, it can be expected that expert families produce more conceptual content than lay families, while there should be no differences in perceptual content.

Relations as a coding category are also drawn from Gobbo and Chi's (1986) study. They included the category of semantic comparison, propositions that compare and contrast two dinosaurs, or rely on absolute comparison that applies the superlative. Gobbo and Chi showed a very large difference between experts and novices in the use of comparisons. They tended to use comparison more often than novices. The relational statements were also an important category in Gelman et al.'s (1998) coding scheme. Gelman et al. (1998) demonstrated that taxonomic relations were more prevalent in talk about animals than artifacts. Research by Gobbo and Chi as well as Shafto and Coley (2003) suggests that there could be more relational talk in the expert families than lay families.

Mental states. According to Carey (1985), mental states are the fundamental organizing principle for young children's reasoning about living kinds. More recent research shows that the commonalities between animals and humans in terms of mental states are made salient through cultural transmission and parental talk (Geerdts et al., 2015; Rigney and Callanan, 2011). It is of interest to see whether expert and lay families differ in the use of references to mental states.

Method

Participants

Eighteen Polish families participated in the project. All the participants, both parents and children were native speakers of Polish. All the materials and conversations were in Polish. In seven of the families, parents declared that they were biology experts. In one of the families expertise was declared for both parents, while in the remaining 6 for only one parent. In all the expert families it was the parent who was biology expert who participated in the study and engaged in the conversation with the child. The profile of biological expertise was very diverse, formal education in biology was not a prerequisite for inclusion. The profiles of expertise included a hunter, farmer, researcher, nature educator, and biology major not pursuing biology as employment. Lay parents were recruited among psychology students at the University of Finance and Management in Warsaw. Some participants in the lay group were relations of the students. Experts were recruited through word of mouth, and an Internet forum for naturalists. 86% of mothers and 86% of fathers in the expert group, as well as 64% of mothers and 55% of fathers in the lay group had higher education. Children ranged in age between 4; 0 (years; months) and 8; 10. Mean age was 6; 1, *SD* = 14 months. For the children of expert parents, mean age was 5; 10, *SD* = 11 months, for the children of lay parents, mean age was 6; 2, *SD* = 19 months. Twelve of the children were girls, three of them were daughters of biology experts. Only one child from the sample grew up mainly in a rural environment, the remaining children grew up in an urban or suburban environment. The distribution of growing up environment did not allow for any meaningful comparisons.

Materials

The study consisted of two components, an online questionnaire and parent-child conversation while viewing a custom-made picture book.

Online questionnaire on children's activities and interests. Prior to viewing the picture book with children, parents completed an online questionnaire about their child's activities and interests. Although the main focus was on children's activities and interests related to living kinds, a broad variety of interests and activities was probed, in order to provide a measure of how parents view the children's interest in the natural world in contrast to their other interests. Parents evaluated their children's involvement in a series of activities and interests on a 7-point scale (see Appendix A). Parents' responses were combined into five measures of children's activity and interest, which included nature and plants, animals, humanities and creative play, social relations, as well as entertainment. A more detailed description of these measures is provided in the Results section. Before responding to the questionnaire parents also responded to open ended questions about their children's interests and activities. The responses to open ended questions are not analyzed here.

Moreover, parents were probed about their children's exposure to the natural world. Parents declared the approximate length of time during the year that the child spends in the urban, suburban and rural environment.

Conversations about picture books. Parents received a wordless picture book containing 24 photographs. The photographs were arranged into 12 pairs presented on the opposite pages. Each pair was related in a non-obvious way, to highlight a variety of biological relationships. These included:

1. Human vs. animal similarities (a woman and a lemur eating)
2. Toy animals vs. real animals (teddy bears and dogs)
3. The role of water (withered trees on a desert and a coral reef)
4. Unfamiliar 'cousins' of familiar animals (grey squirrel, foreign cow breed)
5. Taxonomy vs. function (bat and falcon in flight)
6. Taxonomy vs. appearance (legless lizard and earthworm)
7. Plant and animal offspring nurturance (mother-of-thousands with plantlets and dog nursing puppies)
8. Plant vs. animal reproduction (bird eggs and acorns)
9. Natural and artificial brood parasitism (cuckoo chick fed by reed warbler, tiger female with piglets dressed as tigers)
10. Insects harmful vs. beneficial to plants (caterpillar eating a leaf, bee pollinating a flower)
11. Edible vs. toxic living kinds (amanita mushrooms and apples)
12. Weeds and cultivated plants (dandelion and sunflower field)

Parents' Language Ideology

The study was conducted in Poland between May 2014 and November 2017. Before discussing the picture book with the children, parents completed an online questionnaire. On the completion of the questionnaire, parents received picture books through the mail or directly from the researcher. The picture book was in a closed envelope with the instruction attached on top. The instruction encouraged parents to talk with their children spontaneously. Parents were explicitly asked not to prepare for the conversation, although they were informed that they could view the picture book shortly before the conversation takes place. There was no guidance as to the length and content of the conversation. Specifically, there was no mention of the relationships between paired pictures. Parents were asked to record the conversations (voice only) at their homes, with the use of a smartphone or other device and to submit the recording via e-mail. Before viewing the photographs, parents read a short introductory note included in the picture book, which informed children that the session is to be recorded. The conversations were held between one child and one parent. In the expert group, it was always the expert parent who talked to the child.

Coding

Parent-child conversations are open-ended and unconstrained. They provide a very rich source of data that can be analyzed for a variety of contents. As I reviewed above, studies looking at parent-child conversations within the domain of biology focused on a diverse set of coding categories, that included relational language, the use of generics, the terms for growth, being alive, biological functions, physical descriptions, pronouns and many more. The present analyses draw from the work of Gelman et al. (1998), Gobbo and Chi (1986) as well as Geerdts et al. (2015) by relying on a broad range of coding categories, although the key interest lies in relational language. The speech was coded into five content categories.

Category labels. The first category referred to categorization. It encompassed any category label that was used in reference to the objects presented in the photographs, beginning with the superordinate category terms, such as plant, or animal and ending with the most specific terms, such as reed warbler or peregrine falcon. Gender, social, and age categories were also included, as well as incorrect categorizations. In this sense, the measure is not a reflection of category knowledge, rather, it signals the focus on assigning objects to categories.

Perceptual description. This category included all the references to characteristics that were visible in the pictures, that is, the mentions of body parts, color, size, location, environmental context, numerosity or amount, body posture, and activities that could be readily inferred from the image, such as a fish swimming, a lemur eating, a reed warbler feeding a cuckoo.

Conceptual description. This category was intended for information that participants brought to the task. It included all mentions of features, behaviors and relations characteristic of the entities in the pictures that were not immediately perceptible, such as transformation, growth, feeding, needing water, predatory behavior, camouflage, fertilization, pollination, internal parts, being alive, dying, being ill, habitat, relationships to other living things, including humans, or environment, such as food chain relations. Personal experiences were also included if they contributed to category knowledge regarding these objects, that is, referred to generic rather than transient properties, so, for example, “There was an earthworm at grandma’s” was not included as conceptual content. The phrases were included in the conceptual category even if they referred to observables in case they were generic statements. For example, "Bats fly at night" would be coded as conceptual description while "This bat is flying at night" would be coded as a description of the observable property.

The conceptual category also included any reference to causality, functions, and adaptation, any reference to why an object has a particular feature, or performs a particular behavior, for example, "The piglets have tiger coats so that the tiger mother won't eat them" or "They have no leaves because there is no water".

Relational description. The material was designed in such a way as to promote relational thinking. As described in the materials section, all the pairs of pictures invited comparison or contrast. The relational category included any form of comparison between the items visible in the pictures as well as any objects that were brought to participants' minds while viewing the picture book.

Any explicit mention of comparison or contrast was included in this category. The relational category was double-coded – all the features that were compared entered into the relational category, but they also entered into the perceptual or conceptual category. For example, "Both the girl and the animal are eating" was coded as perceptual description and relational description.

Justifications for categorization, such as "It is a caterpillar because it has hairs", were coded as a relational description on the assumption that the utterance contrasts the target object from related objects by providing the unique difference. In other words, the property that justifies categorization is an explicitly stated differentia in an informal genus-differentia definition. "These are not true eggs!" would be coded as relational description, because it implied the appearance-reality distinction.

Mental states. The final category included any reference to mental states of the objects that were presented in the pictures. References to mental states of entities not present in the pictures were not coded in this category.

Importantly, repetitions were not coded. Only the first reference to a particular content in the context of a specific picture was coded. The most frequent format of parent-child exchanges consisted of question-answer sequences initiated by the parents. Questions were coded only when they carried information in themselves. For example, "What is this?" was not coded as categorization, while "Is this an earthworm?" was. Questions about causes and functions were coded as conceptual content, because they conveyed important conceptual information: "There is a cause/function to this, and I want to know what it is".

Recordings were transcribed verbatim, coded manually in MS Excel. Accuracy of transcription was checked by comparing the transcription of

5% of data performed by an independent transcriber. The agreement reached 98%. The author coded all the material. An independent coder coded 8% of the transcript. First, the codable and uncodable utterances were separated. Uncodable utterance were those that did not refer to the pictures themselves, were either organizing the conversation, e.g., “Let’s move to the next page” or referred to unrelated topics. The agreement on codable vs. uncodable utterances was 89.7% (Cohen’s kappa = .79). The coding categories were assigned to codable units of information rather than the whole utterances on the assumption that a single utterance can contain more or less rich content. The agreement on coding categories between the coders was 90.1% (Cohen’s kappa = .87). Appendix B contains a sample of parent-child exchanges with coding.

Results

Both, the total amount of information brought to the task and a relative focus on each category was of interest. For each child and parent, I calculated the number of units of information in the five coding categories. After that, I divided the number of coded items by the participant’s total to obtain a proportion of items within a given category. In this way, apart from raw frequency measures, I obtained a measure of the focus of each participant on a given coding category relative to other categories. These data are presented in Table 1. Because the number of participants is small, in some analyses I rely on one tailed rather than two tailed significance. I only rely on one tailed significance level when the direction of difference is in accord with the hypothesis. None of the significance levels is adjusted for multiple comparisons.

Biological expertise

First of all, I compared the overall frequency of coded content between expert and lay families. I used nonparametric tests because samples were small and unequal in size, and the distributions were skewed. Expert parents produced more utterances than lay parents (see Table 1) $U = 14.5$, $Z = -2.18$, $p = .029$ (two-tailed). Expert children also produced more utterances than lay children, $U = 20$, $Z = -1.68$, $p = .047$ (one-tailed).

In order to see whether lay and expert families differed in the kinds of information they produced during conversations, I separately compared parents and children from the two groups on the proportions of utterances falling into each coding category (see Table 1 for descriptive statistics).

Table 1. Raw frequencies and proportions of coded utterances within each category for parents and children in the two comparison groups.

	Label	Perception	Concept	Relation	Mental	Total
Parent, lay						
Frequency	8.5 (4.5)	13.4 (6.6)	18.8 (15.6)	6.4 (3.6)	2.6 (2.3)	49.7
Proportion	.18 (.05)	.29 (.09)	.35 (.11)	.13 (.04)	.05 (.03)	(28.9)
Child, lay						
Frequency	23.5 (7.0)	20.1 (12.0)	10.9 (7.3)	3.2 (2.7)	1.5 (2.0)	59.3
Proportion	.42 (.14)	.32 (.11)	.18 (.10)	.05 (.04)	.02 (.03)	(21.0)
Parent, expert						
Frequency	12.0 (5.7)	20.3 (11.3)	52.7 (40.6)	25.3 (18.1)	1.9 (2.5)	112.1
Proportion	.13 (.08)	.20 (.06)	.43 (.12)	.23 (0.06)	.02 (.02)	(71.6)
Child, expert						
Frequency	28.7 (7.6)	24.3 (11.7)	23.3 (13.9)	10.7 (11.8)	2.0 (2.0)	89.0
Proportion	.36 (.13)	.26 (.08)	.26 (.08)	.10 (.08)	.02 (.02)	(37.3)

Note: The totals are for frequencies only. Standard deviations are presented in parentheses.

The analysis of proportions showed a significant difference between lay and expert parents on all measures except conceptual content. Lay parents produced a greater proportion of labels, $U = 19$, $Z = -1.77$, $p = .039$ (one-tailed), perceptual descriptions, $U = 16$, $Z = -2.04$, $p = .041$ (two-tailed), and mental language, $U = 14.5$, $Z = -2.19$, $p = .029$ (two-tailed). Expert parents produced a greater proportion of relational content $U = 6$, $Z = -2.95$, $p = .003$ (two-tailed). There were no differences between lay and expert children in the proportions of content categories.

Differences between parents and children

In order to compare parents with children, I carried out a series of Wilcoxon's signed rank tests. The analysis of proportions yielded a significant difference for labels, $Z = -3.72$, $p < .001$ (two-tailed), children produced more labels than parents. There was also a significant difference for conceptual, relational and mentalistic content, $Z = -3.55$, $p < .001$, $Z = -3.63$, $p < .001$, and $Z = -2.33$, $p < .02$, respectively (all ps two-tailed). For those measures, parents produced more content than children.

Correlations between parents and children as well as children's age

There was a strong correlation between parents and children for the total amount of information produced during the conversations, rho = .70, $p < .001$. The analysis of proportions of specific content types showed a correlation between parents' and children's relational, rho = 0.54, $p = .019$; and mentalistic input, rho = 0.53, $p = .025$.

Interestingly, despite very large age range (almost 5 years) the correlations between children's age and coding categories in parents' and children's input were not significant. Neither did age correlate with the total amount of information produced by parents or children.

Children's interests and activities

Based on the analysis of content and intercorrelations between items, I combined the items from activities and interests questionnaire to create five dimensions potentially relevant to the content of parent-child conversations. Those included (1) plants and nature (Items 7, 10, 23 in the Appendix A), alpha = .80, (2) animals (items 8 and 22), tau = .74 $p < .001$, (3) humanities and creative play (Items 1,2,3,16, 21, 26) alpha = .84, (4) entertainment (Items 4, 5, and 17), alpha = .82, (5) social relations (Items 12, 13 and 27), alpha = .69. Descriptive statistics for those scales are presented in Table 2.

I compared lay and expert children on measures of their interests and activities (nature and plants, animals, humanities, social relations, as well as entertainment). None of the measures yielded significant differences between the groups.

I also carried out nonparametric correlations between the measures of children's activities and interests, with all the coding categories as well as the total number of coded content. None of the correlations were significant, although it is difficult to draw any conclusions from this analysis due to small sample size. There is not enough power in the design to detect any medium-sized effects, and there is no reason to expect strong effect sizes.

Table 2. Means (and standard deviations) for parents' ratings of children's activities and interests. The scale ranged from 1 to 7, with higher values indicated more interest.

	Plants and nature	**Animals**	**Entertainment**	**Humanities**	**Social**
Lay children	3.70 (1.33)	4.68 (2.06)	3.00 (0.98)	4.88 (1.28)	5.82 (1.09)
Expert children	4.43 (0.92)	4.57 (1.62)	3.67 (1.66)	4.86 (0.58)	6.00 (0.79)
Overall	3.98 (1.21)	4.64 (1.85)	3.26 (1.28)	4.87 (1.04)	5.89 (0.96)

Although this was not the aim of the study, I compared parental assessments of children's interests. Friedman's test yielded a significant difference between domains, $\chi2(4) = 27.82$ $p < .001$. A set of post hoc Wilcoxon signed rank tests revealed that social interests received higher scores than any other interests, humanities received higher scores than nature and entertainment, and animals received higher scores than entertainment, all *ps* < .05, two tailed.

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Discussion

The analysis of parent child conversations is an indispensable tool for those trying to understand the shaping of children's reasoning and the sources of variability in children's knowledge. One of the factors that has been largely overlooked in this research is parental expertise. The level of expertise is related to central qualitative differences in the structure of knowledge. It is of great interest to see whether these different forms of knowledge are transmitted cross-generationally, and if they are, what effect this has on children's thinking. The present study analyzed the informational content within parent-child conversations about a nature picture book while controlling for the level of parental expertise within biology. Five content categories were identified, namely category labels, perceptual and conceptual descriptions, relational and mentalistic talk. In the discussion, I will summarize the key findings, relate the observed effects of expertise to a selection of studies on expertise within development of naive biology, and provide a discussion on how the specific content of expert parents' input could help shape children's mature ontological representation of the living domain. Finally, I will offer suggestions for the implementation of the results within the educational system and discuss the limitations of the study.

The summary of results

The analysis of parent-child conversations about picture books shows clear differences between families with a varying level of parental expertise. Expert parents conveyed more information in absolute terms and the kinds of information that they conveyed to their children were also different. Expert parents focused more on comparisons, while lay parents produced more labels, perceptual descriptions and references to mental states. Expert children produced more content overall than lay children but the differences within specific content categories were not significant.

The analyses also show that parents differ from children in the kinds of content they produce. Children mainly focused on providing category labels. This could have been related to the most predominant pattern of exchanges, where a parent asked the child to identify the objects in the pictures and the child responded. Parents and children did not differ in their focus on perceptual description, but parents produced more conceptual and relational content than children.

Parent-child correlations show that there was an active cross-generational interchange of ideas and this was particularly salient for the relational and conceptual content. This result is in line with findings by Gelman et al. (2014) or Tare et al. (2011) who show correspondences between parents' and children's conceptual attitudes.

Surprisingly, there was no relationship between the content of conversations and measures of children's interests and activities. The analysis of questionnaires shows that there is no difference between children of experts and laypeople in their activities and interests related to plants and nature, animals, humanities, social relations, as well as entertainment. It is particularly surprising that children of experts did not show increased interest and activities related to the living domain. This lack of difference may, in part, result from expert parents treating their own interests in nature as a reference point, which would make them harsher judges of their children's interest in nature. Moreover, the measures of interests and activities did not correlate with the content produced during the conversations. The reason for this may lie in the small sample size, small effect sizes, and the lack of refinement of the scale measuring children's activities and interests.

Despite the large age range, there were no correlations between age and the content produced by either children or parents. It is clear that 4-year-olds conceptualize nature differently than 8-year-olds. Moreover, verbal abilities vary greatly across this age range. It is, therefore, unexpected that age does not produce any effects. One of the reasons for this may be related to the specificity of activity that was analyzed in the study. It is likely that younger children in the studied age range engage in picture book viewing with parents more often and they find this activity more natural. The older children and their parents may have grown out of picture viewing together and thus may have found the circumstances awkward, which would inhibit their conversation.

The effects of expertise in light of the extant literature

The present study is the first to look at variability in the content of parent-child conversations about the natural world as a function of parental expertise. There is a related study that focuses on children's expertise and provides surprising findings. Palmquist and Crowley (2007) analyzed conversations between parents and dinosaur expert or novice children in a natural history museum. Unexpectedly, parents of dinosaur experts provided less informational content during the conversation. There was less indication of learning from exhibits in expert children's families than novice children's families. Why could this be? Children's interest in dinosaurs is usually internally generated, rather than a result of parental guidance and encouragement. Children attain a high level of expertise that may not be matched by parental expertise or interest. As children's interest develops, parents turn from teachers to testers, thus often missing the opportunity to learn from novel experiences. The present study differs from Palmquist and Crowley's (2007) in that the sample was divided based on parental rather than children's expertise. It also yields a different pattern of results. The results clearly show that expert families generate more content overall than lay families. The overall amount of information generated suggests that expert families are more rather than less engaged with the picture books. The difference between the present results and Palmquist and Crowley's (2007) findings suggest that at the early stages of knowledge acquisition, for preschool and early school children, it is favorable if parent possesses a superior level of expertise and can serve as a guide and mentor for the child's conceptual development.

The work on the structure of expert knowledge shows parallels to the present findings. Gobbo and Chi (1986) compared expert and novice children's descriptions of dinosaurs and showed that the two groups did not differ in the frequency of explicit propositions (those that were based on observable cues from the picture). However, expert children produced significantly more implicit propositions (those that were not directly derived from perceptual information present in the picture). Additionally, experts' word use revealed greater connectedness within their knowledge structures. They used more grammatical connectives, such as "but", "because", "or". Finally, experts generated significantly more comparisons between the dinosaurs they were describing. Also, Shafto and Coley (2003) point out that the key distinguishing feature of adult biology expert knowledge is its interrelatedness. These data show that in case of experts, knowledge triggered by the image activates related knowledge. This allows experts to produce a greater amount of information overall and a greater amount of relational talk in particular. The present findings show a similar pattern of expert-lay family differences, with more relational content produced by expert parents. All the families were engaged in naming objects in the pictures and describing them, but for expert families, the images activated more relevant domain knowledge than for lay families. For example, the images prompted expert parents to talk about their personal experiences with nature (Appendix B, Example 16), their know-how (Example 11), as well as knowledge acquired from specialist literatures (Example 7). In Example 7, it can be seen how the expert knowledge is used to build a multidimensional comparison between trees that rely on different strategies to distribute their seeds.

It is also of interest to relate the findings relating to mentalistic content to the extant literature. There is research showing that parents promote children's anthropocentric bias by using anthropomorphizing language (Geerdts et al. 2015; Rigney and Callanan, 2011). While the present results suggest that lay parents used more references to mental states than expert parents, the overall frequency of these references was low, with the highest value of 0.05 for lay parents and 0.2 for both groups of children and expert parents. No direct comparison with other studies can be made because coding categories were not the same but Geerdts et al. (2015) reported parent's proportion of about 0.17 and 0.06 for penguins and stick insects (I calculated those values from frequency data they present). For preschool children, these values were about 0.25 and 0.06 respectively. This suggests that anthropomorphizing content was more prevalent in their study than in the present study. This is not surprising. The families in their study only interacted with animals, while much of the content of the picture book consisted of plants, and plants do not invite mental references. Moreover, participants of Geerdts et al.(2015) study observed live animals and their behavior, which naturally elicits explanations in terms of mental states. In the present study, the stimuli were pictures, and the behavior of animals was not frequently inferred. When it was, participants sometimes referred to mental states to account for it, as in Example 1. The fact that expert parents produced fewer references to mental states than their lay counterparts suggests that parental tendency to anthropomorphize animals reported by Geerdts et al. (2015) as well as Rigney and Callanan (2011) may not be universal. It may be characteristic of parents who lack biological expertise. Biology experts do not avoid mental language in reference to animals, but they have so much more information to convey that the proportion of references to mental states in their input is lower, and thus anthropomorphizing messages are less salient and prevalent.

Ontological distinctions

The original motivation for this study came from the finding showing high variability in how preschool children's inductive inferences draw on superordinate biological groupings which mark fundamental ontological distinctions (*animal* and *living thing*). Past research shows that children whose parents were biology experts or those who had a higher general level of receptive vocabulary were more likely to rely on ontological distinctions in induction (Tarłowski, 2006, 2017). The children who participated in the present study were not probed for inductive inference. In order to establish any direct link between the patterns of family conversation and the availability of ontological domains for induction, it is necessary to study both these phenomena in the same set of individuals. This is a direction that should be pursued. However, the present research provides some hints as to how parental expertise may be a potential source of variability in children ontological representation.

That reliance on categories in induction is linked to domain knowledge, is clear from work on adults and children (Fisher, Godwin, & Matlen, 2015; Inagaki, 1990; Opfer & Siegler, 2004; Shafto, Coley, & Vitkin, 2007). Expertise influences the availability of categories in the context of induction. It could be the case that the more facts children know about category members the more likely they are to think of them in terms of common category membership. If this were the case, the ability to rely on abstract high-level groupings in induction would stem from a large amount of specific knowledge, which expert parents readily provide. Expert parents often focused on the phenomena which are central to the biological domain, such as reproduction, adaptation, and ecological relations. In Examples 16 and 7, ecological relationships between plants and animals are discussed. Moreover, in Example 7, the parent describes specific adaptations to reproduction. In Example 10, the parent brings child's attention to the role of seeds in plant reproduction.

Apart from specific category knowledge, there is one cognitive mechanism that could have a strong impact on the representation of ontological groupings. Gentner (1983) argues that comparison promotes structure mapping. Engaging in comparison highlights abstract relational properties. Superordinate categories are based on abstract relations (Murphy, 2004). The properties that unite all the animals or all living things refer to the pattern of motion, and a combination of biological properties and processes that are abstract and not readily available perceptually. Most of the research on how structure mapping facilitates categorization refers to relational rather than entity categories. However, *animal* or *living thing* are entity categories. And yet, if any representations of entity categories are to be strengthened through comparisons, superordinates are the likely candidates.

Graham, Namy, Gentner and Meagher (2010) showed how the comparison mechanism assists preschoolers in focusing on less obvious properties of objects when forming novel categories and that providing labels enhances the comparison effect. Gelman, Raman and Gentner (2009) asked children to list commonalities and differences for two objects that were either from the same ontological domain (two animals) or from different ontological domains (animal and an artifact). Children were prompted either by generic (dogs and cats) or specific language (this dog and this cat). The results showed that comparing objects from the same ontological domain prompted by generic wording made it most likely for children to generate deep rather than surface commonalities. These results suggest that the opportunity to compare objects, paired with language that promotes category generalizations, leads to the higher availability of features that underlie the common superordinate category membership. The present results show that the distinctive characteristics of expert input was the focus on comparisons.

Expert parents draw children's attention to commonalities between kinds (Example 6). They provide explicit information about taxonomic relationships (Example 12) and use comparisons to establish taxonomic membership (Example 14). The correlation between parents' and children's relational content suggest that experts' relational mindset is transmitted to children. Expert children often spontaneously engaged in comparative reasoning (Examples 13 and 15). The fact that expert parents generated more relational talk, and that the tendency to use relational language was reflected in their children suggests that expert children may have better-developed representations of abstract, higher order biological categories. This hypothesis needs to be further investigated.

Overall, the present findings fill an important gap in the extant literature. Past research established that conceptual attitudes can be transmitted across generations (Gelman et al. 2014), both children and adult experts' knowledge is marked by the focus on relations (Gobbo & Chi, 1986; Shafto & Coley, 2003), relational thinking enhances categorization (Graham et al., 2010), and parental expertise is related to children's greater reliance on ontological groupings in induction (Tarłowski, 2006). The present studies confirm that expert parents transmit the relational reasoning to their children and thus suggest that the focus on relational thinking may be mediating parental contribution to children's mature ontological representation. The final confirmation for this hypothesis will require testing both parent-child conversations and children's reasoning across the different levels of parental expertise.

Implications for education

There is growing interest in informal science education. This research shows that learning science is an everyday activity that is not constrained to school settings (National Research Council, 2009). Children and parents discuss science topics in the most mundane of circumstances, such as during cooking or having family lunch. The present study shows that families, regardless of their level of expertise, engage in scientific thinking in the domain of biology. The quantitative analysis of coding categories does not reveal the richness and depth of knowledge about nature displayed by all the families, both expert and lay. That is why it is useful to look at specific examples. Lay parents often conveyed complex biological information to their children. They discussed ecological roles of animals (Example 2), camouflage (Example 3), commonalities between animals and plants in terms of reproduction (Example 5), brood parasitism (Example 8).

Expert parents did not seem to withhold their specialist knowledge from their children out of concern that they would not understand and become discouraged. The content of expert descriptions clearly reveals the profile of parental expertise. Example 11 comes from a farmer, while Example 7 from a trained botanist. Apart from simply sharing domain knowledge, expert parents also reveal strategies of inference making, Example 16. In the same example, a parent shows how to apply biological reasoning to solve little everyday mysteries, thus demonstrating that scientific knowledge can be applied on a day to day basis.

It is not the case that this parental input is too advanced and falls into a vacuum. Children actively engage parents, ask for more information and clarification. They also show an astounding level of expertise on their own. Three expert children spontaneously identified the squirrel as a grey squirrel. One child spontaneously named a reed warbler and peregrine falcon and was corrected on the latter classification. Conversation from Example 14 could well have taken place between adult ornithology enthusiasts.

The conversations also reveal how children use their knowledge to creatively solve interpretative problems posed by the photographic material. Example 9 is particularly interesting in this regard. A 4-year-old knows that animals need food in order to warm up, and she thinks that the warmth comes directly from warm dishes, such as hot soup, or tea. From this, she infers that the nut the squirrel is eating must be warm. Then she realizes the improbability of this conclusion and makes a joke about the squirrel cooking the nut in a pot.

Although the new approach to early biology education is emerging (Poziomek, Tarłowski, Marszał, & Ostrowska, 2015), the dominant approach to early school education still relies heavily on Piagetan theory (Skura & Lisicki, 2012) which is dominated by the language of early limitations rather than early competence and sophistication. This results in educational programs and materials that often fail to present sophisticated biological contents to children. The present results, by showing great sophistication in family discourse about nature, could inspire more research and, eventually, curricular changes that will introduce more conceptual and relational content into early nature education.

Biology is one of those domains that make the cross-generational transfer of expertise quite natural. Children are spontaneously drawn to nature; they show high interest in classifying the natural world. Some researchers argue that this cognitive engagement in the natural world is an evolutionary adaptation (e.g., Medin & Atran, 2004). It is therefore possible for expert parents to convey to their children a direct, albeit simplified, version of conceptual issues that they face in their work. This motivational and conceptual readiness to absorb biological knowledge could be exploited by lay-parents and educators, if they were aware that providing sophisticated conceptual content and highlighting relations is well received by young learners.

Limitations of the study

The major drawback of the present study was a small number of participants. This clearly diminishes the power and reliability of the statistical analyses. However, small sample sizes are not unheard of in this area of research. For example, Tare et al. (2011) studied 12 families, Gobbo and Chi (1986) compared 5 dinosaur experts with 5 novices, Gelman et al's (1998) landmark studies each employed 16 families. Rich data, large effect sizes, and favorable priors offset the small sample size to some extent.

Another problem is related to sampling, the two comparison groups were recruited using different methods and may not be comparable on the dimensions other than biological expertise. Moreover, the notion of biological expertise is rather fuzzy. Biology expert parents do not comprise a natural kind. There is no natural boundary that separates them from other parents on the dimension of transfer of biological knowledge. Unlike most studies comparing expert and novice children, I could not and did not quantify parents' knowledge. Apart from expertise, there are several other factors that contribute to the nature of transfer of biological knowledge from parents to children, these include attitudes toward parenting, living conditions, workload, and many more. Another aspect that makes the lay-expert division fuzzy is the internal variability between experts. There are clearly profiles of expertise. Forest rangers, veterinarians, landscapers, geneticists, molecular biologists, ecologists, ornithologists, hunters, farmers, etc. all have expertise related to the natural world. Not all these diverse profiles of expertise are equally transferable to young children.

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Appendix A

Questionnaire on Activities and Interests Completed by Parents

A. Original Polish version

Aktywności. Czym zajmuje się Państwa dziecko?

W tej części ankiety proszę o ocenę jak ważne są dla Państwa dziecka wymienione poniżej aktywności. Proszę wziąć pod uwagę czas, który dziecko poświęca na daną aktywność, chęć podjęcia tej aktywności oraz wpływ jaki ta aktywność ma na dziecko. Biorąc pod uwagę te wszystkie elementy proszę ocenić na skali od 1 do 7 jak ważna dla dziecka jest każda z poniższych aktywności.
1 oznacza 'zupełnie nieważna' - 7 'bardzo ważna'

1. Czytanie
2. Zabawa twórcza (np. rysowanie, konstruowanie, zabawa lalkami, samochodami)
3. Systematyczne doskonalenie umiejętności (np. gra na instrumencie, taniec, programowanie, nauka języka)
4. Oglądanie telewizji/filmów wideo
5. Granie w gry komputerowe/korzystanie z Internetu
6. Zakupy, spędzanie czasu w galerii handlowej, markecie
7. Aktywności w naturalnym środowisku (np. łowienie ryb, zbieranie grzybów/jagód, fotografia)
8. Aktywności związane ze zwierzętami domowymi lub gospodarskimi (np. zabawa, karmienie, obserwowanie)
9. Prace domowe (np. gotowanie, szycie)
10. Aktywności związane z roślinami (np. opieka, obserwacja, zbieranie)
11. Eksplorowanie najbliższego otoczenia bez udziału dorosłych
12. Zabawy i rozmowy z dorosłymi
13. Zabawy i rozmowy z rówieśnikami
14. Spacery, wycieczki
15. Zorganizowana aktywność fizyczna (np. uprawianie sportu)

Zainteresowania. Jakimi dziedzinami życia interesuje się Państwa dziecko? Proszę ocenić jak ważna dla Państwa dziecka jest każda z wymienionych poniżej dziedzin zainteresowań wybierając jedną z wartości na skali 1 do 7 gdzie 1 oznacza 'zupełnie nieważna' a 7 'bardzo ważna'. Proszę wziąć pod uwagę w jakim stopniu dziecko samodzielnie, systematycznie i usilnie dąży do zdobywania wiedzy na temat danej dziedziny.

16. Sztuka, historia (np. muzyka, malarstwo, wydarzenia historyczne)
17. Rozrywka (np. filmy, gry komputerowe, życie gwiazd)
18. Sport (np. znani sportowcy, piłka nożna, tenis)
19. Wygląd, moda (np. ubrania, fryzura, kosmetyki)
20. Geografia i astronomia (np. mapy, nieznane miejsca, zjawiska pogodowe kosmos)
21. Języki obce
22. Zwierzęta
23. Rośliny
24. Technika (np. samochody, statki, komputery, telefony)
25. Matematyka, logika (np. łamigłówki, szachy, liczenie, mierzenie)
26. Literatura (np. bajki, opowiadania, powieści)
27. Relacje społeczne (np. informacje na temat członków rodziny, znajomych, historie rodzinne, zdjęcia)

B. Ad hoc translation to English

Activities. What does your child do?

Please take into account the time your child devotes to each activity, the desire to engage in this activity and the influence this activity has on the child. Taking all these factors into account, please assess on a scale from 1 (completely unimportant) to 7 (highly important) how important each activity is to your child.

1. Reading
2. Creative play (e.g., drawing, constructing, playing with dolls, cars)
3. Systematic skill practice (e.g., playing on an instrument, dance, programming, learning a language)
4. Watching TV / films on video
5. Computer games/ using the Internet

6. Shopping, spending time in shopping centers or supermarkets
7. Activities in nature (e.g., fishing, mushroom or berry picking, photography)
8. Activities related to domesticated or farm animals (e.g., playing feeding, observing)
9. Housework (e.g., cooking, sowing)
10. Activities related to plants (e.g., tending, observing, picking)
11. Exploring the neighborhood without adult guidance
12. Play and conversations with adults
13. Play and conversations with peers
14. Walks and excursions
15. Organized physical activity (e.g., playing sports)

Interests. What domains of life is your child interested in?

Please assess the importance to your child of each of the listed domains of interest choosing one of the values on the 1 to 7 scale, where 1 means completely unimportant and 7 means very important. Please take into account the degree to which your child independently, systematically and earnestly strives to build their knowledge within that domain.

16. Art, history (e.g., music, painting, historical events)
17. Entertainment (e.g., films, computer games, celebrities)
18. Sport (e.g., famous sportspeople, soccer, tennis)
19. Looks and fashion (e.g., clothes, hairdress, cosmetics)
20. Geography and astronomy (e.g., maps, unknown places, weather phenomena, cosmos)
21. Foreign languages
22. Animals
23. Plants
24. Technology (e.g., cars, ships, computers, phones)
25. Math and logic (e.g., charades, chess, counting, measuring)
26. Literature (e.g., children's fables, stories, novels)
27. Social relationships (e.g., information about family members, family stories or photos)

Appendix B

Original Samples of Parent-Child Exchanges with Coding
(L: Labels; P: Perceptual Information; C: Conceptual Information; R: Relations; M: Mental States). Ad hoc English translation is in Italics.

Speech samples	Coding
Example 1. Girl, aged 7;8, lay parent	
Child: A tu wiewiórka *And a squirrel here.*	L
Parent: Świetnie. Co ona robi, ta wiewiórka? *Great! What is it doing, this squirrel?*	
Child: Nie wiem, chyba chce przeskoczyć, … nie chce już stać w miejscu *I don't know, it probably wants to jump,…* *it doesn't want to stand still any longer.*	M; M
Example 2. Girl, aged 5;6, lay parent	
Child: Wąż albo jakaś dżdżownica albo gąsienica *A snake, or some earthworm or caterpillar.*	L; L; L
Parent: Raczej dżdżownica, tak? *An earthworm, right*?	
Child: yhy *Yeah*	
Parent: Bo gąsienica ma takie jeszcze jakby futerko. Dżdżownica wchodzi i użyźnia ziemie, wchodzi do takich różnych zakamarków w ziemi. *Because a caterpillar has a kind of fur.* *An earthworm enters and fertilizes the soil,* *it enters into crannies in the earth.*	C; R; C; C
Example 3. Girl, aged 7;8, lay parent	
Child: Niebieskie jajka. Może są pomalowane. Ciekawe dlaczego one mają takie brązowe coś na skorupce *Blue eggs. Maybe they are painted. I am* *wondering why they have such a brown* *something on a shell?*	P; L; C; P; C
Parent: Może żeby były bardziej zamaskowane, żeby ich tak łatwo nie można było znaleźć. *Maybe so that they are better camouflaged,* *so that they won't be found easily.*	C; C
Example 4. Boy, aged 8; 10, lay parent	
Parent: Co się z nich robi? Tych co nie pamiętasz?	

Speech samples	Coding
What is made out of them? Those that you don't remember.	
Child: Ale co?	
But what?	
Parent: Ludziki	C
Figurines	
Child: A tak, żołędzie!	L
Ah, yes, acorns!	
Example 5. Girl, aged 4; 0, lay parent	
Parent: Takie maleństwa. Widzisz, taka mama piesek ma takie małe swoje pieski i taki listek ma swoje małe listki, które urosły, widzisz i potem będą takie duże	L; L; C; L; C; R; C
Such little ones. You see this doggie mama has its small dogs and this leaf has its little leaves, which grew, you see? And then they will be this big.	
Example 6. Boy, aged 5;9, expert parent	
Child: Nietoperz, a tu sokół wędrowny.	L; L
A bat and a peregrine falcon here.	
Parent: Tak i oba zwierzątka umieją latać, co?	L; R; C
Yes, and both animals can fly, right?	
Child: Tak, jedno jest nocna, a drugie dzienne.	C; C; R
Yes, one is nocturnal and the other diurnal.	
Parent: A jak myślisz, czymś się jeszcze różnią?	R
What do you think also makes them different?	
Child: Ten ma tu błony, a ten ma tu po prostu skrzydła.	P; P; R
This one has membranes here, and this one simply has wings	
Example 7. Girl, aged 6;8, expert parent	
Parent: Nigdy nie myślałam w ten sposób o drzewach. Na przykład jest powiedziane, że dęby mają takie duże i ciężkie owoce i nie rozprzestrzeniają się na dużą odległość, jakaś sójka może ewentualnie przenieść, a są drzewa które mają bardzo malutkie nasionka z jakimiś włoskami i wiatr je potrafi porwać.	C; C; C; C; C; C; C; R; R; R
I've never thought about trees in this way. For example, it is said, that oaks have such large and heavy fruit and they do not spread on large distances, some jay may possibly carry (them), and there are trees that have very small seeds, with some hairs, and wind can carry them.	

Speech samples	Coding
Example 8. Girl, aged 7;8, lay parent	
Parent: Popatrzcie na te dwa obrazki. Tu jest prawdziwy tygrys i takie oszukane tygrysiątka. A tu prawdziwy ptaszek, ale też nie jego dziecko, prawda? Tu jest inne dziecko i tu też są inne dzieci, ale czy ci rodzice się przejmują tym, że to są inne dzieci? *Look at these two pictures. There is a real tiger and such fake tiger cubs. And here, there is a true bird, but this is not its baby either, right? A different baby here and different babies here as well, but do these parents care that these are different babies?"*	L; L; L; L; R; R; R; M
Example 9. Girl, aged 4; 7 expert parent	
Child: Wiewióra. *A squirrel.*	L
Parent: Fajnie łapkę trzyma. *It's holding her paw in a cute way.*	P
Child: Bo ona zjada orzeszka. *Because she is eating a nut.*	P; C
Parent: Ciekawe którego, włoskiego czy laskowego. *I am wondering which one, a walnut or a hazelnut.*	C; C
Child: Włoskiego i laskowego ma w swojej dziupce. *It's got a walnut and a hazelnut in its mouth.*	
Parent: Może zbiera na zimę. *Maybe she is collecting for the winter.*	C
Child: Widać, że troche sobie zjada bo jest troche jej zimno. A ten orzeszek jest bardzo ciepły bo go ugotowała. Wzięła garnek i ugotowała. *You can see that it's eating a bit, because she is a bit cold. And this nut is very warm, because she cooked it. She took a pot and cooked it.*	C ; C
Example 10. Boy, aged 6;11, expert parent	
Child: A tutaj są żołędzie. *And there are acorns here.*	L
Parent: Żołędzie, bardzo dobrze. A gdzie one rosną? *Acorns, very well. Where do they grow?*	C
Child: Na dębie. *On an oak.*	C
Parent: Na dębie. Super. I co można z tych żołędzi zrobić? *On an oak. Super. And what can be done out of those acorns?*	C
Child: Nowy dąb. *A new oak.*	C

Speech samples	**Coding**
Parent: Nowy dąb, bo to są takie nasionka. Je zasiejesz I wyrośnie nowe drzewo, tak? *A new oak, cause these are seeds. You plant them, and a new tree will grow, right?*	C; C; C
Example 11. Boy, aged 6;11, expert parent	
Child: To są stokrotki. *These are daisies.*	L
Parent: Nie to nie są stokrotki. To jest mniszek albo mlecz. Jak on rośnie to wtedy jest znak że można siać kukurydzę, wiesz? To jest znak że ziemia jest bardzo dobrze nagrzana, wiesz? Jest dobry termin żeby zasiać kukurydzę. *No, these are not daisies. This is a catsear or a dandelion Its growth is an indication, that corn can be planted, you know? It is a sign that the soil is very well warmed up, you know? It is a good time to saw corn.*	L; L; C; C; C; C
Example 12. Boy, aged 5; 9, expert parent	
Parent: A myślisz, ze one są podobne te kwiaty do siebie? *Do you think those flowers are similar to each other?*	R
Child: Tak *Yes.*	
Parent: No, należą do tej samej rodziny, wiesz? *Right, they belong to the same family, you know?*	C; R
Child: I są żółte. *And they are yellow.*	P; R
Example 13. Girl, aged 6;8, expert parent	
Child: To jest motylek. To jest jedyny owad, który ma więcej nóg niż 6… chyba jedyny. *It is a little butterfly. It is the only insect, that has more than six legs, probably the only one.*	L; L; C; R
Parent: Ma więcej nóg niż 6? *It has more legs than 6?*	
Child: Yhy *Yeah*	
Parent: A motyl, ten już dorosły to ma 6? *And a butterfly, the adult one has 6?*	C
Child: Ale gąsienica ma więcej. *But the caterpillar has more.*	L
Parent: Tak? *Really?*	
Child: Tak *Yes*	

Speech samples	Coding
Parent: Wiesz co nigdy nie liczyłam, ale nie wiem jak to jest. Trzeba będzie sprawdzić, bo to nie jest widać, ale to ciekawe wiesz? *You know, I've never counted, I don't know. We will have to check, cause I can't see from the picture, but it is interesting, you know?*	P
Example 14. Boy, aged 5;9, expert parent	
Child: Sokół wędrowny. *Peregrine falcon*	L
Parent: Wiesz co, no właśnie nie. Wiesz co to jest chyba? *You know what, in fact it isn't. Do you know what it probably is?*	
Child: Nie. *No*	
Parent: To małe jak pustułka, ale to chyba nie jest pustułka, tylko drzemlik. *It is as small as a kestrel, but it probably isn't a kestrel, but a merlin.*	P; R; L; L
Example 15. Boy, aged 5;9, expert parent	
Parent: Młody ptak, a wiesz jaki? *A young bird. Do you know what kind?*	L
Child: Nie. Trzcinniczek młody? *No. A young reed warbler?*	L
Parent: No to jest dorosły trzcinniczek. *This is an adult reed warbler.*	
Child: Ej patrz! Ma obrączkę! *Look! It has a ring.*	P
Parent: No, chyba jakiś ornitolog mu założył. *Probably an ornithologist has put it on.*	C
Child: To jest młody trzcinniczek. *It is a young reed warbler.*	
Parent: No właśnie nie. *No, it is not.*	
Child: Czemu taki wielki? *Why is it so huge?*	P; R
Parent: A wiesz dlaczego? *Do you know why?*	
Child: Nie. *No.*	
Parent: Bo to wcale nie jest młody trzcinniczek. To jest coś co udaje młodego trzcinniczka. *Because it is not a young reed warbler. It is something that pretends to be a young reed warbler.*	C; R

Speech samples	Coding
Example 16. Boy, aged 5;9, expert parent	
Parent: Wyrósł nam mały dąb na balkonie, pamiętasz to? *A small oak grew on our balcony, do you remember?* ...	L, C
Child: A ty tego dęba ścięłaś czy co? *And you cut that oak, or what?*	
Parent: No nie, sam zmarniał. Nie wyrósł większy. No ja kiedyś na wiosnę, wychodzę na balkon, patrzę a tam normalnie w doniczce wyrósł mały dąb. Takie miał 3 albo 4 małe listki. Ja mówię, co tu robi dąb? i dopiero sobie przypomniałam, że do nas na balkon przylatują sójki. I sobie myślę: aha, to te sójki musiały zostawić żołędzia. Rósł, rósł i na zimę już się nie obudził, na wiosnę następną. *No, it withered by itself. It didn't grow taller. One day in Spring I go out at the balcony, and I see that a small oak grew in a pot. It had three or four small leaves. And I am like, what is an oak doing here? And then I remembered, that jays visit our balcony, and so I figure the jays must have left the oak. It grew, grew (till) winter ... and it did not wake up next spring.*	C; C; C; C; C; C; C; C