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Acquisition of naïve and scientific conceptions: How linguistic context matters in Singaporean children's understanding of "animal"

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Abstract

312 Singaporean children aged 4, 7, and 10 years from four different home language backgrounds–English, Malay, Mandarin, and Tamil–were tested for their recognition of animals and non-animals. The Malay-speaking group of children was the notable group that showed a different developmental pattern from the other three groups. They performed significantly better on recognition of all animals and of non-archetypal animals, for both the English and the Malay test versions. Age-related patterns suggest a U-shaped performance curve, with 4-year-olds mostly scoring slightly higher than 7-year-olds, in line with the suggestion that archetypal definitions begin to emerge around 3-4 years of age. The notable exception was again the Malay-speaking children, who followed a simple linear improvement. Out of the four languages, Malay has the broadest archetypal definition of animal, which may help explain these effects, suggesting that home language exposure that has broader definitions may strengthen a child's understanding when also learning in the context of a different instructional language. Overall, the study may have implications for understanding the role of language in the formation of scientific concepts as well as for instructional approaches by taking into consideration how everyday language may need to be taken into account when teaching about animals.

Keywords: elementary science, language, conceptual development, animal

INTRODUCTION

A longstanding issue in early pedagogy has been that scientific conceptions are frequently underpinned by an interpretation of everyday world experiences–even before children enter formal science learning contexts. This naïve underpinning, formulated through experiences and discourses in everyday contexts (Allen, 2014; Hast, 2014a), can result in a wide range of preconceived scientific ideas about how the world works. These ideas are based on unique experiences of those everyday contexts (Bliss, 2008), and as a result the preconceived ideas also vary widely, in terms of content and degree of understanding. Moreover, many of these preconceived ideas are incommensurate with accepted scientific views and with the concepts that are, as a result, taught within classroom settings and are often found to be highly resistant to change through instruction, affecting subsequent learning of related concepts (Duit et al., 2013). This can pose a challenge for teachers trying to organize that wide range of conceptions within a shared setting. One of these foundational concepts is "animal".

On a scientific level, animals are defined as multicellular organisms that have limited growth, that can move voluntarily, that actively gather and digest food, and that have active sensory and nervous systems. This is a definition that applies to a wide range of living things, including, for example, sponges and corals, though by no means to all–bacteria, for instance, are living but not classed as animals. However, in the everyday or colloquial use of the term, "animal" is typically restricted to a narrower category, which can even be as limited as to include only four-legged land mammals (Allen, 2015). This restriction can pose a difficulty for science learning since an appropriate understanding of basic concepts such as "animal" underpins subsequent understanding of other biological concepts. As a result, we have here a rudimentary concept of the biological world that can act as a source of misconception and that can interfere with higher level learning. Moreover, it is a concept that is linked to other domains such as ecology and conservation, where an

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Contribution to the literature

- The study showcases the relationship between home language and language of instruction in the context of science learning in Singapore, a multilingual setting.
- Where home language has broader definitions of science concepts, children also show broader definitions in language of instruction.
- Across different languages, children demonstrate archetypal definition development in the same U-shaped pattern, suggesting some stability in scientific concept acquisition regardless of linguistic context.

improved understanding might lead to heightened empathy for and increased conservation efforts towards animals that may not be regarded as animals, such as insects or corals.

The Development of "Animal"

The concept "animal" forms a category. The general ability to form categories appears early in life, at least from two months of age onwards (Westermann & Mareschal, 2014). During early development, categories are initially largely formulated based on perceptual characteristics–things that look similar to each other are seen as belonging to the same group. The particular categorization of animals begins early on in development, too. Even at the preverbal level infants demonstrate capacity for determining whether something is a living being or not (Träuble & Pauen, 2011) or that some animals are different from others, such as cats and dogs (Furrer & Younger, 2005). In the early contemporaneous stages of language development, the phenomenon of overextension can be observed. Children's concepts may be more general than the words used in everyday speech; almost any four-legged middle-sized animal may as a result be referred to as "dog", for instance (Mandler, 2004). This demonstrates early conflict between categorization and language. In further development, children are increasingly able to take into account further properties, recognizing that perceptual features may not always matter for category inclusion (Fouquet et al., 2017). A common belief among children may be that dolphins are fish, due to their appearance (e.g., Pizarro-Neyra, 2011), but learning that they give live birth rather than lay eggs, like fish do, can allow a reformulation of their conception towards understanding that dolphins are actually mammals. However, as language plays a more crucial part in navigating the world, children appear to develop more archetypal definitions of animals. Allen's (2015) study on toddlers illustrates this by showing that 3-year-olds appear to possess a slightly less archetypal definition of "animal" than 5-year-olds do. This also coincides with the suggestion that the explicit formation of scientific misconceptions begins to show first signs before 3 years of age, and that the development of language plays a key role in the generation of such conceptions (Hast, 2018, 2019; Mandler, 2004). Beyond this early stage, a range of studies in different linguistic contexts have demonstrated there is subsequently no single definition for the "animal" category in later development.

"Animal" Across Languages

Research has evaluated children's understanding of the concept "animal" in the context of other languages (Table 1). However, there are two notable shortcomings that the present project seeks to address. First, although the understanding of the concept has been evaluated in a range of linguistic contexts there have been no direct language comparisons. While Allen (2015) argues that the Mandarin 动物 (*dòngwù*) provides rather similar parameters to its users as "animal" does to English speakers, this is not entirely clear and can only limitedly be deduced across studies. This means even a simple comparison of English and Mandarin studies does not give insight into the core matter of concern that this project is targeting. Second, languages were always first language–the native tongue–as well as language of instruction in schools. How is conceptual understanding impacted by exposure to more than one language? Effects of bilingualism have shown to have wide-ranging benefits for cognitive learning (for a review see e.g., Adesope et al., 2010). However, research in this field has typically focused on language learning rather than on scientific understanding. Do Singaporean children understand "animal" differently based on language–both across and within population groups? For example, the archetypal definition of the Malay word for animal, *haiwan*, only excludes humans, whereas the archetype for the Tamil விலங்கு (*vilaṅku*) excludes birds, pests and other microorganisms. Despite the differences each of these archetypal definitions seems in harmony with English, which has two recorded archetypes–one corresponding with the Malay archetype ("any living thing other than a human") and one, broadly, with the Tamil archetypal exclusions ("a mammal, as opposed to a fish, bird etc."). Does multilingual exposure provide a more coherent understanding of "animal", or does it present additional barriers to conceptual change?

The Singapore Context

So as in many other science domains, explicitly verbalized misconceptions about "animals" exist, and this may be due to language and discourse. Singapore

Table 1. Overview of existing "animal definition" studies across different languages

Language	Country	Age group: Pre-school	Age group: Primary school	Age group: Secondary school	Age group: Adults	Studies
English	UK	Include mammals; 3-year-olds include more non-archetypes than 5-year-olds				Allen (2015)
	New Zealand		Animals limited to mammals. Birds, insects, fish, reptiles, humans all seen as own categories.		Only half of trainee primary teachers able to identify all animal instances correctly as animals	Bell (1981)
	Botswana			Include fish; exclude humans		Tema (1989)
	US				*Intuitive* concept may be limited to vertebrates, mainly mammals, in biology undergraduates	Bierema and Schwartz (2015)
Greek	Greece	Include fish; exclude insects, birds, humans	Include fish, insects and birds; exclude humans		Exclude humans only	Papadopoulou and Athanasiou (2005, 2015)
Mandarin	Taiwan		Mostly refer to mammals. Include fish, reptiles, insects. Exclude humans.			Chen and Ku (1998) Yen et al. (2007)
Maltese	Malta	Exclude fish, insects, arachnids				Tunnicliffe et al. (2008)
Slovene	Slovenia		Mostly refer to mammals; 10x more often than to birds or fish, 5× more often than to reptiles.			Torkar and Mavrič (2016)
Spanish	Spain		Exclude humans only.			Villalbi and Lucas (1991)

offers an ideal setting in which to examine the concept of language and concept formation. While the main language of instruction in public schools is English, there are four official languages in the country: English, Mandarin, Malay, and Tamil. And only a third of Singaporean households primarily speak English at home (Department of Statistics, 2016). The Singaporean syllabus for primary science education sets out learning about "living and non-living things" (MOE, 2014, p. 41), making specific reference to animals and their subgroups. This is only required to be addressed in primary 3 and primary 4 (ages 8-10 years). But concepts can already be deeply entrenched even by the time children begin formal education, including about animals. However, there is a lack of understanding what impact multi-linguistic exposure may have on the formation of such conceptual understanding, especially where the language of instruction differs from the language primarily spoken in the home environment–as is the case for most children in Singapore.

Research Statement

Research has evaluated children's understanding of the concept "animal" in the context of other languages, including Mandarin, but there have been no direct language comparisons. Despite Allen's (2015) argument that the Mandarin 动物 (*dòngwù*) provides similar parameters to its users as "animal" does to English speakers, this is not entirely clear and can only limitedly be deduced across studies. Even a simple comparison of English and Mandarin studies would not give insight into this study's core matter of concern. Further, languages were always first language as well as language of instruction, but there is no insight into how conceptual understanding is impacted by exposure to more than one language. As a result, the present study therefore sought to address two key research questions. First, what is the relationship between understanding of "animal" in language of instruction and in the language predominantly spoken at home? To address this question, the study compared task performance across

Figure 1. Examples from English version task, with archetype animal (left), non-archetype animal (centre) and non-animal (right)

different children speaking different languages, and comparisons within children where they principally spoke a language different from language of instruction. Second, how does children's monolingual and multilingual understanding of "animal" develop with age? To address this question, the study also compared task performance across three different age groups.

METHOD

Participants

A total of 312 children took part in the study, which was determined using G*Power (Faul et al., 2007) under the assumptions of being able to detect medium effect sizes, with an error margin of 5% and a 95% confidence level. Two participant variables were considered. First, each child came from one of four different home language (HL) groups according to which language was most frequently spoken in their home environment: English, Mandarin, Malay, or Tamil. Second, each child formed part of one of three age groups: 4-year-olds (50 boys, 54 girls; M_{age}=4.10 years), 7-year-olds (47 boys, 57 girls; M_{age}=7.10 years) and 10-year-olds (50 boys, 54 girls; M_{age}=10.08 years). These three age groups were targeted as they were seen to offer the best insight into Singaporean development in relation to the particular area of inquiry. Archetypal definitions of "animal" are known to appear in toddlerhood, and the older age groups give insight into understanding immediately prior to and after the syllabus addressing the topic. Each of the 12 groups (HL×age) consisted of 26 children. Children were recruited through children centers and primary schools in Singapore. As data collection occurred during Singapore's circuit breaker period when schools were shut, the research could not be conducted in the schools themselves. Instead, schools were asked to distribute participation invitations via their school email systems to relevant parents. Participants were reimbursed through a toy store gift card worth either S$ 5 or S$ 10, depending on whether the children had been asked to complete one survey or two.

Design and Procedure

The study used an online survey format. Through the recruitment process, parents were able to express interest in participating in the study. Once they had done so, they were sent a short background survey where they were asked to provide their child's age and which language is principally spoken in the home. In addition, they were asked about any family pets, since experience through having pets may have some impact on animal categorization (cf. Kovack-Lesh et al., 2008). After completing the background survey, the parents were sent a link to the main survey. The first survey page contained information to the study and required parental consent before the survey itself could be accessed. The survey itself consisted of a total of 50 images (42 animals and eight non-animals), with each image presented on a separate survey page. The animals represented a range of animal species. Of the 42 animals, seven were considered archetypal animals (i.e. four-legged mammals).

Figure 1 shows an example of each image type from the English version. Each picture was accompanied by the question "what is this?" above the image, and the two response options "animal" and "not animal" beneath the image. No labelling of the kind of animal or non-animal was required. Selecting an answer option then led to the next picture. Surveys were prepared in each of the four languages, using the same images in each version.

Children were required to decide whether the images showed animals or non-animals, and the images were presented in a random order. Parents were advised not to help their child in making decisions but were advised, for the youngest group, to help with the reading and completing of the survey. Survey completion took around 15 minutes. The children from the English HL group only completed one survey in English. The children from the other three HL groups completed two surveys, one in English and one in their HL. Within each non-English HL group, order of completion was counterbalanced such that one half of the children completed the English survey first and the other half the

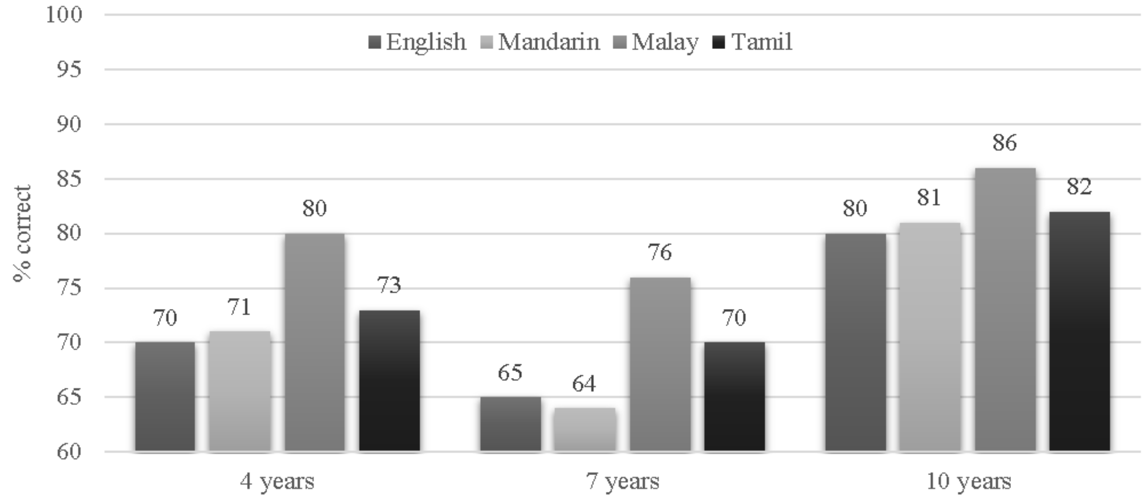

Figure 2. Performance for all animals on English version test across four HL groups

HL version first. Each of these children then completed the second survey approximately six weeks after completion of the first. The children were not provided with feedback concerning correct or incorrect answers.

Ethics

The study was approved by the Institutional Review Board of Nanyang Technological University (IRB-2020-05-025) and followed all necessary procedures for ethical conduct. Ethical approval for the study was granted on 29th May 2020.

Scoring and Analysis

In the first instance, all items were scored according to whether they had been correctly identified as animal or as non-animal, with a score of 1 for each correct item and a maximum score of 50. Since recognition of non-animals was very high, as had been expected, the subsequent analyses focused on recognition of animals only. Analyses were conducted considering the performance in identifying all animals, archetypal animals only, and non-archetypal animals only. Two-way ANOVAs were applied to examine any significant effects of age and of HL on correct scores, as well as any significant age × HL interactions. This was done for the English version of the survey across all children, and for the HL versions. Repeated measures t-tests were applied to examine comparisons between correct scores on different language versions of the survey where children completed both the English and the HL version. In addition, task order for the non-English HL groups, gender and whether children had exposure to pets or not were assessed as well but no significant effects were noted, therefore they are not given further consideration. All analyses were performed using SPSS.

RESULTS

Performance Across English Version Tests

Figure 2 shows the four HL groups and their performances on the English version of the survey. There were significant main effect of HL for all animals, $F(3,11)=8.90$, $p<.001$, $\eta^2=.08$, and for non-archetypes only, $F(3,11)=9.18$, $p<.001$, $\eta^2=.08$, but there was no significant main effect of HL for archetypes only. The Malay HL group performed significantly better than every other group for all animals and for non-archetypal animals alone, but not for archetypes alone, where the groups did not differ in their performances. There were no other significant differences among the HL groups.

There were also significant main effects of age for all animals, $F(2,11)=49.60$, $p<.001$, $\eta^2=.25$, for non-archetypes only, $F(2,11)=3.62$, $p<.05$, $\eta^2=.02$, and for archetypes only, $F(2,11)=49.92$, $p<.001$, $\eta^2=.31$. The 10-year-olds performed significantly better than the 4- and 7-year-olds, but there were no significant differences between the two younger groups. There were no significant interactions between HL and age.

Performance Across Different HLs

Figure 3 shows the four HL groups and their performance on the HL version of the survey. There were significant main effects of HL for all animals, $F(3,11)=11.46$, $p<.001$, $\eta^2=.10$, for archetypes only, $F(3,11)=2.82$, $p<.05$, $\eta^2=.03$, and for non-archetypes only, $F(3,11)=11.18$, $p<.001$, $\eta^2=.10$. The Malay HL group performed significantly better than every other group for all animals and for non-archetypal animals alone, but not for archetypes alone, where the groups did not differ from each other in their performances. There were no other significant differences among the HL groups.

There were also significant main effects of age for all animals, $F(2,11)=39.07$, $p<.001$, $\eta^2=.21$, and for non-archetypes only, $F(2,11)=39.71$, $p<.001$, $\eta^2=.21$, but there

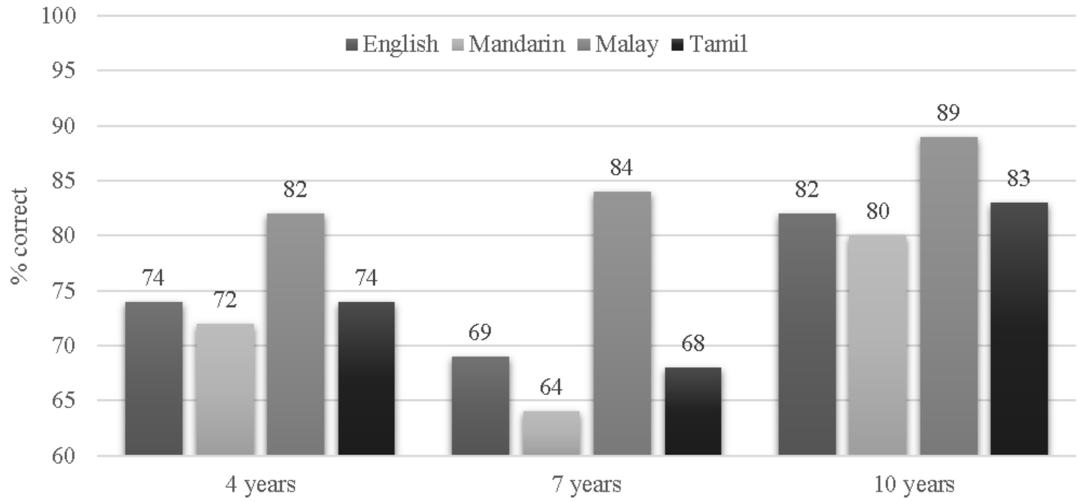

Figure 3. Performance for all animals on English version test and HL version tests, for non-English HL groups only

was no main effect of age for archetypes only. The 10-year-olds performed significantly better than the 4- and the 7-year-olds, but there were no differences between the two younger groups. There were no significant interactions between HL and age.

English-HL Comparisons

When comparing performance between HL and English versions of the survey, no significant differences were noted for the Mandarin and the Tamil HL groups, but the Malay HL group performed significantly better on the HL version than on the English version for all animals, $t(154)=2.08$, $p<.05$.

DISCUSSION

The aim of the present study was to understand the issue of multi-linguistic backgrounds on children's developing understanding of animals. The first key research question asked about the relationship between understanding of "animal" in language of instruction and in the language predominantly spoken at home. The results from the study suggest that for most children it made little difference whether they completed the surveys in English or in another language. For the Mandarin HL group, this would already be supported by Allen's (2015) argument of similar category parameters in Mandarin and English. For the Tamil HL group, the archetype for "animal" is also fairly restrictive, hence again the outcomes are not surprising for this group. The children in the Malay HL group, on the other hand, did show significant effects in their performance, scoring higher that the other language groups for both tests, as well as scoring higher in their HL than in the language of instruction. Out of the four languages, Malay has the broadest archetypal definition that only excludes humans. As a result, it is perhaps not surprising that the Malay group showed a significantly higher correct score for non-archetypal animals than the remaining groups but at the same time is still to some extent restricted by the parameters set by the language of instruction. Thus, home language exposure that has broader definitions may strengthen a child's understanding when also learning in the context of a different instructional language.

The second key research question asked how children's monolingual and multilingual understanding of "animal" develops with age. Both analysis sets showed the oldest children consistently performing significantly better than both the 4- and the 7-year-olds, regardless of language, but with no significant differences between the two younger groups. Nonetheless, patterns emerging actually indicated a U-shaped performance curve, with the 4-year-olds mostly scoring slightly higher, on average, than the 7-year-olds. This seems to be in line with the suggestion that more restrictive archetypal scientific definitions begin to emerge at around 3 to 4 years of age (cf. Hast, 2018, 2019; Mandler, 2004). The older children's significantly improved performance can be associated with educational experience as their testing occurred after having been taught about animals in school, as per the national syllabus in Singapore (MOE, 2014). The notable exception was again the Malay-speaking group, which did not follow the same U-shape trend but instead followed a more linear improvement. Since the Malay *haiwan* is not subject to highly restrictive parameters, it would seem reasonable to assume that a simple improved understanding over time should be observed.

The findings reflect in some detail the challenges that diverse knowledge sources can pose for classroom-based teaching (cf. Duit et al., 2013). However, not only is a wide range of concepts the issue as such, but the language that underpins these concepts also plays a key role. Because the everyday experiences are established through first-hand observation as well as through conversation-based language, such as with parents (Eberbach & Crowley, 2017) it is necessary to understand the interaction and integration of different information sources. This process of integration of information sources, too, starts early in development and has implications for conceptual change in science learning (Hast, 2014b). However, it is evident from the present study that such integration of information may also act as hindrance to learning since information sources may clash when everyday experiences meet formal instructional levels. As such, the role of conversation in the classroom, which is already recognized as being central to early science learning (France, 2021) must be given more nuanced differentiation in light of varied linguistic backgrounds.

Limitations

The present study is the first to offer a more detailed cross-linguistic examination of the development of "animal". Nonetheless it still remains limited in its scope of generalizability for several reasons, but which give rise to future research directions. First, the study illustrates the linguistic effect for only one specific concept. Further studies would need to consider a broader range of scientific domains to examine for consistency of the current observations. Second, the study does not offer any qualitative insight into the children's understanding of "animal", and such understanding might show a further more nuanced cross-linguistic differentiation. Subsequent research would therefore do well to also address this gap. And third, as a recommendation for future research, the study here was concerned with explicit understanding of animal. Studies in other domains of science have shown that young children's expressed ideas may differ from their underlying understanding of those same ideas, which are often seen to then be more accurate (e.g., Hast & Howe, 2015, 2017; also see Hast, 2020)–so what about the underlying awareness of "animal"? This might provide even more detailed insight into the conceptual development role played by language.

Implications

Despite the limitations, the study may nonetheless have a variety of implications for understanding the role of language in the formation of scientific concepts as well as for instructional approaches. For instance, similar to the Finnish inter-disciplinary teaching and learning approach with a focus on transversal competences (Lavonen, 2020; Vahtivuori-Hänninen et al., 2014), the role of mother tongue classes in Singaporean schools could find a new role in the context of scientific pedagogy. Consideration may be given to how mother tongue classes, which are compulsory for Singaporean primary school students, and science lessons could meet so as to offer mutual support in the process of pedagogy whereby both linguistic ability and scientific understanding can be fostered. Beyond the Singaporean classroom, the present findings may also find use in a more careful consideration of pedagogy in increasingly diverse classrooms due to globalization and global migration (cf. Marosi et al., 2021).

Finally, an important implication is that generating a stronger understanding of how the specific concept "animal" develops could potentially impact areas around conservation and the efforts to promote relevant positive attitudes in children. For instance, recognizing that invertebrates, which are generally viewed negatively, fall under the same umbrella "animal" as more endearing species do, such as the pet dog, can improve attitudes towards the less endearing ones, even in pre-schoolers (Borgi & Cirulli, 2015). It can further help in working towards children becoming more pro-environmental (Melis et al., 2020; Young et al., 2018) and improve their understanding of animal conservation (Cornelisse & Sagasta, 2018). For all of these, science education has an important role to play, and thus understanding the role of language in conceptual development in more detail can only be considered beneficial in this respect.

CONCLUSIONS

The present study was an attempt to examine in brief the relationship between language and the developing understanding of scientific conceptions, specifically by drawing on multilingual exposure to everyday concepts. In articulating an outline of this relationship, it has prompted a more careful consideration of the role that language may play in the science classroom as well as of its role in the development of everyday conceptions–and the resulting clashes between these two. In an effort to work towards successful conceptual change that seeks to encompass the wide range of ideas children bring to the science classroom, having this further insight should be beneficial towards more effective pedagogical strategies.

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