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Young children's impressionable use of teleology: the influence of question wording and questioned topic on teleological explanations for natural phenomena

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There is a significant body of research on children's preconceptions concerning scientific concepts and the impact this has upon their science education. One active issue concerns the extent to which young children's explanations for the existence of natural kinds rely on a teleological rationale: for example, rain is for watering the grass, or tigers' stripes are for camouflage. It has been argued that this teleological tendency hampers children's ability to learn about causality in the natural world. This paper investigates two factors (question wording and topic) which it is argued have led to a misestimation of children's teleological tendencies within the area natural phenomena: i.e., those that are time-constrained, natural events or process such as snow, clouds or night. Sixty-six (5- to 8-years-old) children took part in a repeated-measures experiment, answering both open- and leading-questions across 10 topics of natural phenomena. The findings indicate that children's teleological reasoning may have been overestimated as open question forms significantly reduced their tendency to answer teleologically. Moreover, the concept of teleology is more nuanced than often suggested. Consequently, young children may be more able to learn about causal explanations for the existence of natural phenomena than the literature implies.

Keywords: teleology; teleological explanation; natural phenomena; young children

Introduction

Teleological explanations are those which indicate that something exists for a specific purpose (e.g. rain is for watering the grass, puddles are for jumping in, scissors are for cutting paper). With regard to the natural world these types of teleological explanations can imply a purpose where there is none. For this reason, many have claimed the use of teleological explanation to be detrimental when children come to learn about causality in nature. For example, Hanke (2004, p.115) argues that the use of teleology is 'lazy and wrong … a straitjacket for the mind, restricting truly creative scientific thinking' and Kampourakis (2014, p.92) states that teleology is 'the most important obstacle to understanding evolution'. These concerns about the use of teleological explanations are echoed by many other researchers (e.g. Kelemen, 2012, Polling & Evans, 2002).

This paper considers how others have investigated children's preconceptions about the natural world, specifically natural phenomena (e.g. rainbows or night). Natural phenomena are investigated as while the appropriateness of teleological explanations for organisms and their traits (e.g. capybara or zebras' stripes) is debated, there exists no such controversy for the existence of natural phenomena: teleology is

absolutely incorrect. Two factors are explored with regard to previous data collection methods: question wording and questioned topic. Question *wording* here relates to the manner in which a question is phrased, with the view that a question can be worded in a way which leads respondents into provided a certain type of response. Questioned *topic* refers to the subject of a question, that is, the type of natural phenomena which is under discussion (e.g. rain in the question: why is there *rain*?).

It is argued that prior work has worded questions in a manner which could be considered leading towards a teleological answer and, at times, used a small number of questioned topics to explore children's ideas. Consequently, it will be suggested that the way previous studies have been designed could have led to researchers misestimating children's teleological tendency and research is needed to address that. Moreover, following consideration of philosophical debates about teleological explanations, rather than treating teleological explanations as a homogenous group, this paper considers types of teleological explanation, some of which do not follow the standard definition of teleology used in the literature. Lastly, it is argued that a teleological style of explanation may be due a fragmented (rather than coherent) structure of knowledge about the natural world. Overall, it is suggested that children's use of teleological explanations may be more nuanced than currently indicated in the literature, and their use of such explanations to account for the existence of natural phenomena can be influenced by the design of the questions used to elicit their preconceptions.

The extent of teleological explanations

In a range of studies children, aged 3- to 10-years-old, have been shown to primarily provide teleological explanations to account for things in the natural world (e.g. Kampourakis, et al., 2012; Keil, 1995; Kelemen, 1999a, 2003). Kelemen argues that this tendency for children to provide teleological explanations to questions about things in the natural world means that children prescribe some form of intentional design to natural kinds, believing they exist for a purpose, to serve a function or to achieve a goal (Kelemen, 1999). Thus it can be considered that teleological explanation is indicative of a preconception that things in the natural world exist for a purpose. The term preconception is used here, rather than misconception, as these are children's ideas before they have received formal education, on such matters as causality in the natural world. Therefore, these ideas are not considered to be misconceptions as children have not be taught the scientifically-consistent conception. Children's preconceptions can be particularly difficult for teachers to change (Peacock et al., 2011). Consequently, evidence indicating that children have a preference for teleological explanations is a cause of concern for educators.

Research into children's teleological explanations usually investigates a number of categories (what constitutions a category is returned to later). The categorised used in literature are wholes and parts of organisms (rhinos or rhinos' horns), natural objects (clouds or points on rocks) and artefacts (hammers or watches' hands). Although, teleological explanations for the existence of artefacts are correct and therefore not an educational problem, they are investigated in literature as a benchmark for teleological explanation (i.e. as artefacts should have teleological rationales, if children provide similar numbers of teleological explanation for artefacts and, for example, organisms then this could indicate a teleological view of organisms).

Investigation by categories (e.g. organisms and natural objects) has resulted in two competing theories about how children apply teleology. Children are viewed as either being selective in their application of teleology, only applying it to certain groups

of topics, artefacts and organisms' traits (Kampourakis et al., 2012; Keil, 1995), or promiscuous, applying it to anything and everything (Kelemen, 1999a, 2012).

Evidence for the selective nature of teleological reasoning comes from an early study on children's teleological explanations. Keil (1992, 1995) presented children, aged 5- to 7-years-old, with explanations for the categories of natural objects and organisms. The questions asked children to choose between a causal (a scaled-down scientific) explanation or a teleological explanation. For topics in the category of organisms and artefacts children primarily chose teleological explanations, suggesting they believe organisms and their appendices serve a specific purpose. However, for topics of natural objects children preferred the causal explanations. This, Keil claims, indicated children are selective in applying teleology and do not attribute purpose to natural objects or phenomena.

The proposal that teleological reasoning is only prevalent within the categories of organisms and artefacts was challenged by Kelemen (1999a). Four- and five-year-olds were asked *what is X for?* for 12 topics across three categories (artefacts, natural objects and organisms). The aim of her study was to explore whether children attribute purpose to different categories in a selective or promiscuous manner, as detailed above. Therefore, while the focus was children's teleological explanations, the goal was to survey the scope of their thinking not to elicit solely teleological responses. Participants provided teleological rationales for artefacts (~65% of responses), organisms (~55%) and natural objects (~65%, means taken from graph, Kelemen, 1999a, Fig 1 & 2); therefore, suggesting that young children prescribe purpose to all types of category, a notion dubbed, by Kelemen, promiscuous teleology.

In a second study, within Kelemen (1999a), 4- and 5-year-olds were presented with hypothetical scenarios, using the same categories as above. Each scenario comprised of an individual stating that the topic X was intended for a specific task, while another individual claimed that although X could be used for a certain task it was not specifically intended for that task. The results supported the original study, participants chose the teleological option ~85% of the time for artefacts, ~80% for organisms and ~75% for natural objects, (means taken from graph, Kelemen, 1999a, Fig 3); therefore, providing further evidence for the children's "promiscuous" application of teleology. The prevalence of promiscuous-teleology across a wider age-range is supported by additional studies (Kelemen, 1999b; 2003) where 6- to 10-year-olds chose multiple-choice options which prescribed function to the appendages of organisms and natural objects, although teleological explanation did slightly decrease with age.

More recent research investigating 5- to 8-year-olds teleological reasoning (Kampourakis et al., 2012) explored children's explanations topic in the same three categories (organisms, natural objects and artefacts). Children provided teleological rationales for the organisms and artefacts; however, for natural objects, teleological explanations were limited and decreased significantly with age. Kampourakis et al. proposed that this decrease between Reception and Year 2 shows a tendency for children to move from promiscuous-teleology to selective-teleology as they age. It is debatable how, and if, children move from a promiscuous-teleology to selective-teleology as they age, but it is evident that as children develop their propensity to provide teleological rationales across-categories decreases.

Measuring teleological explanations

The studies outlined above suggest that teleological explanations are used by children to account for the existence of organisms and at times for natural objects and phenomena.

However, examination of the methods used in these studies suggests that number of teleological explanations provided by children may have been overestimated. Firstly, by using leading questions and, secondly, though the selection of questioned topics.

The often-cited paper by Kelemen (1999a) asked *what is X for?* The word *for* implies a purpose and so questions phrased in this manner could inadvertently lead children into explaining the topic's existence teleologically, due to demand characteristics, which result in biased data as the participant attempts to provide answers that the interviewer may want to hear (Orne, 1962). This use of potentially misleading questions is reminiscent of the Piaget-Donaldson debate, typified when McGarrigle and Donaldson (1974) reframed a number of potentially misleading tasks used by Piaget (1952) to assess conservation, the reframed tasks showed a considerable increase in children's ability. Consequently, data gathered using, e.g. *what is X for*, may provide an unrepresentative picture of children's teleological explanations.

Consideration of the question wordings used in previous studies (Kampourakis et al., 2012; Keil, 1995; Kelemen, 1999a, 1999b; Polling & Evans, 2002; Tao, Oliver, & Venville, 2011) shows that there are two main forms of question wording: is the question-subject (X) for something and if so what, and, why does the question-subject (Y) have this appendage (X). These two question types, *is the question-subject for something and if so what* and *why does the question-subject have this appendage* (i.e. *what is the purpose of a certain appendage*?), are effectively the same generic leading-question format: *what is X for?*, a question format which seeks to inquire about the purpose of X.

Kelemen (1999a) does suggest that *what is X for?* could be leading, but maintains that further research using fixed choice options, between teleological and scientific explanations, negates the error and supports the findings. However, it is argued that fixed choice options do not measure what a child actually thinks only which of two options they prefer, or even which of two options they dislike least. Kampourakis et al. (2012) expand upon this arguing that when researching children's actual ideas, rather than their forced-preferences, open-questions are a necessity.

Regarding the influence of questioned topic, the studies described above often use limited topics to account for children's reasoning within a category. Keil (1992, 1995) used a generic green plant and emeralds to represent children's reasoning about all topics within the categories of organisms and natural objects. It seems unlikely that an entire category can be represented by a single topic. Other studies have used more topics to represent a category but the range of topics may not constitute a representative sample.

Kelemen (1999a) found a broad application of teleology across category. The category of organisms explored fourteen topics, a reasonable number, however, the category of artefacts only included six topics and only two topics were used to assess reasoning about natural objects. This appears a disproportionate split of questioned topics, especially when considering the use of only two topics to propose a theory shift from selective- to promiscuous-teleology. Follow up studies by Kelemen (1999b, 2003) also used a small number of questioned topics: four organisms and four natural objects. Furthermore, research by Kampourakis et al. (2012), a quasi-replication of Kelemen (1999b, 2003) only explored two topics to represent each of the categories of organisms, artefacts and natural objects. Again it seems apparent that two topics cannot measure children's reasoning about a whole category. In Kampourakis et al. (2012) there was limited evidence for teleological reasoning in the category of natural objects. However, for children of a similar age Tao et al. (2011) found evidence of 8- to 9-year-olds provided teleological rationales for the Sun, Moon and seasons, which are examples of

natural objects and phenomena). These findings suggest that within-category investigation is needed to properly assess children's teleological explanations, as collapsing topics across-category may hide within-category variation.

Although the use of categories is common, how categories are formed is not discussed. However, classifying topics in this manner has commonalities with work by Chi. In her framework everything can be placed within a number of ontological categories. There are three main overarching categories, called ontological trees: entities, processes and mental states. Each ontological tree has a number of subcategories, which in turn have more subcategories. Everything can be placed in a certain category, within a certain tree. Depending upon the granularity of categorisation, this category could be a broad category (e.g. dachshund placed within organisms) or a highly defined subcategory which has numerous parent levels (e.g. dachshund placed within dogs, within mammals, within animals, within organisms, within entities). . Placing a new topic within a tree results in it inheriting the qualities of the ontological category, categorised topics are considered static unless there is robust conceptual change (Chi, 2008).

While it is not certain that previous research has used Chi's framework for classification by ontological category, the structuring of categories shares similar features and provides a rationale for future exploration. Chi's classification system is used in this paper as a) it provides a method of bounding research into natural kinds and b) it is a convention of research into teleological explanation, so abandoning this framework would make comparisons to earlier work ineffectual. Using Chi's ontological categories indicates that a distinction is needed between natural objects (e.g. rocks) and natural phenomena (e.g. wind), in previous work these categories have been collapsed into one category, often called natural objects. Chi's work would suggest that natural objects are placed in the ontological tree of entities (tangible objects), whereas, natural phenomena are within the ontological tree of process (events which occur over time). This paper maintains this distinction, treating the two as separate categories.

Types and acceptability of teleological explanations

Teleological explanations are those that explain the existence of something in relation to an outcome or purpose it serves. A number of authors have attempted to classify different types of teleological explanations. Combining previously used sub-classifications indicates four sub-categories of teleological explanation; these are displayed in Table 1.

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Table 1

Types of teleology arising from literature

Category	Explanation	Relevant literature
Design-teleology	A topic is explained in relation to a purpose or goal for which it was designed. The topic has the singular purpose of aiding/supporting something, the something can be itself or another entity; it acts upon an entity to produce a result which is not a scientifically valid. For example, 'Rain is for watering the plants' or 'day is for waking up the birds'	Woodfield, 1979; Zohar & Ginossar, 1998; Kelemen 1999a Polling & Evans, 2002.
Religious-teleology (a subcategory of design-teleology)	This is a specific type of design-teleology. A topic is explained in relation to a purpose or goal for which it was designed, however, a god or other supernatural being is invoked to designer of the topic. For example, 'there is a storm because god is angry'	Woodfield, 1979; Kelemen & DiYanni, 2003; Lindeman, Svedholm-Hakkinen, & Lipsanen, 2015
Functional-teleology	A topic is explained in relation to a function that it performs, within a system, or a goal which it pursues. What is paramount is that the function or goal is appropriate for the topic. The topic can be explained scientifically using teleological language. It is an appropriate teleological explanation. For example, 'an eagle's wings are for flying'.	Woodfield, 1979; Zohar & Ginossar, 1998; Kelemen, 2012
Relational-teleology	A topic is explained in relation to a purpose for which it can be used or an effect which the topic causes. The purpose or effect is human-centric. For example, 'snow is used by children for making snowmen' or 'night is a time period which people usually use for going to sleep'	ojalehto, Waxman & Medin, 2013; Olson, 2003

The use of teleological explanations has long been seen as problematic by some philosophers of science (Ruse, 1989). Considering the objections to teleology explored in this section and the types of teleological explanations shown in Table 1 the position that teleology is problematic refers specifically to the use design-teleology and its subcategory of religious-teleology. Design-teleology is argued to be a debilitating factor which restricts truly creative scientific thinking (Hanke, 2004), because it places the focus on purposes, resulting in children having the misconception that natural kinds have a teleological rationale.

Design-teleological thinking is considered by Kampourakis (2014) to be the main conceptual barrier in understanding evolution, as individuals confuse artefact inspired design-teleology with organism functional-teleology. For example, a child may

apply their conceptual framework about artefacts (that they have a creator and are designed for a purpose) to the development of an organisms' trait, such as rhinos' horns. Thus resulting in a view that rhino's horns serve a purpose (functional-teleology) but also that they are designed by a creator to serve that purpose (design-teleology). A preconception that organisms and their traits are designed can lead to problems when learning about evolution, as such preconceptions are highly resistant to change.

The use of teleological explanation in relation to organisms and biological traits is debated. Briefly, opponents argue that it should not be used or can be misleading (see Hanke, 2004; Kampourakis, 2014) whereas proponents suggests that functional-teleological explanations are a necessity to discussions about evolution (see Amundson & Lauder, 1994; Ruse 1989). These arguments typical come from philosophy of science or psychology. However, research in the field of science education indicates that high school students can, and do, use teleological explanations for biological concepts, without sacrificing scientific rigour (Zohar & Ginossar, 1998); essentially using teleology as a cultural method of describing rather than a stand-alone explanation.

Some teleological explanations may arise because children conflate cause with effect (Olson, 2003); for example, *she put her hood up because it was raining* (causal) with *it was raining because she put her hood up* (effect). This is supported by the relational-deictic framework (ojalehto et al., 2013), which suggests that when children provide teleological responses they are not stating that a topic has a designed purpose (design-teleology) but merely relating the topic to a purpose (or multiple purposes) for which it can be used, or an effect that it causes (e.g., how children use snow for making snowballs). This form of explanation is further referred to as relational-teleology. As the paper by ojalehto et al. is theoretical it provides no empirical evidence about the number of teleological explanations which are relational-teleology, nor if children are even expressing this type of teleology.

However, if children show a preference for relational-teleology this would mean that their teleological explanations are not based on the belief that a topic is designed for a specific purpose, but rather are discussing the topic in relation to a purpose for which it could be used. This would indicate that some teleological explanations may result from patterns of language and so may be limited though developing children's understanding of appropriate styles of explanation for scientific contexts.

Constructing teleology

As teleology is a style of explanation that results from the naïve idea that nature has purpose, it is worth considering how this naïve idea is constructed. Is it coherent (knowledge-as-theory, see Ioannides & Vosniadou, 2002) or fragmented (knowledge-in-pieces, see diSessa, Gillespie & Esterly 2004). These two stances on individuals' conceptions have different origins and implications for supporting conceptual change.

The coherent view of naïve ideas argues that they are part of structured concepts which cannot be isolated but rather form a web of ideas (Amin, Smith & Wiser 2014). A key area of the debate surrounds the context in which children use certain naïve ideas (diSessa, 2014). Knowledge-as-theory implies that children's intuitive ideas are limited in number and stable across numerous contexts (Amin et al., 2014). In a key paper Ioannides & Vosniadou (2002) found that children in similar age ranges provided a small number of similar explanations (naïve ideas) about the concept of force. This finding they propose indicates an explanatory framework that was consistently applied by individuals across contexts; therefore, demonstrating an explanatory system that displays considerable coherence.

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Knowledge-in-pieces (diSessa, 2014) asserts that naïve ideas are a collection of fragments that combine when needed to form an idea. These fragments are often referred to as p-prims which are microgeneralisations that arise from individual's experiences (diSessa et al., 2004). These p-prims cannot, by themselves, be considered objectively correct until they are combined by an individual in a certain context. That p-prims may be combined differently across individuals and contexts, give rise to the principle that naïve ideas are numerous and variable, they will not be coherent across a group of students. Therefore, the fragmented stance suggests that children's intuitive ideas will differ depending upon the context in which they are explaining, and when asked a question a certain group of children may provide a wide range of contradictory responses. In a quasi-replication of the aforementioned Ioannides & Vosniadou (2002), diSessa et al. (2004) showed that altering the context of questions resulted in a considerable departure from Ioannides & Vosniadou derived set of coherent ideas for physical forces: children's naïve ideas varied considerably both within and across individuals.

Consequently, this raises the question of whether children's naïve ideas about the causes of natural phenomena comprise of a coherent theory or a collection of fragments. Answering this question involves exploring within-child variation across contexts and across-child variation across contexts (i.e. different topics within an ontological category).

Purpose of study

The argument that demand characteristics may influence children's responses suggests that previous studies may be misleading due to wording questions in a teleological manner. This argument underpins the first research question, does question wording influence children's explanations about the existence of natural kinds? It is hypothesised that a teleologically leading question will produce more teleological responses than a neutrally worded question.

Previous work has investigated only a small number of topics and not considered within-category variation. This begs the question, does questioned topic influences children's tendency to provide a teleological response? If there is substantial variation across topics then this has implications for a) theories that children's teleological reasoning is "promiscuous", and b) implies that caution is needed when interpreting results of studies that used a limited number of topics, and c) that explanations about the natural world may result from fragmented rather than coherent knowledge.

This paper also investigates the types of teleology do children display when they provide teleological explanations to ascertain the proportion that are relational rather than design. If responses primarily display relational-teleology then children may not be suggesting a topic exists specifically for X, but rather referring to X in relation to something for which is could be used, or the reaction it causes in people. A broad tendency to use relational- over design-teleology would suggest that teleology is not the barrier it is claimed to be as relational-teleological explanations may result from natural patterns of language, not a fervent belief that nature has purpose.

These three research questions are explored to evaluate the current positioning on children's use of teleological explanations. That is, whether children's use of teleology is robust and maintained across different contexts (i.e. question wording and questioned topic) and whether their explanations conform to the standard definition (design-teleology) or if their use of teleology is more complex.

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Method

Design

A 2x2 within-subjects factorial design was used to test the influence of question wording on children's explanations. The first factor, question wording, was within participants and had two levels: the open-treatment (*why is there X?*) and the leading-treatment (*what is x for?*). As each child was asked both types of question, the second factor, treatment order, determined if their first question set comprising of either the leading- or open-questions: i.e., half the children were randomly assigned to receive a block of open then leading questions whereas the other half had a block of leading then open questions. As each treatment consisted of five questions, during one interview with a break in the middle children were asked about ten topics, and so each participant received questions about the ten topics in a randomised order. As question set order and topic order were randomised separately, across the sample the topics were approximately split between the two treatments (e.g. half of the total questions about rain were asked using the leading-treatment).

Material

A preliminary study was conducted to identify suitable topics for discussion. The goal was to identify topics for which children could articulate a response irrespective of accuracy and so was not concerned with whether children's responses were teleological or scientific. A wide pool of potential topic candidates was identified from previous studies (DiYanni & Kelemen, 2005; Kampourakis et al., 2012; Keil, 1995; Kelemen, 1999a, 1999b; Piaget, 1929; Polling & Evans, 2002) along with additional topics generated from discussion with colleagues.

Twelve 6- and 7-year-olds (female = 6) were interviewed in groups of four. They were asked *why is/are there X?* for 20 topics of natural objects and natural phenomena[1]. After consideration of participants' responses, children's opinions about question difficulty and interviewer observations, a number of these 20 possible topics were eliminated if children struggled to provide any form of response to the question. In particular, natural objects, such as rocks, proved particularly difficult for children to provide any response to, which is surprising considering the focus on natural objects in previous work (see Kelemen, 2003; Kampourakis et al., 2012). The use of such a generic question format may have failed to cue children to provide an etiological explanation for the formation of, for example, rocks, However, a targeted question such as *how are rocks formed?* would be considered an etiologically-leading question and be subject to the problems associated with leading-questions. Consequently, it was decided to focus only on topics of natural phenomena: darkness, day, light, night, rain, rainbows, snow, storms, waterfalls and waves.

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[1] Natural objects included caves, icebergs, mountains, rocks, sand, soil, stars, the moon and the sun. Natural phenomena included darkness, day, light, night, rain, rainbows, snow, storms, waterfalls, waves and wind.

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Participants

The participants were 66 children, aged 5- to 8-years-old, recruited from three classes within the same primary school from a large city in the Midlands of the UK. This school is single-form entry, is judged to be performing well on national scales, and is above the national average for both pupils from minority ethnic groups and those entitled to free school meals. The sample consisted of 22 children from each of Year 1, Year 2 and Year 3 (M = 86 months, SD = 10.84, Female = 34). No child was classified as having Special Educational Needs or English as an Additional Language.

Procedure

Children were informed that the interview would be recorded and presented with the following statement:

> Some of these questions may be tricky but that's OK, because people have different ideas about the answers. I think you might have some really good ideas and I just want to know what you think. Remember there are no right answers, it is just what you believe. If you're not sure about an answer, just say, I don't know, OK?

This statement was included to discourage children from trying to guess a 'correct' answer.

In individual 10-minute interviews, participants then received five questions using the leading-treatment or open-treatment, dependent upon treatment group. Following these questions, children played a short drawing game before resuming the interview with the five remaining questioned topics using the counterpart question wording. If children took a substantial amount of time to respond to a question the question was repeated, then were offered the choice to either 'have some more thinking time or move onto the next question'. Interviews took place in a quiet communal area outside of the classrooms. The study was approved by the University's ethics board.

Measures

Children's responses were coded on two levels. At Level 1, answers were coded as *teleological*, *scientific* and *other* (Table 2), and were used to explore the influence of question wording and questioned topic. At Level 2, teleological responses were sub-classified to allow for investigation of the types of teleological explanations children provided (see also Table 1).

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Table 2

Coding rubric for children's responses at level 1

	Teleological (0)	Scientific (1)	Other (NA)
Explanation	The topic is given a purpose, a function or a goal, which aids or supports either itself or another entity.	A scaled down, causal explanation for a topic, answer does not contain teleological notions. It may not be scientifically correct.	Descriptive responses (participant provides a description of the topic), Non sequiturs (participants answer is an unrelated comment, it is not related to the topic), Don't know (participants state they "don't know" the answer or are "unsure") or No answer (participant provides no response).
Example	'There are waterfalls so wild animals have a place to drink' or 'there is night to tell us to go to sleep'	'It snows because the clouds get cold and all smushed up together'	

Whilst theoretically different, design-teleology and relational-teleology could prove difficult to distinguish, especially as there is no published coding scheme to differentiate the two. Linguistic analysis provides a method of solving this coding dilemma. Explanations employing design-teleology will have the topic as the subject of the answer, and the subject will be acting upon an object. For example, in the response *rain is for watering the grass*, the subject (*rain*) is acting on (*watering*) the object (*grass*). Conversely, relational-teleological explanations, those which account for the topic as something which an agent uses, will introduce an agent into the response via a subject complement (e.g. *we* or *I*) or implicitly adding an agent via a verb, which implies an agent (e.g. *making* or *learning*). For example, in the above statement, snow is *for making snowmen*, the subject complement (*for making snowmen*) implicitly implies an agent via the verb (*making*); therefore, the topic (*snow*) is used by an agent for a subjective purpose (*making snowmen*).

To establish the extent of inter-rater reliability, 10% of the data, (66 responses) were coded by a second researcher. Cohen Kappa indicated a very good level of agreement ($K = .885$, $p < .001$ for Level 1 coding and $K = .841$, $p < .001$ for Level 2 coding).

ANCOVA was used to analyse the independent variables of question wording and treatment order, as it facilitated the analysis of the two experimental variables and a covariate: *children's age*, which is known to be a factor influencing children's use of teleological explanations. Cochran's Q test was used to analyse the influence of questioned topic upon children's responses, as this required a non-parametric test which allowed for the analyses of whether $k = 10$ treatments produced the same outcomes across participants (i.e. where children's responses consistent across the ten question

topics). Chi-squared goodness-of-fit tests were used to explore differences in response type between the different treatments.

Results

Influence of question wording

Overall, 69.2% of responses were teleological, with the leading-treatment questions eliciting 80.0% teleological responses and the open-treatment 58.4%. However, 72 responses out of the possible 660 were coded at Level 1 as *other*, which were then removed from the data. This resulted in 588 valid responses to the 10 questions, 457 (77.7%) of which were teleological and 131 (22.3%) were scientific. Examples of children's teleological explanations for the ten topics investigated are detailed in the supplementary Tables 1 - 10. Splitting the data by treatment shows the leading-treatment received in 264 (92.1%) teleological answers, whereas 193 (68.2%) teleological responses were given to the open-treatment.

A 2x2 ANCOVA was conducted with the independent variables of question wording (*leading-* and *open-treatment*) and question set order (*first question set-Leading* or *first question set-Open*). The dependent variable was the summed responses to the leading- and open-questions, resulting in a participant score of 0-5 for each treatment. The covariate was participants' age in months, which was mean centred to avoid compromising the main effect. Means are displayed in Table 3.

Table 3

Mean percentage of scientific responses split by question wording and question set order

	Percentage of scientific responses (*SD*)		
Question wording	First question set-Leading (n = 33)	First question set-Open (n = 33)	Overall (n = 66)
Leading	7.88% (15.76)	7.88% (12.18)	7.88% (13.97)
Open	26.06% (26.68)	37.56% (33.07)	31.82% (30.37)

Results indicate that question wording had a significant effect on children's responses, F (1,63) = 44.57, $p.$ < .001, η_p^2 = .41, as a significantly greater number of teleological responses were given in the leading-treatment condition (92.1%) than in the open-treatment (68.2%). Participant age also predicted responses: older children provided fewer teleological answers, F (1,63) = 4.40, $p.$ = .041, η_p^2 = .06, although there was no interaction between question wording and age, F (1,63) = 0.01, $p.$ = .962, η_p^2 < .01. Question set order did not significantly influence responses, F (1,63) = 1.72, $p.$ = .179, η_p^2 = .02, nor was there a significant interaction between question wording and question set order, F (1,63) = 2.59, $p.$ = .093, η_p^2 = .04. The test results suggest that children were not primed to provide teleological or scientific responses if the first question set they received was leading- or open-treatment, respectively.

Influence of topic

The proportion of scientific responses varied between the topics ranging from 12.5% for

waterfalls to 75.0% for rainbows. Cochran's Q test was used to investigate if there was a difference in the amount of teleological responses for the ten topics. Due to missing data (those coded as *other*), this test was conducted with a sample size of $n = 34$. The results suggest that there is a significant difference between the responses provided to ten topics, $Q\ (9) = 33.29, p. < .001, \eta_Q^2 = .11$. However, this data set is biased due to the significant influence of the leading question wording therefore, further investigation is conducted with data pertaining to only the open question wording as the more neutral condition.

To investigate if certain topics received more teleological (or scientific) responses than other topics, ten (one per topic) chi square goodness-of-fit tests were used. As previous work has only investigated a limited number of topics, there is no published work that can be used to predict the effect of topic on response type (the split of teleological to scientific responses). Consequently, the expected value was set to the weighted-mean number of teleological and scientific responses (for the open-treatment) across the ten topics from this study (.624: .376), which is a conservative method as a topic is being compared against an average which includes itself. Thus, this analysis can identify which (if any) topic deviates from this average. Crammer's V (ϕ_c) is provided as a measure of effect size with the results shown in Table 4.

Table 4

Goodness-of-fit test results for response type by question topic

		Percentage of responses				
Topic	n	Teleological response	Scientific response	χ^2 ($df = 1$)	$p.$	ϕ_c
Darkness	29	69.0%	31.0%	0.53	.465	0.14
Day	31	74.2%	25.8%	1.84	.175	0.24
Light	33	72.7%	27.3%	1.50	.220	0.21
Night	33	81.8%	18.2%	2.44	.118	0.27
Rain	30	63.3%	36.7%	0.01	.915	0.02
Rainbows	28	25.0%	75.0%	16.68	.001	0.77
Snow	38	68.4%	31.6%	0.59	.443	0.12
Storms	25	32.0%	68.0%	9.84	.002	0.63
Waterfalls	32	87.5%	12.5%	8.60	.003	0.52
Waves	18	50.0%	50.0%	1.18	.278	0.26

The results show that the observed values for rainbows, storms and waterfalls are significantly different to the mean responses for the ten topics. Rainbows and storms resulted in less teleological responses than the average, whereas waterfalls resulted in children providing more teleological explanations than the average value for the ten topics.

Type of teleology

Coding the teleological responses at Level 2 resulted in 133 responses displaying

design-teleology and 324 indicating relational-teleology. The percentage scores for type of teleology advocated indicates an approximate 3:7 split for design-teleology vs relational-teleology (29.1% vs 70.9%).

To further investigate this preference for relational-teleology, as above[2], ten (one per topic) chi-square goodness-of-fit tests were used to determine any preference for response type (design-teleology or relational-teleology) for each topic. Again due to the bias associated with the leading-treatment only the responses to the open treatment were used. As there is no published work that can be used to predict the type of teleology children are espousing, the expected values were set using the weighted-mean levels of design- and relational-teleology (.350: .650). Results are shown in Table 5.

Table 5

Goodness-of-fit test results for type of teleology by question topic

		Percentage of responses				
Topic	*n*	Design-teleology	Relational-teleology	χ^2 (*df* = 1)	*p*.	ϕ_c
Darkness	20	20.0%	80.0%	1.99	.158	0.32
Day	23	4.3%	95.7%	9.52	.002	0.64
Light	24	12.5%	87.5%	5.36	.021	0.47
Night	27	14.8%	85.2%	4.86	.028	0.42
Rain	19	52.6%	47.4%	2.58	.108	0.37
Rainbows	7	42.9%	57.1%	0.19	.665	0.16
Snow	26	26.9%	73.1%	7.93	.005	0.55
Storms	8	100.0%	0.0%	14.83	.001	1.36
Waterfalls	28	32.1%	67.9%	0.10	.747	0.06
Waves	9	44.4%	55.6%	0.35	.555	0.20

The results show that the observed values for day, light, night, snow and storms are significantly different to the mean. Teleological explanations for storms showed a preference for design- over relational-teleology, whereas, day, light, night and snow mirrored the overall mean preference for relational-teleology but with a higher proportion of responses than the weighted-mean.

Discussion

This study had three aims, to investigate 1) the influence of question wording on children's tendencies to provide teleological explanations about the existence of natural phenomena, 2) the influence of questioned topic within the category of natural phenomena, on children's propensity to provide teleological rationales, and 3) the type

[2] Due to data coded as *other* and the removal of scientific responses, Cochran's *Q* test was not appropriate due to loss of sample size. However, each topic could be explored independently.

of teleology, design or relational, that children use to account for natural phenomena. Before addressing these questions, a clear finding is that regardless of question wording, questioned topic and age, children demonstrated a considerable inclination to provide teleological explanations for natural phenomena. The following explores the findings pertaining to the three research questions and the implications arising.

Influence of question wording

The data support the hypothesis that question wording influences children's responses to questions about scientific topics. Children provided a significantly large number of teleological responses (91.4%) to leading questions (*what is X for?*), whereas the open questions (*why is there X?*) received only 64.3% teleological answers. Therefore, questions phrased using teleological-language can exacerbate children's strong tendency to provide purposeful explanations for questions about natural phenomena. There was no significant interaction between question wording and question set order, although the partial-eta shows a small effect size. There does appear to be a trend that children who received the leading-treatment first to provide lower levels of scientific responses when they received the open-treatment. This possible trend would have made the hypothesis test more conservative. Older children provided fewer teleological and more scientific responses, supporting findings by Kelemen (1999b, 2003) and Kampourakis et al. (2012). However, regardless of age, participants predominantly provided teleological responses to the leading-treatment, while the open-treatment question received fewer teleological and more scientific answers. Consequently, leading question wording was found to bias results across the entire age range investigated.

The findings raise problems for the interpretation of previous work into children teleological explanations. Research using teleologically-biased questions or explanations to elicit children's explanations about the natural world is likely to have been influenced by the impact of purposeful-statements. For example, 'does Y help X?', 'is it better for X to have Y?' (Keil, 1995), 'what is X for?', 'is X for Y, or not?' (Kelemen, 1999a), 'is X useful for something?' (Kampourakis et al., 2012). Even if children have been given the option to decline to answer, suggest it was a strange question or eschew an explanation that contained a teleological bias, they are still exposed to teleologically-biased language. Children can be prompted by the leading phrases used in leading and multiple-choice questions or may refrain from stating that do not know an answer if they could relate a topic to a purpose for which it could be used.

From an educational point of view this finding indicates that the language used to phrase questions or explanations about scientific topics can place demand characteristics upon respondents. Employing purposeful language (willingly or unwillingly) leads children into providing teleological explanations. This is problematic as children's ability to talk, and think, about scientific concepts rests, at least in part, on their understanding of scientific terminology (Dawes, 2004). Consequently, educators must model for children how to use language to question, analyse and communicate ideas. This is particularly pertinent to young children as the focus of Early Years science education 'is to enable pupils to experience and observe phenomena, looking more closely at the natural […] world around them' (DfE, 2013, p. 146). The implications for assessment are clear; the findings support calls for the use of open questions in research into children's explanations (Kampourakis et al., 2012). Children should not be inadvertently prompted into explaining natural phenomena as purposeful or agentic, and therefore, the use of teleological-leading language is serious concern.

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It is suggested that teleological explanations are caused by exposure to intentional artefacts (Kelemen, 1999a) and by religious education (Lindeman et al., 2015). Demand characteristics placed upon children by teleologically-leading language can now be added to this list. While not an independent cause it appears to be an exacerbating factor. Teleologically-worded questions may intensify children's tendencies to provide teleological explanations, to propose purpose where there is none.

Influence of topic

The results show that the topic of the question can have a considerable influence on response type, with the proportion of teleological responses (within the open-treatment data set) ranging from 25% for rainbows to 88% for waterfalls. Three out of ten topics of natural phenomena significantly differed to the weighted-mean level for the category of natural phenomena. For waterfalls children were more likely to provide teleological explanations than is suggested by the category weighted-mean score, whereas the topics of rainbows and storms received significantly more scientific explanations that was suggested by the mean value for natural phenomena. This suggests that teleological reasoning is not consistent within the ontological category.

This finding has two main implications. First, it could be inferred that children's explanations for natural phenomena support the 'promiscuous' teleology stance. 58.4% of children's total explanations, when averaged across topics, were teleological, close to Kelemen's (1999a) findings of ~70% teleological explanations for natural objects. However, that conclusion would be misleading. When averaged across topics children may employ teleology for the category of natural phenomena, but the results of this study suggest that their application of teleology is more nuanced. Children provided significantly different numbers of teleological explanations depending upon the topic they were explaining. Within the category of natural phenomena, children displayed selective-teleology, not promiscuous-teleology. Consequently, caution needs to be taken interpreting the results of studies if they used only a limited number of topics, as depending upon the topics investigated studies may have over, or under, estimated children's teleological tendencies.

The second implication relates to the structure of knowledge about the natural world. It was postulated that that understanding the nature of children's naïve ideas can be informed by exploring if there was a) within-child variation across contexts and b) across-child variation across contexts. Looking at response type (teleological vs scientific, and design- vs relation-teleology discussed in the next section) it would appear that across the range of topics, children's responses did exhibit reasonable variation within children (i.e. a child varied in response type across the range of topics) and b) exhibited variation across children (i.e. the participants provided a range of varied response types for any given topic). Consequently, children's naïve ideas about the causes of Natural Phenomena are argued to be a form of fragmented knowledge. If children's knowledge about natural phenomena is fragmented it would indicate a diminished barrier to learning, as following diSessa's argument, conceptual change would require the incremental reshaping of targeted knowledge elements. It is viewed as a diminished barrier not because teleology is less of a problem but because a fragmented construction suggests a new way of tackling the barrier that is teleology. Teleological thought and explanation does not need to be entirely eradicated in young children's discourse. Rather through the gradual reframing of elements of children's ideas, educators could gradually 'chip away' at children's preconceptions which result in teleological explanation. This could be achieved through target interventions, for

example where individuals learn when and where teleological explanation is appropriate (e.g. learning heuristics, Zohar & Ginossar, 1998).

Type of teleology

With regards to type of teleology, the results show that, overall and by treatment type, there is an approximate 3:7 split for design-teleology and relational-teleology. Consequently, for the topics investigated in this category of natural phenomena children's teleological explanations are more likely to be relational than to exhibit design-teleology. Furthermore, there is an influence of topic, as certain topics were significantly more likely to be explained via relational-teleology (day, light, night and snow) rather than design-teleology (storms). This variation in type of teleological explanation across individuals and topics supports the claims made above about the fragmented structure of naïve knowledge about the causes of natural phenomena.

These results indicate that the majority of children's teleological explanations advocate relational-teleology rather than design-teleology, and the finding is applicable to the majority of natural phenomena investigated. The results of this study provide empirical support for the suggestions made by ojalehto et al. (2013) and the notion that children express relational-teleology. The implication of this finding is that teleology may be less of a developmental problem than previously proposed. If children are using relational-teleology instead of the usually referred to design-teleology it suggests that when children provide teleological explanations that they may not always be expressing a fervent belief that a something exists *for a specific purpose* but rather discussing it in relation to *how it could be used*. Perhaps, therefore, relational-teleology is a cultural method of describing natural phenomena, a natural pattern of language, similar to the explanations given by high-school students in the study by Zohar & Ginossar (1998). It is not necessary a specific belief that X exists for a purpose, but rather a style of discourse about X. That is, children participate in discussion around natural phenomena which considers them in relation to an effect which they have, or a purpose for which they can be co-opted; for example, a child may not believe *rain is for watering the grass* but may use this explanation due to prior discussion where rain is discussed in relation to it watering the grass. Consequently, it is possible that relational-teleology indicates that some teleological explanations may be due to certain patterns of language whereby children relate natural phenomena to a purpose for which it could be used, further empirical work exploring children's naturally-occurring discourse is needed to support this argument.

Conclusion

Has there been an overestimation of young children teleological tendencies? Children do display a strong bias towards providing teleological explanations for natural phenomena. However, the results of this study suggest a more complicated picture.

Firstly, children can be influenced by the way in which questions are worded, resulting in an overestimation of children's teleological responses. Secondly, children's teleological explanations are not consistent within the ontological category of natural phenomena, with certain questioned topics being more likely to be explained teleological, or scientifically, than others. Thirdly, sub-categorisation of teleological explanation suggests a more nuanced understanding of teleology. The majority of topics of natural phenomena provoked responses classified as relational-teleology. This finding does not match the commonly used definition of teleology, which implies

design-teleology. Consequently, when children espouse these purposeful explanations they may simply be using teleological language as a descriptive tool to explain how a topic could be used (similar to many popular science books, Hanke, 2004, and educational textbooks, Zohar & Ginossar, 1998; Talanquer, 2007). The variation in response type (both scientific vs teleological and design- vs relational-teleology) across the topics suggests that naïve ideas, children's preconceptions and knowledge about natural phenomena may have a fragmented structure. A fragmented view of knowledge might imply that teleological explanation can be limited using target interventions, focusing on the big idea that nature is causal not purposeful, a concept which can be applied to any topic. A question raised from these findings is how can we develop methods to limit children's acceptance and use of teleological explanations for the existence of natural kinds?

Confining the topics to the category of natural phenomena is a limitation of this study, and further research is needed to confirm if the results are applicable to different ontological categories. However, taken together these findings suggest that teleology may not be the major barrier it has been claimed to be, but the high number of teleological responses for both question wordings and all topics certainly suggests it is still a considerable hurdle.

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Supplementary Table 1
Examples of teleological explanations for darkness

Theme of teleological explanation	Example (there is darkness …)
Darkness is an aid for helping people to go to sleep	"because you don't always need light […] because, like, if you tried to sleep and it was sunny it would be a bit too light"
Darkness is for scaring people	"for being scared"
Darkness is for nocturnal animals	"so the night animals get a turn to come out"
Darkness is a time for celestial bodies to appear	"for the starts to come out"

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Supplementary Table 2
Examples of teleological explanations for day

Theme of teleological explanation	Example (there is day …)
Day is for helping people to see	"so you can see and people don't have to walk in the night time cos you can't see very well in the night"
Day is for children to go to school	"for going to school, so you can learn lots of things"
Day is for children to play	"for us all to be active and run about"
Day is for waking people up	"for telling us to wake up, cos day is for being awake not asleep"
Day is for people to go to work	"for people to go out, like, if they need to get to work"

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Supplementary Table 3
Examples of teleological explanations for light

Theme of teleological explanation	Example (there is light …)
Light is for helping people to wake up	"so everyone knows it is daylight so they will get up"
Light is for supporting plant growth	"so that the plants can go"
Light is for enabling people to see	"so people can see better cos if it's, like, dark you'd be, like, bashing into lampposts"

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Supplementary Table 4
Examples of teleological explanations for night

Theme of teleological explanation	Example (there is night …)
Night is for nocturnal animals	"so, like, the insects can come out at night, like, slugs worms and those slugs with shells"
Night is a time for people to go to sleep	"so you can get some rest from all the things you have done in the day"
Night is a time for celestial bodies to appear	"for the stars and the moon to come out"

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Supplementary Table 5
Examples of teleological explanations for rain

Theme of teleological explanation	Example (there is rain …)
Rain is for supporting plant growth	"for keeping all the plants, grass and flowers healthy"
Rain is for animals	"so animals can drink it, like, if there is a little hole where it goes"
Rain is for children to use in play	"so people can play in it, in case you want to jump up and down in puddles"
Rain is for washing	"for, like, washing your car and washing stuff."

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Supplementary Table 6
Examples of teleological explanations for rainbows

Theme of teleological explanation	Example (there are rainbows …)
Rainbows are for aesthetic pleasure	"for making people happy"
Rainbows are for marking treasure	"so that people might think that that there is treasure at the end of the rainbow"

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Supplementary Table 7
Examples of teleological explanations for snow

Theme of teleological explanation	Example (there is snow …)
Snow is a substance which facilitates Christmas	"there's snow cos you know […] it needs to be snowing or no one would know it was Christmas"
Snow is for children to use in play	"basically, so children could build snowmans and play snowball fights"
Snow is for animals	"so some animals can live in snow"
Snow is for cooling people down	"it is because […] otherwise everyday it would be hot and we'd would get burnt"
Snow is for filling bodies of water	"so when it melts you can use the water in water fountains, ponds, lake and sometimes people chuck it in the sea and then add a bit of salt. Put a bit of salt in it and chuck it in the sea"

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Supplementary Table 8
Examples of teleological explanations for storms

Theme of teleological explanation	Example (there are storms …)
Storms are for producing water	"to make more rain, so you can get more water"
Storms are for supporting plant growth	"we have rain specially for the plants"

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Supplementary Table 9
Examples of teleological explanations for waterfalls

Theme of teleological explanation	Example (there are waterfalls…)
Waterfalls are for providing humans with water	"so you can get water'"
Waterfalls are for providing animals with water	"to make water for the animals that are in the wild"
Waterfalls are for aesthetic pleasure	"to make the place look even nicer with a little waterfall or a big waterfall"
Waterfalls are for children's play	"so people can swim in it"

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Supplementary Table 10
Examples of teleological explanations for waves

Theme of teleological explanation	Example (there are waves …)
Waves are for aiding sea life	"cos if there was no waves […] the animals that live in the sea won't be able to move."
Waves are for children's play	"for making the sea more fun, so people can go on the skateboard, like surfing on it"