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The Enduring Effects of Early-Learned Ideas and Local Folklore on Children's Astronomy Knowledge

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Abstract

The research described here examined the sources of knowledge of astronomy of children (age 3–18) in China and New Zealand, together with the development of their awareness of competing sources, ranging from everyday language, childhood literature and folklore to the scientific accounts prevalent in schools. The authors cite examples of the *bootstrapping* encountered during these years, where children's expanding knowledge and how they process questions intended to probe their understandings—their metacognitive strategies—are mutually beneficial. The semi-structured interviews utilising three modalities (verbal language, drawing and play-dough modelling) carried out with pupils ($n = 358$), and questionnaires administered to their parents ($n = 80$), teachers ($n = 65$) and local librarians ($n = 5$), focused on young people's understanding of daytime and night-time and the roles played by the Sun and Moon in creating familiar events. The findings underscore the arguments put forward by the authors in a recent article in this journal concerning the *co-existence* of everyday and scientific concepts. The influence of early-learned ideas deriving from pre-school experiences, recalled by children and largely corroborated by family members, was found to be extensive. Evidence of the *migration of folklore* in one of the two settings investigated (on the North East China Plain) and therefore its continuing influence on children's comprehension is provided. With respect to teaching, the authors argue the benefits to be had in making more explicit with young students the differences between early-learned (everyday-cultural) ideas—particularly local community knowledge and folklore—and the scientific content found in the school curriculum.

Keywords Children's cosmologies · Metacognition · Everyday and scientific concepts · Bootstrapping · Folklore · Astronomy

Migration of folklore whereby parents and grandparents have brought their folklore about natural occurrences (such as those involving the Earth, Sun and Moon) with them when they migrate from one territory to another—in this case, myths about night and day relating to the hills and mountains around Shandong in Eastern China (e.g. 'night is when the Sun is hiding behind the mountains'). Such knowledge being evidently carried to Jilin on the NE China plain, with migrants passing their folklore on to their children and grandchildren (see Blown and Bryce 2017; Gottschang and Lary 2000).

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Introduction

The research described here deals with the *sources* of astronomical knowledge which young people in China and New Zealand identified during a set of interviews; where they said where their learning came from. The questions were put to them following in-depth, semi-structured interviews concerning their grasp of ideas about the motion and shape of the Earth, Sun and Moon (ESM); and their concepts of gravity, time, daytime and night-time, seasons and eclipses; as part of a longitudinal, cross-cultural, ethnographic, comparative study in Changchun, China and Wairarapa, New Zealand. These are described by the authors from a variety of perspectives as follows:

- the cultural factors permeating the acquisition and development of children's concepts (Bryce and Blown 2006);
- the changes which occur as knowledge is restructured (Blown and Bryce 2006);
- the similarities and differences in the gender effects apparent in comparative studies (Bryce and Blown 2007);
- the conceptual coherence detectable in children's developing ideas (Blown and Bryce 2010);
- the relative gains, overlaps and deficits in expertise across the novice-expert continuum (Bryce and Blown 2012);
- thought-experiments about gravity in the history of science and in research into children's thinking (Blown and Bryce 2012);
- the confusions detectable in young people's ideas about the shape and size of ESM (Bryce and Blown 2013);
- the relationships between what is revealed as children manipulate their own play-dough models of the ESM and their apparent conceptualisations of these astronomical bodies (Bryce and Blown 2016);
- the switching between everyday and scientific language evident in what they articulate during interviews (Blown and Bryce 2017).

The authors also checked how aware they were of the *kinds* of sources from which they drew their knowledge. Additionally, a sample of teachers, parents and librarians were interviewed in relation to these children's likely sources of knowledge. Based on the literature and pilot studies conducted in 1987 and 1989, the authors started from the assumption that young children's *everyday* concepts would result from parents, grandparents and other caregivers or significant adults, children's literature, myths, legends and the folklore of their local communities; and that their *scientific* concepts would, with age, be increasingly sourced from teachers and other 'serious' sources—such as books and magazines; TV and films; the Internet; museums, planetariums and observatories; and visiting experts (such as astronomers) arranged by schools. The authors hypothesised that, with increasing age, children's thinking would become more *disembedded*¹ as they increasingly recognise the distinctions between the

¹ Donaldson (1978) discusses two co-existing modes of thought: *embedded* and *disembedded* which permeate children's thinking. The former is analogous to *everyday* thought and language as used by children and adults in their daily lives "within the supportive context of meaningful events". The latter is synonymous with *scientific* (formal or abstract) language as used by scientifically literate adults, which moves "beyond the bounds of human sense" and may do so "in a way that leaves out content and meaning entirely" (pp.76–77) (see Blown and Bryce 2017).

figurative and the literal worlds and dispense with simple analogies from everyday life and anthropomorphic accounts of phenomena they encounter. We show the wide range of children's sources of knowledge and argue the benefits that should accrue to science educators becoming more familiar with them, the persistence of early learned ideas and their effects, and the importance of careful guidance to better achieve scientific learning. Before describing the investigation in greater detail, the authors review what previous researchers have found concerning the sources of children's astronomy knowledge.

Review of Previous Studies of Children's Sources of Astronomy Knowledge

In their seminal study of *children's cosmographies*, Sneider and Pulos (1983) identified teachers, parents and books as major sources of knowledge about Earth's shape and gravity. Some half of the 159 children from California, USA who were interviewed by them mentioned school lessons or field trips to museums or planetariums; a third referred to books they had read; a sixth had discussed such matters with members of their family; and an eighth recalled TV programmes or films. 'Fewer than one-tenth of the children mentioned their own observations as sources of information' (p. 208). These findings influenced their evaluation of the earlier work of Nussbaum and Novak (1976) who were the first researchers to raise the question of children's knowledge sources; Nussbaum (1979) who stressed the significance of informal learning; Nussbaum and Sharoni-Dagan (1983); Mali and Howe (1979, 1980) who emphasised the critical role of schooling; and Klein (1982) who concluded that socio-economics, learning about science concepts in a second language, and self-esteem might also influence the acquisition of scientific knowledge. Together with their own comparative study, these led Sneider and Pulos to conclude that concepts of the Earth's shape and gravity may be considered as 'physico-cultural' concepts, i.e. that 'the acquisition of these concepts involves a coordination of observable phenomena and culturally transmitted information' (p. 220). Hannust and Kikas (2007) express essentially the same point, referring to two information sources: 'observations of the world and explanations given by other people' (p. 90). These references to the cultural nature of concepts are in keeping with Vygotsky's (1962, 1978, 1986, 2012) findings that concepts are shaped by socio-cultural interactions with others. Siegal et al. (2004) discuss whether young children may hold 'both intuitive and scientific concepts—[in separate mental spaces]—without knowing clearly when and where each type of concept should apply (but with no indication of synthesis)' (p. 321–322). Their article emphasises the need for that synthesis (or integration) and they recommend that future research should look into teaching methods by which the coordination of knowledge from different sources can be encouraged. In their view 'there are cases in which cultural transmission can effectively protect knowledge from intuitions that are sometimes fallible' (p. 323).

Nobes et al. (2003) similarly argue the importance of lessons and explanations from adults to combat the difficulties inherent in confused prior learning and intuitions. In a follow-up study, however, Nobes et al. (2005) noted that fragmented knowledge results from topics being taught piece-meal in schools, thereby underlining the need for further research to more fully explicate when, or under what circumstances, learners' ideas become more logical and consistent in a given domain. In Blown and Bryce (2010), we looked closely at the question of coherence in children's thinking, versus 'knowledge-in-pieces', the term used by diSessa (1988). There are divisions of opinion among researchers regarding this matter. On the one

hand, those in favour of coherence argue that children's ideas are in the form of *concepts*—differing from adult concepts only in degree of scientific accuracy—and organised into *coherent* theory-like structures—akin to adult theories but less precise scientifically (see Carey 1985a, 1985b, 1991; Chi and Slotta 1993; Donaldson 1976, 1978; McCloskey 1983; Murphy and Medin 1985; Vosniadou and Brewer 1992, 1994; Vosniadou et al. 2008; Vosniadou and Skopeliti (2014); Blown and Bryce 2006, 2010). While on the other hand those in favour of incoherence argue that children's ideas are composed of fragmented pieces of knowledge (phenomenological primitives or *p-prims*) which are loosely connected and lack the characteristics (*commitment* or *systematicity*) distinctive of scientific theories (see diSessa 1988, 1993, 2008; diSessa et al. 2004; Nobes et al. 2005). Our own empirical findings from multi-media interviews, described in Blown and Bryce (2010), firmly suggest that children's developing ideas demonstrate coherence. Furthermore, our analysis ties in with Barsalou's (2003, 2008) treatment of concepts as *skills*, a consideration increasingly favoured in treatments of grounded cognition.

The majority of research into the structure of children's astronomical knowledge has been from a constructivist perspective tracing its roots to the work of Piaget (1929, 1930). However, recently in New Zealand, the development and implementation of the Early Childhood Curriculum *Te Whāriki* (Ministry of Education 1996) has provided an opportunity for incorporation of socio-cultural theory and practice based on the work of Vygotsky (1978, 1986). This introduces the concept of 'children's working theories' (akin to Claxton's (1990) 'mini-theories') which are synonymous with children's knowledge and skills. As such, they act as bridges between the fragmented worlds of 'knowledge-in-pieces' and coherent theories as children learn to make sense of the world (see Hedges 2014).

Jarman and McClune (2007) interviewed 105 children age 9 to 12 in Belfast, Northern Ireland, concerning their awareness of a specific item of scientific news in the field of astronomy and identified five main media sources of scientific knowledge. Following the re-classification of Pluto from a *planet* to a *dwarf planet* by the International Astronomical Union in 2006, they asked *Why was Pluto in the news?* Those that knew that Pluto had been in the news and why were asked where they had gained their information from. The responses (published as a bar graph) were approximately television (33%); radio (12%); newspapers (20%); Internet (10%); other people (parents, peers, teachers) (30%). No doubt the *New Horizons* spacecraft fly-by photos of Pluto and its moons taken in 2015 would have been shared by similar sources with an emphasis on visual media (which did much to restore Pluto's status as a member of the Solar System albeit under a different classification). More recently, Plummer and Krajcik (2010) have again re-emphasised the role of teachers and parents in the acquisition of scientific knowledge: particularly through observational astronomy:

While many of the first grade students (35%) describe the sun as rising and setting, nearly all third grade students could give this description (95%). This suggests that early elementary students are likely to easily acquire this level of knowledge, possibly through guided observations by their parents and teachers. Such observations could include the sun appearing low in the sky in the morning, high in the sky later in the day, and then low in the sky at the end of the day (p. 778).

Kallery (2010) reported on teaching astronomy to children age 4–6 using videos and cultural artefacts such as globes to support instruction. Multi-media methods involving children's verbal responses, drawings and play-dough modelling were used to answer questions. These investigated the shape and motion of the ESM using action research and collaborative

development processes within a socio-cultural framework with the teacher in a central mediating role between children and adults at school and home.

Recently, in his retirement article as Editor-in-Chief of the Journal *Science & Education*, Matthews (2014) made a plea for the role of teachers as transmitters of culturally determined knowledge,

... in virtue of the teacher departing from constructivist principles and actually telling the class something and correcting student beliefs against established external, objective knowledge, and not relying on ‘what makes sense’ to the student or what the majority position is after a round of brain storming (p. 17).

This reminds us that the scientific world view is also, or has been, culturally determined (with input from Eastern and Western sources) and has now become universal.

Parents also have the potential to guide or scaffold their children towards more scientific views (Kallery 2010). Some evidently do, and it would seem that a number successfully encourage their offspring to focus on the science propounded in school. Certainly when (US) children reach adolescence, *interest and successful participation* in science does seem to be shaped by family encouragement (Sha et al. 2016). With respect to gains in *knowledge* in younger children, both parents and teachers should be aware of the influence of misleading children’s literature and the extent to which myths, legends and folklore impact on the development of children’s concepts. The case of basic astronomy: what brings about daytime and night-time; the seasons, the movement of the Sun and the Moon; distinctions between stars and planets; and so forth, is a rich field where—differently in different cultures—alternative stories abound to account for phenomena which conflict with scientific considerations. Researchers need to recognise that teachers, parents and grandparents come from a variety of learning experiences. Some, particularly in China, have had their own schooling interrupted by events beyond their control resulting in their education being less scientific than ideal (see Wikipedia 2017, *Cultural Revolution* and Oxford Reference: *Overview: Cultural Revolution: Quick Reference* (2018)). However, and as we reported in Bryce and Blown (2006), there was surprisingly little difference between the scientific concepts of Chinese and New Zealand children; a similarity which we attributed to the universal scientific world view of teachers in both countries and access to scientific ideas through electronic media. For example, children in China have access to many of the science programmes shown on television in New Zealand (see ‘Results’ section).

Metacognitive Strategies and Conceptual Knowledge: Bootstrapping

Metacognition, ‘thinking about thinking’ or ‘knowing about knowing’, has received much attention from researchers since the term was introduced in the 1970s by the developmental psychologist John Flavell (see Flavell 1976). As children acquire knowledge, they begin to think about its meaning and interconnected ideas (not necessarily correctly). Kuhn and Dean (2004) define metacognition from the perspective of cognitive psychology as the developing ‘awareness and management of one’s own thought’. They argue that the construct bridges the concerns of educators interested in children’s knowledge and understanding and researchers who investigate the development of skilled thinking. Lai states that most recent research indicates that massive improvements in metacognition occur during the first 6 years of life;

and that it improves with appropriate instruction, there being empirical evidence to support the notion that students can be taught to reflect on their own thinking (Lai 2011, p. 2).

Researchers like Georgiades (2004) note the concerns there now are to blend metacognitive thinking with science subject matter itself, a point emphasised by Schneider (2008) in his detailed review of studies relevant to science education. Furthermore, Zimmerman's (2007) comprehensive analysis of studies where the development of children's metacognitive strategies and their conceptual knowledge can be monitored, concluded that:

... these two aspects of cognition *bootstrap* one another... These strategies, in turn, foster a deeper understanding of the system via more sophisticated causal or conceptual understanding, which (iteratively) foster more sophisticated strategy usage. One of the continuing themes evident from studies on the development of scientific thinking is that children are far more competent than first suspected, and likewise, adults are less so. This characterization describes cognitive development in general and scientific thinking in particular (p. 213).

The notion of *bootstrapping* as a metaphor means to better oneself by one's own actions, unaided, the expression 'pulling oneself up by the bootstraps' originating in nineteenth century writing. The term has crept into philosophy and science, being of interest to investigators in various fields, including statisticians, computer scientists, biologists, developmental psychologists, language acquisition and science education researchers. In statistics, the computation of a metric is done on *repeated* samples to improve the estimate of the population value for that metric (which of itself cannot be achieved on single samples). In computer science and artificial intelligence, the expression is used to refer to *inductive* techniques. For example, Riloff and Jones (1999) report on their attempts to produce a (bootstrapping) algorithm for semantic lexicons that generates both the lexicon and extraction patterns, doing so on an *iterative* basis. Dawkins (1995) refers to the switching on and off of genes in the cellular development processes through which a full repertoire of cells is generated in a living creature, these mechanisms involving iterations. In her consideration of what contributes to the capacity of children to acquire culturally constructed knowledge through immersion in the adult world, Carey (2004) deems language to be hugely significant and deploys the term bootstrapping to 'explain cases of learning that many have argued are impossible' (p. 59). Of close relevance to the subject of the present paper, Morgan and Demuth's (1996) text analyzes how the acquisition of language begins with auditory perceptions, their analysis and primitive linguistic representations which permit syntactic inductions. They state that:

The deductive consequences of these inductions allow infants to exploit new forms of information (semantic, syntactic, or pragmatic) for linguistic purposes and may also allow infants to use aspects of input that were once indecipherable. Access to these new forms of information paves the way for the development of more detailed linguistic representations (p. 20).

The bootstrapping metaphor may also be applied to the metacognitive interactions between the child and the learning environment within the zone of proximal development (ZPD) (Vygotsky 1978) whereby the child recognises the need to take control of their own learning to the extent of asking questions from significant adults or looking up information in the library or online. Scaffolding is a two-way process involving metacognitive bootstrapping by the child assisted by access to knowledge in an environment conducive to scientific learning.

Thus ‘bootstrapping’ and ‘scaffolding’ are complementary processes: ‘bootstrapping’ where the child increases their knowledge independently; ‘scaffolding’, where they do so with the help of parents and teachers within the ZPD where the child is ready to build on what they already know with the assistance of others (see Bruner 1985). In science education specifically, Koslowski (1996) underlines the collaborative discussion and argumentation which scientists actually engage in, recognising that scientific enquiry involves bootstrapping—her definition is ‘using theory to constrain data and using data in turn to constrain, refine, and elaborate theory’ (p. 281). When students participate in collaborative argumentation during their school education in science (and in other subjects, appropriately handled), they are learning how to learn. As Bricker and Bell (2008) put it: ‘Argumentation makes people’s ideas visible, it can promote conceptual change because some of the ideas it surfaces might afford avenues for cognitive dissonance, it fosters co-construction of knowledge, and it provides space for deep articulation of the issues at hand’ (p. 41). Like Koslowski, these writers emphasise the need for researchers to recognise how collaborative practices and reasoning really operate in science. They also urge researchers to take on board ‘what everyday argumentative competencies youth develop and bring to the classroom’ (Bricker and Bell 2008, p. 48). These bear significantly on how students learn *science*, learn to *do science* and learn *about science* (c.f. Hodson 1998; and Bryce and Day 2014), and accords with effective questioning strategies used in in-depth interviews designed to ascertain what young people know in particular fields, such as the astronomical ideas figuring in the present research.

Research Aims

Guided by these considerations, we set out to:

- RA1: identify what children regard as the sources of their astronomy knowledge, together with corroborations from teachers, parents and (where appropriate) librarians;
- RA2: exemplify the awareness which children reveal of the variety of sources which they use or have used, notably in the transition from everyday to scientific thinking and language.

Methodology

Participants

There were 688 participants in all: 538 children (270 from NZ² including 125 boys and 145 girls; 268 from China including 144 boys and 124 girls); 65 teachers (31 from NZ; 34 from China); 80 parents (38 from NZ; 42 from China); and 5 librarians (3 from NZ; 2 from China) (see Table 1). The children attended kindergartens and schools in Wairarapa, Wellington Region, North Island, NZ; and Changchun, Jilin Province, North East China. The teachers and parents were from the local school communities. The librarians were from the National Library Services that served local schools. The number of children in each age group varied from survey to survey but aimed at a minimum of $n = 30$ for each 3–4 year span (ages 3–5, 6–

² New Zealand is abbreviated to NZ.

8, 9–12, 13–15, 16–18) and averaged $n = 50$ in the most complete survey in NZ in 1998 and in China in 2000. Children age 3 to 18 in each culture participated because of the nature of the longitudinal study which followed the development of children's astronomy concepts from kindergarten and pre-school, through primary school to secondary school. Young people from each culture were 'twinned'³ within their own culture into matched pairs as far as possible on the basis of age, ethnicity, gender, general ability and socio-economic background (parents' occupations) to form survey and control groups. They were then matched across cultures so that NZ children were being compared with 'similar' children in China. 'Twinning' was done by class teachers so that in general children were being compared with their peers in the same class and school.

Comparative Cultures for Longitudinal Ethnographic Studies

New Zealand was selected because it is the home of the first author who conducted pilot studies in the field in 1987–1989. These were followed by cross-cultural longitudinal studies from 1993 to 2003; and from 2004 to 2006; to investigate whether the cosmologies found in children in NZ would be found in children of other ethnic groups and cultures (following the recommendations of Nussbaum and Novak 1976, for such cross-cultural research). China was selected as the comparison culture because at that time (1993) it was considered to be a very different culture from NZ with ancient roots, a different language system (pictographic versus alphabetical) and thought to be less scientifically advanced than NZ with less access to scientific media and thus likely to have different children's cosmologies. China was also chosen because the researcher had connections with teachers in China through the NZ–China Friendship Society who arranged for him to undertake research into children's science concepts while teaching in China. In retrospect, this period was to be marked by rapid change as China modernised but the cultures remained sufficiently diverse for a comparative study to be viable.

Procedure

The methodology incorporated both constructivist and socio-cultural elements influenced by the work of Piaget and Vygotsky; the former based on Piaget's premise that learners construct knowledge through their activities and experiences; the latter building on Vygotsky's theory that learning is a process founded on children's social encounters and interactions with adults and peers. The procedure was based on an ethnographic and longitudinal approach whereby the researcher (first author) spent several months in each school culture becoming an accepted member of the community. Generally, the children were interviewed one-to-one as with Piagetian clinical interviews (see Piaget 1929, 1930), with an interpreter present in China. Younger children (age 3–12) were interviewed using an extensive interview guide (see

³ 1. We had 'matched pairs' *within* cultures to provide a survey and control groups to measure the influence of repeated interviews and Socratic dialogue as part of a longitudinal study.

2. We had matched pairs *across* cultures (NZ and China) to ensure that we were comparing children of similar socio-economic background (based on parents occupation).

3. As far as possible general ability (based on teacher assessment), age, gender and ethnicity (e.g. NZ European, NZ Māori; Chinese Han, Man) were also taken into consideration in 'twinning' children.

4. We also tried to match children in the same school and class with the same teachers to reduce variables such as curriculum coverage; and to make it easier to keep track of children over time.

Table 1 Participants

Group	Children		Teachers	Parents	Librarians
	Boys	Girls			
NZ	125	145	31	38	3
China	144	124	34	42	2

There were 688 participants in all: 538 children (270 from NZ; 268 from China), 65 teachers, 80 parents and 5 librarians

Appendix A) and older children (age 13–18) completed a written questionnaire (see Appendix B), both with Socratic dialogue. Finally, the participants completed a questionnaire on Sources of Astronomy Knowledge with the assistance of the researcher who asked the questions verbally and took notes on responses (see Appendix C).

The interviews were usually held outdoors or in a room with an outdoor view. The setting was kept as natural and informal as possible with other children and adults being welcome to observe the interviews and experiments. With very young children (aged 3–4), a teacher might also be present as an observer to put children at ease in an unfamiliar one-to-one interview setting. However, when the opportunity arose, small group interviews were conducted in a socio-cultural setting as used by Vygotsky (1962, 1978, 1986, 2012) to clarify points raised in the individual interviews (see protocols in Results). Interviews were initially conducted with children outdoors observing the changes in the motion of a shadow stick shadow as a result of the apparent motion of the Sun. They then observed the Moon if it was visible and where possible repeated these observations within a few days so gaining a sense of its motion (observations of the Moon were sometimes conducted in small groups to enable the maximum number of children to observe the Moon in daytime). While waiting for changes in the shadow stick shadow, we kept children focused on the motion of ESM by a series of questions about associated concepts of time such as a day, month and year, and whether these were related to the motion of the ESM. This was followed by questions on daytime and night-time, as shown in the interview guide (Appendix A). They then moved to a suitable room indoors with a view of the Ground and Sky where they drew the shape of the ESM, the Ground and Sky, themselves and a friend who lived a long way away ‘on the other side of the Earth’. These activities gave insights into children’s concepts of Earth shape, habitation of Earth and identity with Earth as detailed in Bryce & Blown (2013). Thereafter, children participated in a series of thought-experiments concerning gravity, involving

1. Dropping and throwing balls: plotting the trajectory of the ball;
2. Predicting what will happen to water in a bottle on this side and the other side of the Earth;
3. Describing what would happen to a ball dropped into a hole through the Earth;

as described in Blown and Bryce (2012). These activities were followed by play-dough modelling of the shape and motion of the ESM, daytime and night-time; then drawing and modelling the seasons and eclipses.

Interviewing young children in ethnographic research is challenging for teacher-researchers because children naturally ask questions to extend their knowledge and expect the interviewer to teach: they are too young to make a distinction between teacher and researcher. This presented a dilemma for the researcher who, as a science teacher, wanted to engage in Socratic

dialogue to guide or scaffold the child with everyday concepts to a more-scientific view. But as a researcher, he recognised his role was to be objective and impartial so as to have the least possible influence on the child's responses. Finding the balance between these sometimes conflicting roles was a constant challenge and the results show that the main interview did influence children, so that in the follow-up longitudinal studies those children who had been interviewed in the past had more advanced scientific concepts than their control twins. To minimise this effect in repeated interviews, the researcher compromised: when it was likely that the child would be interviewed again (the survey group in the longitudinal study), he referred children in need of scaffolding to their teachers or the library; and when he was unlikely to meet the child again (the control group), he answered their question to the best of his ability. By its very nature, the analogy of scaffolding implies building on the child's existing knowledge, be that knowledge everyday scientific, or a mixture of both. Attempts to eradicate the foundations of early learned ideas are likely to end in failure. A better approach is to lead the child to recognise that there are alternative ways of interpreting what they see and what they know: one of which is the scientific view.

The interviews were recorded on audio and videotape and transcribed by the researcher (first author) (with the assistance of interpreters in China). These protocols together with the researcher's field notes, and children's drawings and models, provided the main contextual qualitative evidence of sources (informing RA1) and processes of metacognition (informing RA2). The data were initially analysed and coded by the first author using the authors' Cosmological Concept Categorisation Scheme covering 13 cosmological concepts: Earth Motion, Sun Motion, Moon Motion, Time, Daytime and Night-time, Earth Shape, Sun Shape, Moon Shape, Gravity Thought Experiments, Seasons and Eclipses as described by Authors (2006a, 2006b, 2013)—see Appendices D, D1, D2 and D3. Periodically, a range of exemplars from each category were checked by two astronomers from Carter National Observatory in Wellington, NZ, with an intercoder agreement of 85–95%; *Cohen's kappa* = .83 to .94. The follow-up questionnaires given to teachers, parents and librarians provided in-depth information on sources such as nursery rhymes, fairy tales, myths and legends which may have influenced children's everyday language repertoires. They also gave details of scientific literature and media used by teachers in schools and by parents in the home which likewise could have contributed to children's scientific repertoires.

Because of space restrictions, we have omitted extensive protocols of children's responses to the researcher's questions during interviews and Socratic dialogue including discussion on sources of knowledge (teachers, parents, books, TV, etc.), as these arose during the course of the interviews. We have also omitted drawings, photos and video recordings of children's play-dough models of the shape and motion of ESM. These data provided an in-depth analysis of children's cosmologies in three modalities (verbal language, drawing and play-dough modelling). Examples of metacognition arose during the interviews encouraged by Socratic dialogue. The comprehensive study of the shape and motion of ESM also afforded a clear focus for the questionnaires on sources of astronomical knowledge.

The data were collected over a period of time by a series of surveys in NZ and China. The main cross-cultural longitudinal survey of children's cosmologies of ESM (with children age 3–12) took place in 1993 in NZ and 1994 in China (see Table 2). This was followed by a longitudinal follow-up survey with control groups in 1998 in NZ and 2000 in China (the children now being age 8–18). A second survey (with new

survey and control groups of children, age 3–12, to provide fresh data for comparative purposes; some of the original groups having reached adulthood: e.g. age 12 in 1993; age 22 in 2003) took place in 2003–2004 in NZ and 2005 in China. This was followed by a second longitudinal follow-up survey with control groups 2005 in NZ and 2006 in China. Finally, to investigate questions raised by deeper analysis of the data such as cultural mediation of knowledge and migration of folklore, surveys of teachers, parents and librarians took place in 2012–2013 (see Appendix E, upper section), and surveys of parents of Shandong ancestry in 2013–2016 (see Appendix E, lower section). These were conducted by the researcher (in NZ) and researcher with interpreters-research assistants (in China). The procedure involved a combination of interviews based on the questionnaires and collation of written responses. The main surveys (1993–2006) were conducted by the first author with interpreters-research assistants in China. During much of this time, the researcher taught in NZ and China and because of the ethnographic nature of the research, surveys could not be conducted simultaneously in both cultures. Thus, in general, there is a 1- or 2-year gap between comparative surveys but this was allowed for when selecting age groups.

The current paper reports on the sources of knowledge identified by children, parents, teachers and librarians that children utilised in participating in the main studies (structured interviews) of children’s cosmologies of the Earth, Sun and Moon as described. The principal gaps which the research reported in this paper are concerned with are:

- how teachers, parents and librarians (libraries, books) continue to be major sources of scientific knowledge despite the rise of electronic media (the Internet) during the period of these studies;
- the extent to which folklore—both local and imported by migration—is also identified as an important source;
- how metacognitive bootstrapping and a growing awareness of co-existing everyday and scientific repertoires of knowledge result from divergent sources.

Table 2 Detail of surveys

Year	Survey	Age (years)	Purpose of investigation
Studies of children’s astronomy concepts			
1993	1st NZ Survey	3–12	Investigating all aspects of children’s cosmologies.
1994	1st China Survey	3–12	Investigating all aspects of children’s cosmologies.
1998	2nd NZ Survey	8–18	Longitudinal follow-up to 1st Survey.
2000	2nd China Survey	8–18	Longitudinal follow-up to 1st Survey.
2003	1st New NZ Survey	3–12	Further exploration of children’s cosmologies.
2004	2nd New NZ Survey	4–13	Longitudinal follow-up to 1st New Survey.
2005	1st New China Survey	3–12	Further exploration of children’s cosmologies.
2006	2nd New China Survey	4–13	Longitudinal follow-up to 1st New Survey.
Studies of children’s astronomy resources			
2012	NZ parents, teachers and librarians		Researching children’s books, TV, Films, DVDs.
2013	China parents, teachers and librarians		Researching children’s books, TV, Films, DVDs.
Studies of migration of folklore			
2014	China: parents of Shandong ancestry		Researching migration of folklore.
2015	Parents of Shandong ancestry		Follow-up researching migration of folklore.
2016	Parents of Shandong ancestry		Further follow-up researching migration of folklore.

Results

There was substantial evidence from the interviews of children using knowledge from a wide variety of sources to create their everyday (cultural), scientific and other concepts of astronomical phenomena. Children frequently revealed their sources of information during the interview without prompting. In other cases, they were asked where they learned about the ESM. At the end of the interview, participants completed a questionnaire on their sources of astronomical knowledge either verbally (with younger children) or in writing; the sources being grouped by thematic analysis as follows.

Categories of the Identified Sources from Interview and Questionnaire Responses

Parents or people at home: Typically, reference was made to *my mother, Mum, my parents, my grandparents* (quite commonly in the case of everyday knowledge), *my sister/brother* (less frequently).

Children's literature and folklore: Children often referred to stories they had been told (without precise identification of by whom or in what setting, but occasionally in books or comics at home)—stories like *The cow jumped over the Moon; Maui and the Sun; The Monkeys and the Moon*; or festivals which their family celebrated, such as the Chinese *Mid-Autumn Moon Festival* when the Moon is full. Young children commonly made references to the Sun *going home* at night, and the Moon *going home* by day.

Teachers: Regarding scientific ideas, children often referred to what they had learned from their teacher, or during lessons in school.

Scientific books or magazines, the Internet: Sometimes reference was made to maps, pictures, computerised displays (*surfing the net*).

Museums, planetariums and observatories: Fairly frequent mention of these was made by children in both cultures. For example, NZ children mentioned visits to *Te Papa*—the NZ National Museum and *Carter Observatory and Planetarium* in Wellington; and Chinese children recalled visiting the museum in *Jinyue Park* and the *Observatory in Changchun*.

Television: Reference was commonly made to TV programmes including news items (e.g. by a China child: *When the Shenzhou 6 (spacecraft) went into space, I saw on television that the Earth was blue*).

Other sources: Reference was sometimes made to the Bible and God. For several children, heaven was a place where (*good and kind*) *people live*.

There was considerable evidence of young children (including many well into primary school) citing everyday ideas as they spoke about where they learned about daytime and night-time [fully exemplified and discussed in Blown and Bryce 2017]. Many of the protocols indicate figurative expressions, animism and anthropomorphism, such as the Moon *going to bed* and *sleeping* by day and the Sun doing so by night (not infrequently embellished—*closing its eyes* or *the clouds are its bed*). There was also much evidence of folklore as the source of children's knowledge including *the Sun going behind the hills* at night-time, even in locations where there were no mountains in the vicinity whatsoever [in the North East China plain—see our discussion concerning the *migration of folklore* in Blown and Bryce 2017] and later in this text. Transitions to disembedded thinking became apparent in examples where children alternated in their explanations between everyday-animistic language influenced by their cultural heritage of traditional stories, myths and legends and the scientific language used by

teachers to explain things. Imaginative reasoning reflects the emergence of logic and analogy, precursors of metacognitive use of language to share conceptual meaning. Examples included children in the early parts of an interview referring to the Sun *sleeping* at night then, later, when asked about where that took place, explicitly discounting *bed* and expressing a more technical idea, sometimes leaving the dialogue ‘hanging’. Or individuals who considered the Sun to be behind the mountains at night, then describing sunrise as the Sun *climbing up the hill* at sunrise, in a metaphorical sense.

Following the completion of this research, the authors came across a Chinese folktale *Yeh-Shen: A Cinderella Story* based on the Chinese manuscript *Youyang Zazu* which, according to Palmer et al. (2012, p. 49) is dated to the Tang dynasty (618–907 A.D.) [Waley 1947 provides a translation of this folktale.] Of relevance is that Palmer et al.’s report is about how students in China learn about their culture through such tales which emphasise *figurative* language. The authors also observe that while most research about figurative language focuses upon its understanding and interpretation, there are few studies of it in relation to society and culture. The point here is that the migration of folklore which the current authors have described is concerned with concepts being transmitted in the form of figurative language: e.g. ‘The Sun goes to sleep behind the mountains’.

Examples of Children Demonstrating Metacognitive Skills While Selecting Between Co-existing Repertoires of Ideas from Everyday and Scientific Sources of Knowledge

Although relatively rare, there were a few cases of children being recorded self-analysing their responses and correcting them from everyday to scientific to suit the interview setting. For example, in a follow-up group interview with three NZ children: *Tanya, Samantha and Rhiannon* where R denotes the researcher and C the child.

R. ...we’re going to talk about children’s ideas about the Earth and the Sun and the Moon...particularly what happens to the Sun at night-time and what happens to the Moon in daytime...Rhiannon...I think I asked you earlier...what do you think is happening here with the Earth and the Sun and the Moon at night-time?

Rhiannon (NZ European: Female: age 13 years 5 months)

C. When it’s at night-time the Sun goes over to the other side of the world.

R. Right (carry on).

C. And it shines there...so there’s daytime there...

R. Why does the Sun go to the other side of the world?

C. Then it’s daytime on the other side of the world and night-time here.

R. But earlier you said that the Sun goes to sleep, didn’t you?

C. Yes.

R. What did you mean by that?

C. Well it’s just because it’s not here anymore, on this side of the world at night, so we just say “it’s gone to sleep” and stuff...

R. But you’ve got no idea where you got that idea from?

C. Not really.

R. What happens to the Moon in daytime?

C. It goes to the other side of the world because it’s night-time over there...

R. Right (carry on).

C. And it also goes to sleep...

R. I think also you talked about the Moon sleeping in daytime, is that right?

C. Yes...sort of.

Tanya (NZ European: Female: age 13 years 8 months)

R. Tanya, what do you think of these ideas?

C. Well, well the Moon really doesn't go anywhere because we can still see it in the daytime sometimes...and...but I guess that other people over the other side of the world can see it so, it must basically go to the other side of the world or something...

R. Have you ever thought that it goes to sleep though?

C. When I was little maybe, I can't remember that far...

R. You can't remember where you got the idea from?

C. No.

R. I suspect that it comes from things like story books?

C. And sometimes on television programmes like cartoons...they have like the Sun and Moon going to sleep.

Samantha N. (NZ Māori: Female: age 13 years 8 months)

R. What do you think about it Samantha, what happens to the Moon in daytime?

C. I don't know, because you can see it...like yesterday I could see it...but like it's still not on the other side of the world and they need to be able to see it...and we can see it in daytime sometimes.

R. That's true...younger children don't think you can see it...but you're right because I looked yesterday as well and it was quite high in the Sky, wasn't it?

C. (Nods).

R. Just beyond a quarter moon?

C. (Nods).

R. ...and sometimes they're very surprised...children are very surprised...to know that you can see the Moon in daytime.

C. (Nods).

R. What about the Sun at night-time?

R. Where does the Sun go at night-time?

C. I don't think the Sun actually moves closer to the Earth...it probably can...still (be) there a bit...because the Earth is not facing it...when it's facing it, then...on the other side of the Earth we can't see it.

R. Yes...but you've never thought of the Sun or the Moon going to sleep, have you?

C. Not that I can remember.

R. What about the Earth?

R. Does anyone ever think that the Earth goes to sleep?

C. In daytime it's always moving or something...

R. So it's to do with moving...sleep means not doing anything...?

C. Yes.

As shown by the exemplars of Tanya, Samantha and Rhiannon self-analysing their interview responses and translating their everyday ideas into scientific concepts to match the context, children employ a variety of cognitive and linguistic skills reflecting an awareness of alternative repertoires and a mastery of language to share ideas and convey meaning. Having brought up their recent observation that the Moon is sometimes visible in daytime, the three children adjust their reasoning about where it moves in relation to the Earth and, with some uncertainty,

question the origins of their memory of it ‘being asleep’. These findings confirm the work of those researchers we cited earlier with respect to metacognition, particularly in respect of bootstrapping. During Socratic dialogue, the researcher mentions having observed the Moon ‘yesterday’. It is advantageous for the researcher to be able to share observations in this way—with the child and researcher talking about the same phenomena as a shared experience.

Examples of Co-existence of Everyday and Scientific Ideas of Daytime and Night-time

Although our analysis tended to treat everyday and scientific sources separately, concepts derived from these sources co-exist so that when children create concepts, they generate shapes and motions from a variety of sources. These diverse origins are reflected in combination with children’s drawings and models as illustrated below.

Emma (NZ European: Female: age 6 years 7 months).

Questions about the Shape, Nature and Structure of the Earth, Ground and Sky.

R. What is the Earth made of?

C. Blue and green stuff...like the Sky and grass.

R. Where is the Earth?

C. Up in space.

R. Can you point to where the Earth is?

C. (Points upwards).

Modelling Earth in Play-dough

R. What Shape is the Earth?

C. A circle.

R. A circle like a disc or a circle like a ball?

C. A ball.

R. What shape is the Ground?

C. Square.

Draw the Ground

R. Where have you drawn the Ground?

C. Down the bottom of the paper.

R. What shape is your (drawing of the) Ground?

C. It’s just a line.

R. Is the Ground on the Earth?

C. I can do it so.

R. Is the Ground part of the Earth?

C. Yes.

Draw the Sky

R. Where have you drawn the Sky?

C. Across the top of the page.

R. What shape is your (drawing of the) Sky?

C. I’m not sure.

R. Is the Sky part of the Earth?

C. No.

Emma described and modelled the Earth as ball-shaped, and drew the Earth as a planet-like object in space from a scientific perspective. However, she described the ground as ‘Square’ and drew the ground and sky flat and horizontal as they appear in the everyday world. Her

drawings of 'Self' and 'Friend' standing on the horizontal ground rather than on the spherical Earth is further evidence of conflicting knowledge sources (see Fig. 1a). Thus her concept of the Earth is neither completely scientific nor everyday but a combination of the two depending on the context of the question asked. However, rather than 'knowledge-in-pieces' (as advocated by diSessa, 1988, 1993, and supported by Nobes et al. 2005), this demonstrates the remarkable ability by children to make sense of a rich variety of information from diverse sources in order to construct a coherent world view (as argued by Carey 1985a; and supported by Vosniadou and Brewer 1992, 1994).

Similarly, in China:

Zhang Zhe (China: Han: Male: age 8 years 10 months).

R. Tell me about the Earth?

C. The Earth is round like a ball full of air.

R. Where is the Earth?

C. The Earth is very close to the Sun and Moon.

R. Can you point to where the Earth is? Is it up there (I point to Sky), or out there (I point to nearby buildings), or down there (I point to floor)?

C. The Earth stands between the Sun and the Moon.

Drawing the Earth, Ground and Sky

Introduce A4 paper and coloured felt pens for drawing the Earth, Ground and Sky

Draw the Earth.

C. (Draws Earth).

R. What are you drawing there?

C. Different countries.

R. What's the blue part?

C. Ocean - except for this blue part all the rest of them are countries.

Look out of window at the Ground

R. Tell me about the Ground?

C. There are many different things on the Ground and when the Sun shines on these things they have a shadow.

R. What shape is the Ground?

C. Flat.

R. Tell me about the Sky?

C. The Sky is also very blue.

R. Why is the Sky blue?

C. I don't know why the Sky is blue in daytime, but at night-time it's deep blue because that's the colour of the universe.

R. What shape is the Sky?

C. Flat.

Draw the Ground and Sky

R. Where have you drawn the Ground?

C. There (points to lower part of page).

R. What shape is your drawing of the Ground?

C. Flat.

R. Is the Ground on the Earth?

C. Yes.

R. Is the Ground part of the Earth?



Fig. 1 **a** Emma (age 6 years and 7 months) drew the Earth as a planet like object in space from a scientific perspective. However, she described the Ground as ‘square’ and drew the Ground and Sky flat and horizontal. Her drawing of ‘Self’ and ‘Friend’ standing on the horizontal ground below the Earth rather than on the spherical Earth in space is further evidence of conflicting knowledge sources. Thus, her concept of the Earth is neither completely scientific nor everyday but a combination of the two depending on the context of the question asked during the interview. **b** Zhang Zhe (age 8 years and 10 months) drew the Earth as a spherical planet like body in space. However, when he drew the Ground and Sky, he reverted to an everyday perspective with the Ground ‘flat’ below and the Sky ‘flat’ above his drawing of ‘Earth’. He drew ‘Self’ standing on the everyday Ground, whereas ‘Friend on the other side of the world’ is standing on the spherical Earth, thus combining scientific and everyday concepts from different sources of knowledge.

- C. Yes.
- R. Where would the Ground be on here then?
- C. Here (points to upper part of drawing).

- R. Just put an arrow up like that (from lower drawing of Ground to surface of Earth).
 C. (Draws arrow).
 R. Where have you drawn the Sky?
 C. There (points to top of drawing).
 R. What shape is your drawing of the Sky?
 C. Flat.
 R. Is the Sky part of the Earth?
 C. Yes.

Zhang Zhe drew the Earth from a scientific perspective as a planet-like body. However, when he drew the ground and sky, he reverted to an everyday perspective with the ground ‘flat’ below and the sky ‘flat’ above his drawing of ‘Earth’. Retrospectively, he indicated with an arrow that the ground is on the Earth. He drew ‘Self’ standing on the everyday ground, whereas ‘Friend on the other side of the world’ is standing on the spherical Earth, thus combining both scientific and everyday concepts. Scientific ideas are also evident in his drawing of countries and oceans on the Earth, and lunar phases (see Fig. 1b).

Results of Follow-up Questionnaires for Parents, Teachers and Librarians

The short questionnaire given to parents, teachers and librarians asked for details of any stories that they had told children about ESM. In the case of parents and teachers of older children, stories and literature about astronomy in general were sought. In the case of parents and teachers of younger children, they were asked for stories related to daytime and night-time; particularly, any that mention the Sun *going to sleep* at night-time, and the Moon *going to sleep* in the daytime. Or stories that refer to the Sun and Moon *going home to bed* or *going home behind the hills or mountains* at these times. They were also asked for details of any books (including nursery rhymes, fairy tales, myths and legends) which may have influenced children’s thoughts. Similarly, they were asked for the details of any TV programmes, videos or DVDs that their children had viewed (see Appendix E). Among the responses (NZ parents: $n = 38$; NZ teachers: $n = 31$; China parents: $n = 42$; China teachers: $n = 34$), songs and nursery rhymes were commonly cited; e.g. *The cow jumped over the moon...*; *The man in the moon came down too soon...*; *The Sun has got his hat on...* Popular stories were also quoted; e.g. Many children in China are told about *Yi* (also known as *Hou Yi*) the great archer who shot down surplus Suns; *Chang’e*, goddess of the Moon; *Yutu* (*Chang’e’s* pet rabbit); and *Wu Gang* who live on the Moon. Local librarians in both China and New Zealand identified a range of children’s books, DVDs and videos concerned with daytime, night-time and associated basic ideas in astronomy. From the sample offered, very many of those items intended for young readers express such ideas in animistic terms quite explicitly and convincingly (that is, emphatically *teaching* animism); some recount mythical stories involving animism, endeavouring (at best) to contextualise folklore and distinguish between it and scientific understanding of phenomena associated with ESM; and a few convey muddled thinking not helpful to children’s scientific grasp of basic ideas in this whole area. Appendix F contains an annotated list of texts and other media in these three categories.

Figure 2 displays graphically the sources identified by children for each of four stages in school, in the two countries (NZ and China) where the interviews were conducted. The data were based on the question: *Which three of these sources (of knowledge) were most important to you?*—taking the first choice only into account.

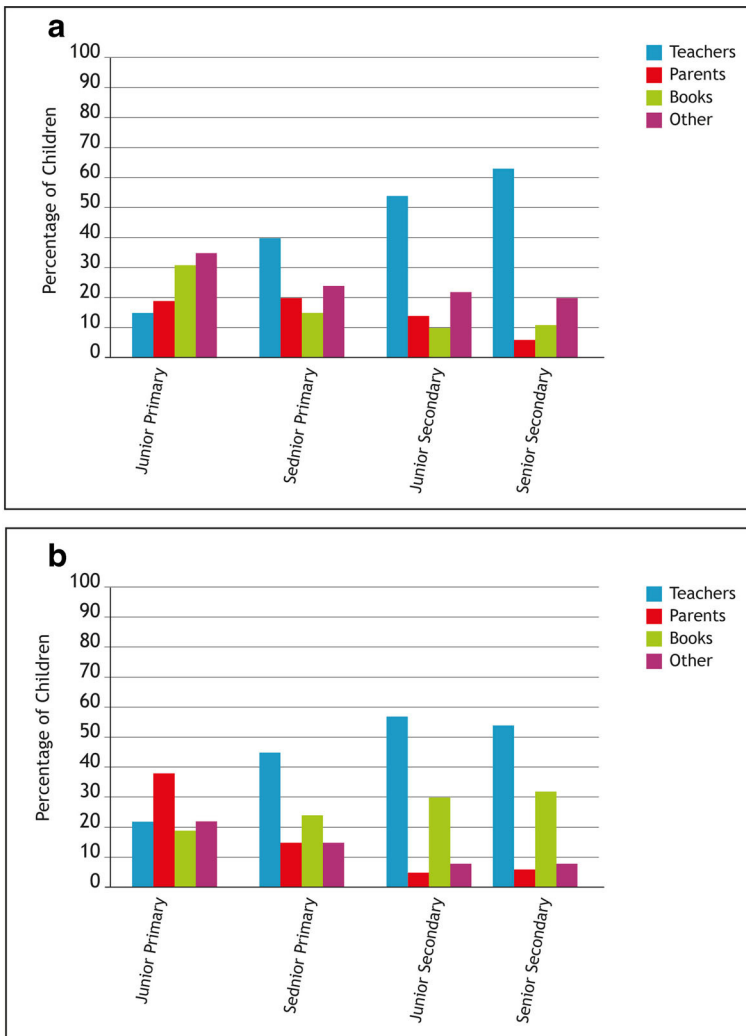


Fig. 2 **a** Most important sources of astronomical knowledge across age groups and cultures—New Zealand (1998–2000). **b** Most important sources of astronomical knowledge across age groups and cultures—China (1998–2000).

The results show that the influence of parents, books and other sources combined can be seen to be greater than that of teachers in the *Primary* years during the period of acquisition of everyday concepts. The role of teachers as sources of scientific knowledge becomes dominant at *Secondary* level. The influence of enthusiastic teachers and parents with a love for nature and science cannot be overestimated. For example, on encouraging the emergence of disembedded thought/language, teachers and parents could engage in unconventional teaching and learning experiences (perhaps as outdoor education during a school camp) such as observing sunrise and sunset with their children and imagining the Earth moving (rotating) towards the Sun (sunrise) or away from the Sun (sunset). In other words, we have to give children ‘direct experience with phenomena’ (Nussbaum and Novak 1976, p. 549) to enable them to break away from traditional contexts (see Qiantang tidal bore, Appendix F). There is also a need to be more selective about

the role of children's literature to ensure a balance between everyday and scientific perspectives, or to use stories based on folklore to lead into alternative (scientific) explanation. Disembedding (Donaldson 1978) could also be enhanced by the use of media such as drawing and modelling (as in the use of children's drawings and play-dough modelling by Kallery 2010) to reinforce concepts being introduced by verbal language, so encouraging the growth of scientific concept-skill (see Blown and Bryce 2010; Barsalou 2003).

The similarity between the cultures is striking and underscores the argument that children in cultures that have adopted a scientific worldview where children attend school and are taught by scientifically minded teachers, whose parents have also adopted a scientific world view and who enjoy access to libraries and the Internet, have similar sources of astronomical knowledge. The greater dependence of China students on books from Senior Primary may reflect greater emphasis on formal physical science in Chinese society and in the school curriculum from primary school onwards.

Further analysis is shown in Fig. 3 where the majority of sources are compared between cultures across time (between two different groups 6 years apart). These show that (a) dependence on teachers as a knowledge source declined in NZ but remained high in China; (b) reliance on parents as a source declined over the same period in NZ but not in China; (c) books remained high as a major source in both cultures; (d) television was the fourth most important source after books, teachers and parents; and (e) other children (peers) decreased from 39 to 35% in NZ, and increased from 28 to 34% in China. As shown in Figs. 2 and 3, teachers, parents and books remained the major sources of astronomical knowledge throughout these studies (1993–2006). This was against a backdrop of rapid technological change such as access to the Internet and other electronic audio visual media at home and school influencing educational practice and recreational pursuits in both cultures. There was also greater access to information on general astronomy and space exploration through TV, movies and DVDs during this period influencing children in both countries but this did not change the major sources for reference and knowledge of astronomy.

Findings in Relation to the Literature on Earth Science and Astronomy

Our findings are in general agreement with those of previous researchers but there were noticeable exceptions. For example, whereas our results agree with those of Sneider and Pulos (1983), that teachers, parents and books are major sources of knowledge about the Earth's shape and gravity, we also found that children's own observations were, in some cases, major sources (see Appendix C, row 16). This is consistent with Hannust and Kikas's (2007) recent finding that children's sources reflect 'observations of the world and explanations given by other people' (p. 90). Like Nussbaum and Novak (1976) and Nussbaum (1979), our results highlighted the role of informal learning such as the interview itself (resulting in longitudinal survey children who had been interviewed before having enhanced learning over control groups who were interviewed only once). This could be interpreted as an example of scaffolding through Socratic dialogue; although in this case, unintentional from the perspective of the longitudinal study (see Appendix C, row 17, 'This study').

We also found strong evidence in support of Klein's (1982), Mali and Howe's (1979, 1980) and Nussbaum and Sharoni-Dagan (1983) emphasis on the all-important role of schooling. Overall, the range of sources and their relative importance was similar to that found by Jarman and McClune (2007). Our results also support the more recent view of Plummer and Krajcik (2010) that teachers and parents with a scientific worldview are key sources of scientific knowledge.

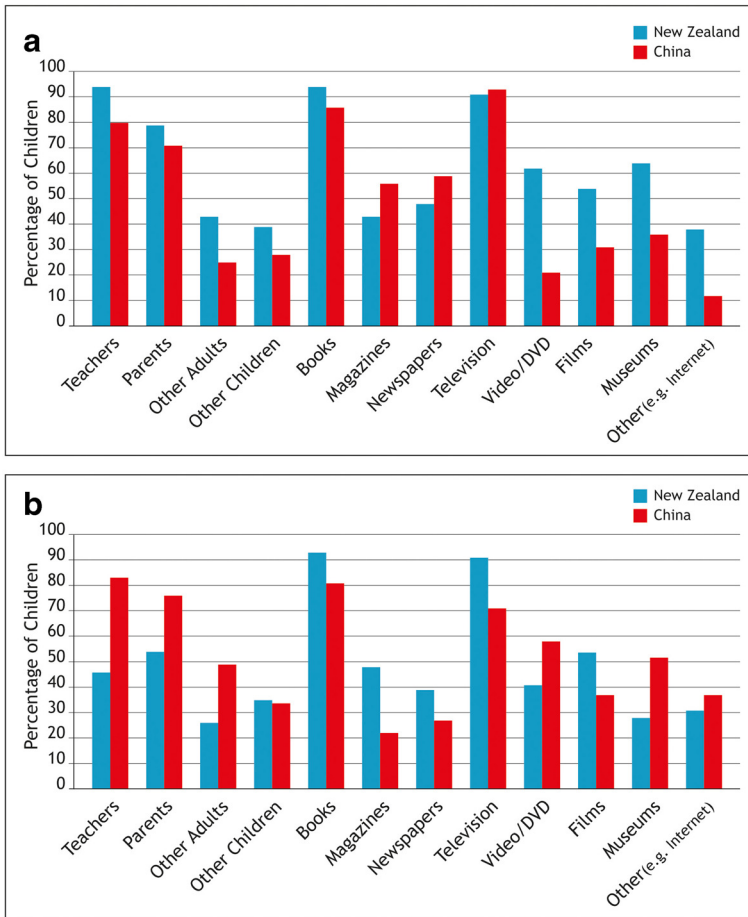


Fig. 3 **a** Sources of astronomical knowledge: comparison between cultures over time (1998 and 2000). **b** Sources of astronomical knowledge: comparison between cultures over time (2004 and 2006).

In respect of the aforementioned *coherence* of children’s knowledge, our findings differ from Siegal et al. (2004), Nobes et al. (2003) and Nobes et al. (2005). The current authors found no evidence of fragmented ‘knowledge-in-pieces’ (as argued originally by diSessa (1988) and countered by us in Bryce and Blown (2006, 2016) and in Blown and Bryce (2006, 2010). On the contrary, the current authors found that children had rich alternative repertoires of knowledge based on everyday and scientific interpretations of their worlds. Possibly, some previous researchers have misinterpreted switching between these alternatives as fragmentation rather than acts of translation from everyday to scientific and vice versa. In other words, some researchers may have focused on minor mistranslations rather than on the richness of co-existing ideas capable of expression in alternative language modes—possibly as a consequence of limited time spent with children and restricted research samples. The current studies embraced an ethnological approach with relatively large samples ($n = 538$ pupils) and few time constraints on individual interviews involving several years contact with the respective communities. The current authors have also previously reported on differences in

methodology [particularly open versus closed (forced-choice) questions] resulting in differences in responses: see Blown and Bryce (2012); Bryce and Blown (2012).

Findings in Relation to the Literature on Metacognition

As shown by the exemplars of Tanya, Samantha and Rhiannon self-analysing their interview responses and translating their everyday ideas into scientific concepts to match the context, children employ a variety of cognitive and linguistic skills reflecting an awareness of alternative repertoires and a mastery of language to share ideas and convey meaning. These findings confirm the work of those researchers we cited earlier with respect to metacognition, particularly in respect of bootstrapping. Similarly, the protocols of Emma and Zhang Zhe showing children constructing coherent world views by interweaving, combining and translating concepts from diverse sources of knowledge (folklore, culture, scientific) demonstrate that even relatively young children show some degree of mastery and conscious control of alternative modes of expression, as argued by Bryce and Whitbread (2012). While difficult to capture in interview situations (relying as they do on unique one-to-one Socratic dialogue between child and researcher in a conducive environment for interchange of ideas), the evidence suggests that these cognitive and linguistic skills are commonplace as children develop consciousness of the world and an increasing degree of control through language and thought. The role of scientifically minded teachers in this process through strategies such as scaffolding within the ZPD cannot be overestimated.

Findings in Relation to Theory, Methodology and Cultures

In light of the literature, it may be helpful to place the sources of astronomical knowledge in the context of the overall study, the questions on sources having been put to children following an extensive interview about their astronomical concepts. The main study utilising the interview guide yielded spontaneous contextual information on sources of knowledge either directly or through Socratic dialogue which formed the qualitative base of the analysis (see protocols in Results and Fig. 1). The questionnaire and interview on sources of astronomical knowledge administered at the end of the main study provided more general information on sources and the quantitative basis of the analysis (see Figs. 2 and 3).

In terms of the main study, it was found that an ethnographic approach involving the researcher spending relatively long periods of time in each school setting utilising elements of both constructivist and socio-cultural methods afforded children in both cultures the opportunity to share their cosmologies and their sources of knowledge. The use of Piagetian interview techniques combined with Socratic dialogue produced data similar to that found by other researchers. The application of a multi-modal approach provided an opportunity to triangulate verbal language with drawing and play-dough modelling modalities. In this respect, the methodology diverged from the classical Piagetian approach and used drawing and modelling as tools in the socio-cultural sense. However, the researcher avoided the use of pre-made cultural artefacts such as globes, maps and pre-made models since these were thought to influence the outcome by reducing conceptual variability. The results showed that NZ and Chinese children's concepts were remarkably similar, a result that the authors attributed to both being taught by teachers with a scientific world view. There were however some cultural differences such as differing ideas about the nature and phases of the Moon attributed to the use of a lunar calendar in China. Although the development of cosmological concepts followed similar paths in NZ and China and could be seen to become more scientific with

age, there was no evidence of the *ages and stages* theorised by Piaget, thus echoing findings by many researchers over the years (*c.f.* Ausubel 2000). Some very young children were found to have scientific ideas, whereas some older children were found to hold essentially everyday concepts: the two modes (everyday and scientific) being found to co-exist.

The same pattern between cultures was evident with similar sources of knowledge being identified, but there were some differences such as greater reliance on teachers and parents in China in the latest survey. The latter is probably a result of China's one child family policy: a socio-cultural influence that, combined with competition for higher education leading to secure employment, caused parents to invest greater time and energy into their child's education than in NZ. This is not entirely altruistic on the part of parents and grandparents since investment in the education of their offspring brings socio-economic benefits to the entire family. [See our detailed discussion and references in Blown and Bryce 2010].

Pre-school and after-school classes in China also provided greater opportunity for scaffolding which may have accounted for Chinese children having more advanced science concepts than their NZ counterparts at senior primary school; an additional factor being specialist science and technology teachers at primary level in China.

Findings in Relation to Research Aims

The authors set out to (1) identify what children regard as the source of their astronomy knowledge, together with corroborations from teachers, parents and (where appropriate) librarians; and (2) exemplify the awareness which children reveal of the variety of sources which they use or have used, notably in the transition from everyday to scientific thinking and language.

With respect to RA1, we have described, through excerpts from interview protocols taken from the main study guided by the semi-structured Piagetian interview with Socratic dialogue, children's knowledge sources in their own words, and illustrated how knowledge from scientific sources may conflict with and co-exist with everyday ideas to form semi-scientific cosmologies (see Fig. 1). In addition, we have summarised the results of the interview and questionnaire on sources of astronomical knowledge applied at the end of the study. The major sources identified in both cultures were teachers, parents and books; a pattern that has persisted over the years of the longitudinal study (see Figs. 2 and 3 on sources in general; and Appendix G on books, television and films as sources).

Addressing RA2, the authors have included excerpts and protocols of children switching between co-existing everyday and scientific ideas and vice versa as they try to respond to questions about the shape and motion of the ESM and related concepts such as the cause of daytime and night-time. Such switching is thought to be relatively commonplace; indeed the norm; but such episodes are difficult to capture and record because children are aware of being engaged in a 'language game' with the researcher where they are expected to talk and think scientifically but everyday concepts come through as children compose a response based on a variety of sources of knowledge (see Blown and Bryce 2017; Donaldson 1992). Donaldson draws attention to the critical role of 'language games' in a practical rather than a philosophical sense as preparation for making sense of the language of adults, what Donaldson (1992) calls 'using language in an intellectual way', at school and in the everyday world; enabling children to switch from their natural children's language to adult language, as the situation or rules of the game demand:

Some parents encourage close attention to words before their children go to school. They talk to their children *about* words, not just *with* words. They play language games.

The children of such parents go to school with a great advantage: when it comes to the interpretation of speech they are already able to move from mode to mode as the occasion demands. Their teachers usually decide that they are ‘intelligent’ (p. 118).

The Migration of Folklore

In a recent research paper (Blown and Bryce 2017), we reported that there was evidence from children’s interviews and drawings of astro-geographical concepts which were at odds with the interview setting in China. For example, many children spoke of and drew the Sun setting behind mountains, but (unlike the case in Wairarapa, New Zealand) no mountains are visible in Changchun, a city in Jilin Province, on the North East China Plain. Further investigation revealed that several of these children were offspring of parents and grandparents who had migrated from Hebei and Shandong—more mountainous regions to the south—to Jilin, a distance of more than 1200 km. This raised the question of whether the migrants brought their folklore with them and passed it on to their children and grandchildren. The migrants from Shandong came from both urban and rural areas (Gottschang and Lary 2000, p. 3). Thus the folklore that they brought with them would have been rich in myths, legends and stories embedded in natural settings such as hills and mountains; and as farmers and farm labourers, they would have personal experience of natural phenomena such as sunrise and sunset against the backdrop of their villages surrounded by hills. Some migrants made repeated return journeys to their old homes whilst others made a one-way planned trip. This would allow a gradual assimilation of folklore. To test this hypothesis (of migration of folklore), we gave a short follow-up questionnaire to parents of Shandong ancestry to see whether concepts such as the Sun and Moon rising from behind and setting behind mountains are part of traditional folklore and appear to have been passed on to children who have never been there. As shown in Appendix H, there was clear evidence in support of the theory that parents and grandparents from Shandong brought their ideas, myths and legends about mountains and hills, and their relation to astronomical events such as sunrise and sunset with them when they moved to Jilin.

Concluding Discussion

The findings address both research aims satisfactorily, having (1) identified what children regard as the source of their astronomy knowledge, together with corroborations from teachers, parents and librarians; and (2) exemplified the awareness which children reveal of the variety of sources which they use or have used. We should therefore encourage teachers and parents to teach children astronomy and to ensure that local libraries are retained and are well stocked. Children should be taught how to discriminate between folklore and scientific knowledge. Although everyday and scientific knowledge coexist, children should be taught which is appropriate in different contexts. For example, ‘I watched the Sun set’ is part of everyday language; but from a scientific perspective, this effect is due to the rotation of the Earth. Media such as movies, TV and DVDs can illustrate these phenomena and are valuable sources for children and teachers. While the results confirm those reported in Blown and Bryce (2017) concerning the coexistence of everyday and scientific ideas and expressions, the extent of the continuing influence of early-learned ideas during the primary school years is marked.

The research has focused on one area of children's knowledge and, while corroborations of the findings should be sought in other areas, there is little reason to suppose that the results will be confined to ideas in this area alone—apart from acknowledging the longstanding fascinations over astronomical phenomena which have prevailed in cultures worldwide, thus lending them to rich forms of folklore and intrigue. The extent of the influence of early-learned ideas bearing on many school topics is likely to be similar, if perhaps less marked for that reason.

Thus, with respect to instruction in school, the transition to scientific thinking and language as children respond to questions is challenging for teachers, though metacognitive awareness does provide opportunities for constructive analogical bridging (see Bryce and MacMillan 2005; Gentner 1983, 1989). The findings here support the recommendation made earlier by the current authors that, rather than attempting to *replace* everyday language with scientific language, as has been argued by some writers, their coexistence should be more explicitly recognised and managed positively. The *bootstrapping* which occurs between growing knowledge and the metacognitive strategies which children develop (exemplified in this study) underscores the attention which needs to be paid to scaffolding within the ZPD (*c.f.* Bruner 1985; Wood et al. 1976; Vygotsky 1978, 2012).

Tackling this sensitively and satisfactorily requires much more than simply rehearsing what was in children's past then proceeding to set out scientific considerations. Pursuing the detail of the *differences* between everyday and scientific ideas thoughtfully, taking the time required for pupils to internalise them and articulate them during group discussion, will have considerable benefits for current and future learning. Hedges (2014), referred to earlier in the literature review, also considers that teachers need to be more alert to what she describes as children's 'working theories', the term suggesting the prospects for revision and development with experience, particularly when appropriately scaffolded by adults. Her article gives illustrations demonstrating the involvement of *beliefs* as well as *knowledge* in children's thinking, and relevant to the New Zealand Early Childhood Curriculum (see *Te Whāriki*, Ministry of Education 1996).

An issue raised in practice is what happens in all early learning settings where programmes may be dominated by (well intentioned) interpretations of Piagetian or Vygostkian theory, these ensuring the use of concrete materials to give children an experiential base for commonplace ideas. Fleer and Ridgway (2007), for example, reflect on the observations they have made about the relations between everyday and scientific concepts in such early learning contexts, noting that more time was spent on building more everyday concepts. However: 'Less time has traditionally been devoted to introducing scientific concepts, particularly *in ways that interlace everyday and scientific concepts*' (p. 42, emphasis added). Niebert et al. (2012) advice on the merits of handling metaphors and analogies with care is useful in this regard; to be effective, they must be grounded in real pupil experiences—'*earlier knowledge resources*' if we follow Wagner's (2010, p. 1) analysis of what brings about the transfer of learning. A crucial step for schoolteachers is to realise that, not infrequently, young pupils will probably be *alternating* between everyday and scientific connotations as they wrestle with the new ideas they are encountering in science. We argue (see Blown and Bryce 2010, 2017) that children maintain a coherent world view to enable them to make sense of and function in the world. Careful attention must therefore be paid to those clues which signal the personal meanings which pupils are likely to come up with during lessons, personal meanings derivative of their own family exchanges and local folklore which have such enduring influences on the acquisition of scientific understanding throughout school.

Reflecting on the preparation of future teachers for both primary and secondary schools, our research suggests that teacher educators also require to be become aware of the richness of

children's cosmologies and the co-existence of everyday and scientific ideas, not simply in the astronomy areas dealt with here, but in respect of the world in general. In addition, the resources available to students and children (and the public at large) need to be vetted by responsible and knowledgeable adults to ensure that a balance is maintained between everyday and scientific knowledge (be it from books, television, DVDs, film or the Internet). We would argue that this suggests an additional role for teacher educators, for they are probably best placed to make the greatest difference given the extent of the challenges signalled by the findings on the continuing influence of early learning. Drawing from the data we described earlier and in Blown and Bryce (2017), the following four figures on the developmental spectrum perhaps most vividly epitomise what needs to be faced up to:

The proportions of children giving *animistic* responses to questions asked about the causes of daytime and night-time (*The Sun goes to bed at night; The Moon sleeps behind the mountains during the day*) are approximately:

- 30% in the 3—6 year range—*unsurprising?*
- 20% in the 7—9 year range—*interesting?*
- 10% in the 10—12 year range—*worrying?*
- 5% in the 13—15 year range—*alarming?*

Clearly, early-learned ideas persist into late childhood in coexistence with scientific concepts and can be recalled in certain contexts.

Finally, two things are worth recognising. The first is that in the non-science areas of the curriculum (language, art, history, and so on), folklore is rightly celebrated and values infuse the cultural activities used in lessons. Strong messages of ethics and respect are conveyed in folk tales where clear, straightforward explanations are used to generate feelings aimed at social unity and shared human values; these are what adults set store by. A generalised message therefore accompanies *any* folklore brought into school lessons: the ideas are reputable with the implication that these are 'how things should be'. Thus, family-based stories, even those not particularly associated with moral values (as in the research we have described), count as respectable knowledge. Science teachers should therefore not be surprised at the resilience of all early prior learning. Hence, during the initial stages of instruction, interchanging everyday and scientific meanings should be teased out explicitly in the classroom but with due care for the community origins and values implicit in children's thoughts. For example, as Fler and Ridgway (2007) suggest, rather than spending time building more everyday concepts divorced from scientific concepts, more time should be spent on interweaving everyday and scientific concepts, thereby allowing opportunities for 'bootstrapping' to take place. One way in which this could be done would be to found metaphors and analogies on children's own experience as Niebert et al. (2012) recommend.

The second thing to recognise is that there is a rich tapestry of folklore in our pre-scientific history which can be used to scaffold from everyday to scientific ideas. Some folklore has tended to become so engrained that it is taken as fact (e.g., Newton's apple). Teachers, teacher educators, and parents should be aware of what is and what is not folklore. As we report above in the case of children's literature, ideas such as 'the Sun rising and setting' are so embedded in our psyche that they are accepted intuitively as 'fact' when in truth they are misconceptions based on centuries of everyday observation and experience passed down through stories, legends, myths and folklore.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Appendix A Interview Guide for Kindergarten and Junior School Children (Abridged)

Motion Study

Questions about the motion of the Sun, Earth and Moon

Outdoors in sunshine observing the divergence of shadows of a shadow-stick and a pencil

1. Tell me about the Sun?
2. Where is the Sun?

Take care that children do not look directly at the Sun.

3. Has what is happening to the ruler shadow got anything to do with the Sun?
4. Is the Sun moving?
5. How is the Sun moving?
6. Why is the Sun moving?
7. Tell me about the Earth?
8. Where is the Earth?
9. Has what is happening to the ruler shadow got anything to do with the Earth?
10. Is the Earth moving?
11. How is the Earth moving?
12. Why is the Earth moving?
13. Tell me about the Moon?
14. Where is the Moon?
15. Has what is happening to the ruler shadow got anything to do with the Moon?
16. Is the Moon moving?
17. How is the Moon moving?
18. Why is the Moon moving?

Observe the Moon if visible. Take note of shape and record for future interview.

Shape Study

Questions about the shape, nature and structure of the Earth, ground and sky

Venue: A small room or library with a view of the Ground and Sky

1. Tell me about the Earth?
2. What is the Earth made of?
3. Where is the Earth?
4. Can you point to where the Earth is?
5. What Shape is the Earth?
6. *If response is 'Round' ask, What do you mean by 'round?'*

Round like a disc or round like a ball or round in some other way?

Do this in each case where the child responds 'Round'.

Drawing the Earth, Ground and Sky

Introduce A4 paper and coloured felt pens for drawing the Earth, Ground and Sky

Draw the Earth

1. Tell me about the Ground?
2. What is the Ground?

Look out of window at the Ground

3. What is the Ground made of?
4. Where is the Ground?

Point to the Ground

5. What shape is the Ground?
6. Is the Ground always the same shape?
7. What colour is the Ground?
8. Why is the Ground that colour (those colours)?

Draw the Ground

9. Tell me about the Sky?
10. What is the Sky?
11. What is the Sky made of?
12. Where is the Sky?

Point to the Sky

13. What shape is the Sky?
14. Is the Sky always the same shape?

Look at the Sky

15. What colour is the Sky?
16. Why is the Sky that colour (those colours)?

Draw the Sky

17. Where have you drawn the Earth?
18. What shape is your (drawing of the) Earth?
19. Where have you drawn the Ground?
20. What shape is your Ground?
21. Is the Ground on the Earth?

22. Is the Ground part of the Earth?
23. Where have you drawn the Sky?
24. What shape is your (drawing of the) Sky?
25. Is the Sky on the Earth?
26. Is the Sky part of the Earth?

Modelling the Shape, Nature and Structure of the Earth with Play-dough (Video)
Introduce play-dough for modelling. Give child a lump about 40 mm in diameter
Make the shape of the Earth (using play-dough)

1. What shape is your (model of the) Earth?
2. Is the Earth always the same shape?
3. Is your Play-dough model Earth the same shape as your drawing of the Earth?
4. When you were drawing the Earth were you thinking of this (play-dough) shape?
5. If not, what is the difference between them?
6. If they are different, why are they different?
7. Are they meant to be the same shape?
8. Why have you made your play-dough Earth that shape?
9. *Ask child to hold their play-dough model in one hand*
10. Where would the Sky be (with respect to your model Earth)?
11. Why would the Sky be there?
12. Where would the Ground be?
13. Why would the Ground be there?

Questions about the Shape, Nature and Structure of the Moon

1. Tell me about the Moon?
2. What is the Moon made of?
3. Where is the Moon?
4. What shape is the Moon?
5. Is the Moon always the same shape?
6. Does the Moon always look the same shape?
7. If the Moon changes shape, why does it change shape?
8. If the Moon changes shape, when does it change shape?
9. What different shapes can the Moon be?

Drawing the Moon

Draw the Moon and if you think there are different shapes draw them too

1. How big is the Moon?
2. Is the Moon bigger than the Earth?
3. Is the Moon bigger than the Sun?

Modelling the Shape, Nature, and Structure of the Moon using Play-dough (Video)

1. If that was the size of the Earth (indicate their model of the Earth), how much play-dough would you need to make a model of the Moon?

Make the shape of the Moon—a little Moon—a model of the Moon

2. What shape is your Moon? (Your play-dough Moon)? (Your model Moon)?
3. Is your play-dough Moon the same shape as your drawing of the Moon?
4. If not, what is the difference between them? (allow for phases)
5. Why are they different?
6. Why have you made your Moon that shape? (those shapes)?
7. Does the Moon always have the same shape?
8. If not, why does the Moon appear to change shape?

Questions about the Shape, Nature, and Structure of the Sun

1. Tell me about the Sun?
2. What is the Sun made of?
3. Where is the Sun?
4. What shape is the Sun?
5. Is the Sun always the same shape?
6. Why does the Sun shine?

Drawing the Sun

Draw the Sun

1. How big is the Sun?
2. Is the Sun bigger than the Earth?
3. How many Earths would fit across the Sun?
4. Is the Sun bigger than the Moon?

Modelling the Shape, Nature, and Structure of the Sun using play-dough

1. If that was the size of the Earth (indicate their model of the Earth), how much play-dough would you need to make a model of the Sun?

Make the shape of the Sun—a little Sun—a model of the Sun

2. What shape is your Sun? (your model Sun)
3. Is your play-dough Sun the same shape as your drawing of the Sun?
4. If not, what is the difference between them?
5. Why are they different?
6. Are they meant to be the same shape?
7. Why have you made your play-dough model of the Sun that shape?

Habitation and Identity Studies

Questions about Life on Earth

1. Is there anything on the Earth?
2. What is on the Earth?
3. Tell me about what is on the Earth?

4. Is (Kindy, School) on the Earth?
5. If not, where is (Kindy, School)?
6. Are there people on the Earth?
7. Where are people?
8. Are we on the Earth?
9. If not, where are we?
10. Where are we on the Earth?
11. Where are we now?
12. Where do people live on the Earth?
13. If not on Earth, where do people live?
14. If on Earth, do people live all over the Earth?
15. Or do people live only on parts of the Earth?
16. Which parts of the Earth do people live on?
17. Why do people live there?
18. Are you on (in) the Earth?
19. If not, where are you then?
20. If you are on the Earth, where are you on the Earth?

Identifying 'Self' with the Earth

Make a drawing of yourself where you are (on the Earth)

Make a little self, a little drawing of yourself. Label yourself as 'Me'.

21. Where have you drawn yourself?
22. Why have you drawn yourself there?
23. What are you standing on?
24. How are you able to stand there?

Introduce child's Play-dough model of the Earth from the Shape Study. Introduce model person representing the child.

This is a model of yourself. Place the model of yourself where you think you would be on the play-dough Earth.

25. Where have you placed the model of yourself?
26. Why have you placed the model of yourself there?
27. What are you standing on?
28. How are you able to stand there?

Questions about Friends who live a long way away

1. Do you know someone who lives a long way away?
2. So far away that it would take a whole day in a jet airliner to visit them?
3. Who do you know that lives a long way away?
4. Have you been in an airliner or aeroplane (train, bus) before?
5. If so, where did you go?
6. How long did it take you to go there?

If you have never been in an aeroplane, think of someone who lives so far away that it would take more than 4 weeks in a train to go to see them.

Questions about Countries that are a long way away

1. Do you know a country that is a long way away?
2. So far away that it would take a whole day in a jet aircraft to go there?
3. Or more than 4 weeks in a train?

Introduce dolls or models of Kangaroo, to talk about Australia; Kiwi, to talk about New Zealand; and Panda, to talk about China

4. Have you ever seen animals like these before?
5. Do you know the names of these animals?
6. Do you know where these animals live?
7. Do you know where China (Australia or New Zealand) is?

Many people think that China (Australia or New Zealand) is on the other side of the Earth from where we live in New Zealand (China).

Questions about a Friend who lives on the other side of the Earth

Imagine that you have a new friend, a friend that you have never met before, imagine that your new friend lives a long way away in another country like China (Australia or New Zealand) on the other side of the Earth. So far away that it would take a whole day in an aeroplane or over 4 weeks in a train to visit them.

Identifying 'Friend with the other side of the Earth

Just as you have drawn yourself where you thought you would be on the Earth, so I would like you to draw your friend where you think they would be in China (Australia or New Zealand) on the other side of the Earth, as far away from you as they could possibly be.

Draw your friend on your drawing

Label your friend as 'My friend'.

1. Where have you drawn your friend?
2. Why have you drawn your friend there?
3. What is your friend standing on?

Introduce a model person representing their friend.

This is a model of your friend. You will see that your friend is also playing ball. Place the model of your friend on your play dough model of the Earth where you think that your friend should be.

4. Where have you placed the model of your friend?
5. Why have you placed the model of your friend there?
6. What is your friend standing on?
7. How is your friend able to stand there?

Appendix B

Questionnaire for Secondary Students

Motion Study

1. Does the Earth move?
2. How does the Earth move?
3. Why does the Earth move?

4. Draw how the Earth moves (on your Motion Drawing).

Use lines and arrows to indicate motion: thus: -----> or ----->-----

5. Write the word “Earth” alongside your drawing of the Earth.
6. Does the Sun move?
7. How does the Sun move?
8. Why does the Sun move?

9. Draw how the Sun moves (on your Motion Drawing).

10. Write the word “Sun” alongside your drawing of the Sun.
11. Does the Moon move?
12. How does the Moon move?
13. Why does the Moon move?

14. Draw how the Moon moves (on your Motion Drawing).

Shape Study

Questions about the Shape, Nature and Structure of the Earth, Ground and Sky

1. Tell me about the Earth?
2. What shape is the Earth?
3. Is the Earth always the same shape?
4. What is the shape of the Earth like? Like a ...
5. **Draw the Earth (on your Shape Drawing)**
6. Write the word “Earth” alongside your drawing of the Earth.
7. What shape is your drawing of the Earth?
8. What is your drawing of the Earth like? Like a ...

9. Make the shape of the Earth with green play dough.

10. What shape is your model of the Earth?
11. What is your model of the Earth like? Like a ...
12. Tell me about the ground?
13. What shape is the ground?
14. What is the shape of the ground like? Like ...

15. Draw the ground (on your Shape Drawing)

16. Write the word “Ground” alongside your drawing of the ground.
17. What shape is your drawing of the ground?
18. What is your drawing of the ground like? Like ...
19. Tell me about the sky?
20. What shape is the sky?
21. What is the shape of the sky like? Like ...

22. Draw the sky (on your Shape Drawing).

23. Write the word “Sky” alongside your drawing of the sky.
24. What shape is your drawing of the sky?
25. What is your drawing of the sky like? Like ...

Questions about the Shape, Nature, and Structure of the Sun

26. Tell me about the Sun?
27. What shape is the Sun?
28. Is the Sun always the same shape?
29. Does the Sun always look the same shape?
30. What is the shape of the Sun like? Like a ...

31. Draw the Sun (on your Shape Drawing).

32. Write the word “Sun” alongside your drawing of the Sun.
33. What shape is your drawing of the Sun?
34. What is your drawing of the Sun like? Like a ...

35. Make the shape of the Sun with red play dough.

36. What shape is your model of the Sun?
37. What is your model of the Sun like? Like a ...

Questions about the Shape, Nature and Structure of the Moon

38. Tell me about the Moon?
39. What shape is the Moon?
40. Is the Moon always the same shape?
41. If the Moon changes shape,
why does it change shape?
42. Does the Moon always look the same shape?
43. If the Moon appears to change shape,
why does it appear to change shape?
44. What is the shape of the Moon like? Like a ...

45. Draw the Moon (on your Shape Drawing).

46. Write the word “Moon” alongside your drawing of the Moon.
47. What shape is your drawing of the Moon?
48. What is your drawing of the Moon like? Like a ...

49. Make the shape of the Moon with yellow play dough.

50. What shape is your model of the Moon?
51. What is the shape of your model Moon like? Like a ...

Viewing the Earth from the Moon.

52. Imagine that you could go to the Moon.
53. When you arrived there you looked at the Earth.
54. Where would you look to see the Earth from the Moon?
55. What would the Earth look like from the Moon?
56. What shape would the Earth be?
57. What shape would it look like?

Identity Study

1. **Draw yourself (on your Shape Drawing).**
2. Write the word “Me” alongside your drawing of yourself.
3. **Draw a friend or person who lives on the other side of the Earth from you (on your Shape Drawing).**
4. Write the word “Friend” alongside your drawing of your friend.

Appendix C

Sources of Astronomical Knowledge: Where Did You Learn About the Earth, Sun and Moon?

Name: _____ Age: _____ Class: _____ School: _____

- Source Tick \checkmark or Cross X
1. Teachers
 2. Parents
 3. Other adults
 4. Other children
 5. Books
 6. Magazines
 7. Newspapers
 8. TV
 9. Videos
 10. Films
 11. Radio
 12. Museums
 13. Planetariums
 14. Observatories
 15. Astronomers
 16. Own observations
 17. This study
 18. Toys
 19. Models
 20. Other sources (e.g. Internet)
 21. Which three of these sources were most important to you?
1 2 3
 22. Do you recall studying the Earth, Sun and Moon with Mr. Blown before? If so, when?
 23. Do you recall making the shape of the Earth, Sun and Moon with play-dough before? If so, when?

Appendix D

Cosmological Concepts Categorisation Scheme

The Cosmological Concepts Categorisation Scheme was developed by the authors to classify children's concepts into ordinal scales from least scientific to most scientific to enable comparisons between concepts and to afford statistical analysis using nonparametric tests.

The elements of the scheme were as follows:

Motion and nature of the Earth, Sun and Moon and associated concepts of time

1. Motion and nature of the Earth
2. Motion and nature of the Sun
3. Motion and nature of the Moon
4. Motion of the Earth, Sun and Moon and associated concepts of time
5. Daytime and night-time

Shape and structure of the Earth, Sun and Moon

6. Shape and structure of the Earth including habitation of Earth and identity with earth
7. Shape and structure of the Sun
8. Shape and structure of the Moon

Gravity thought experiments

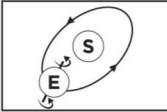
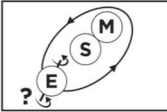
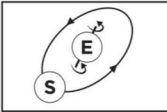
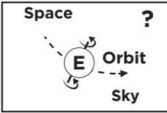
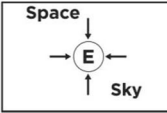

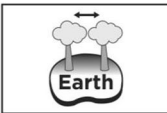

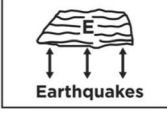
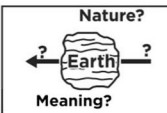
9. Throwing and dropping balls

10. Drink bottles problems
 11. Hole-through-the-Earth (*Alice*) Problem: ball falling down a hole through the Earth
- Extension studies
12. Seasons
 13. Eclipses
-

Note. Each element had descriptors and thumb-nail sketches encapsulating the key ideas. These were arranged in order from bottom (value 1) to top (value 10) to form 10-point ordinal scales from least scientific to most scientific (see Siegel and Castellan Jr. 1988).

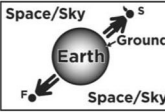
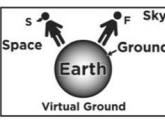
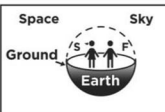
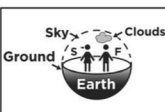
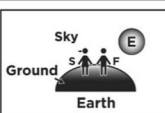
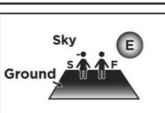
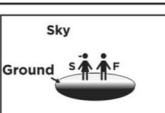
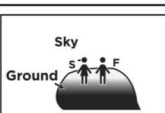
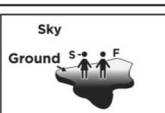
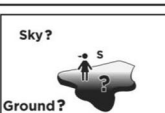
The schemes for Motion and Nature of the Earth, Shape and Structure of the Earth, and Daytime and Night-time are shown in Appendices D1, D2, D3.

Appendix D1 Categories of Concepts of Motion and Nature of the Earth.

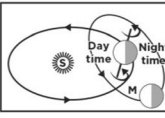
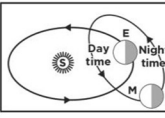
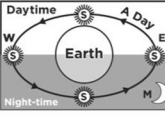
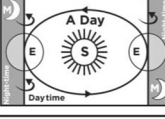
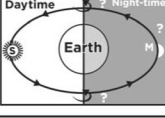
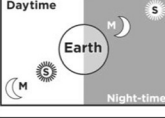
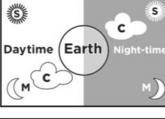
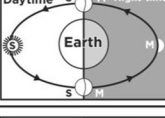


Cosmological Element “Motion & Nature of the Earth”	Thumb-nail Sketch of Concept
<p>10 Earth planet in space Rotates (spins) on axis Revolves in orbit around Sun or around Sun and Moon Drawing: Spin indicated by axis of rotation and/or motion arrow(s)</p>	
<p>9 Earth planet in space Revolves in orbit around Sun Does not spin or spin uncertain</p>	
<p>8 Earth planet or ball-shaped object in space Rotates (spins) on axis Does not revolve (orbit) around Sun, or revolution uncertain Drawing: Spin indicated by axis of rotation and/or motion arrow(s)</p>	
<p>7 Earth planet or ball-shaped object Located in space or sky Rotation (spin) and Revolution (orbit) around Sun uncertain; e.g., revolves around Moon Moves continuously in some way; e.g., “moves from East to West”, or “moves in a circle”, or moves “round and round”, or “moves with the wind”, or “moves across sky”, or “rolls”, or appears to move by relative motion</p>	
<p>6 Earth of uncertain nature Located in space or sky Stationary or motion uncertain</p>	
<p>5 Earth flat or disc-shaped or uncertain Location also uncertain Moves continuously in some way; e.g., “round and round”, or “up and down”, or “horizontally”, or “rises and sets”, or “moves around in circles”, or “moves across sky”, or “spins” (disc) “Follows us when we move” (inanimate relative motion)</p>	
<p>4 Earth of uncertain nature Location also uncertain Motion irregular, or intermittent, or indirect, or uncertain e.g., “only moves at night-time”, or “trees move in the wind”</p>	
<p>3 Earth animate: moves just like a person who “walks”, “runs”, “sleeps at night” Does not spin at night “because it is tired” “rolls”, “lands on ground”, “flies”, “follows us”</p>	
<p>2 Earth flat (slab, disc or pancake) or uncertain in nature Location also uncertain Stationary Moves only during earthquakes Drawing: Ground horizontal below; Sky horizontal above</p>	
<p>1 Uncertain of motion or nature or meaning of Earth Not sure of what Earth is, or if/how Earth moves</p>	

Appendix D2

Categories of Concepts of Earth Shape, Structure, Habitation and Identity

Cosmological Element "Earth Shape, Structure, Habitation, & Identity with Earth"	Thumb-nail Sketch of Concept
<p>10 Earth is ball-shaped (spherical) or like an egg on its side (oblate spheroid): Ground synonymous with surface; Sky synonymous with atmosphere or space: People live all over the curved surface (land)</p> <p>Interview: "ball", "basketball", "football", "globe", "golf-ball", "netball", "orb", "sphere"</p> <p>Analogies: spherical or ball-like: e.g., "apple", "orange", "walnut"</p> <p>Drawing: circle with indication of sphericity, e.g., rotation arrows, or axis of rotation, or shading of day/night "Ground" & "Sky" around Earth: "Self" & "Friend" on opposite sides of Earth. Play-dough</p> <p>Model: spherical.</p>	
<p>9 Earth is ball-shaped or like an egg on end (prolate spheroid): Ground as surface; Sky encircling or on surface: People live on the curved top surface (land) indicating a "virtual ground" below and "virtual sky" above the Earth</p> <p>Interview: Non-spherical: e.g., "circle", "ellipse", "elliptical", "ellipsoid", "oval", "round", "rugby ball"</p> <p>Analogies: Non-spherical: e.g., "egg", "kiwifruit", "pear", "watermelon"</p> <p>Drawing: Circle without any indication of sphericity by way of lines or rotation arrows, axis, or shading "Ground", "Sky" around Earth: "Self", "Friend" with feet facing "virtual ground".</p> <p>Play-dough model: Spherical. May draw ground and sky above or below to Earth with arrows to surface of Earth (ground) and around Earth (sky)</p>	
<p>8 The lower part of the Earth is shaped like a ball cut in half</p> <p>Ground horizontal inside or on top of Earth: Sky horizontal above or around outside of Earth</p> <p>Habitation Interview: People live "inside" transparent dome of the Earth on flat Ground</p> <p>Drawing: circle: "Ground" inside Earth: "Sky" around Earth: "Self" and "Friend" drawn on surface inside Earth Play-dough</p> <p>Model: Ball or hemisphere with virtual hemisphere dome or twin hemispheres representing Ground and Sky</p> <p>Habitation model: Models of "Self" & "Friend" standing "inside" Earth or on surface vertical to "virtual ground"</p>	
<p>7 Earth shaped like a ball cut in half. Ground and Sky inside Earth. People live "inside" transparent dome of the Earth</p> <p>Drawing: "Ground" inside Earth: "Sky" inside Earth: "Self" and "Friend" drawn standing on flat Ground inside Earth</p> <p>Play-dough model: Ball or hemisphere with virtual hemisphere dome or twin hemispheres representing Ground and Sky</p> <p>Habitation model: Model of "Self" and model of "Friend" on flat surface of Ground inside Earth</p>	
<p>6 Curved/Ball Dual-Earth concept: Upper one ball-shaped in Space/Sky; Lower one dome-shaped (Ground)</p> <p>Habitation Interview: People live on lower, upper, or both Earths</p> <p>Drawing: Circle representing ball-shaped Earth in sky/space: convex curve representing Ground on lower Earth. Sky horizontal above or encircling Earth: "Self" and "Friend" drawn standing on lower, upper, or both Earths</p> <p>Play-dough model: Ball-shape representing upper Earth in sky/space: bun-shape representing lower Earth</p> <p>Habitation model: Model of "Self" and/or model of "Friend" on lower, upper, or both Earths. Curvature of lower Earth may be indicated by perspective with "Friend" smaller than "Self"</p>	
<p>5 Flat/Ball Dual-Earth concept: Upper one ball or disc: lower one disc, oval, rectangle, square</p> <p>Habitation Interview: People live on lower, upper, or both Earths</p> <p>Drawing: Circle representing upper ball-shaped Earth in sky: Ground (lower Earth) rectangular or horizontal below Sky rectangular or horizontal above lower Earth: "Self" and "Friend" standing on lower, upper, or both Earths</p> <p>Play-dough model: Ball-shape representing upper Earth in sky: pancake or rectangular or virtual lower Earth</p> <p>Habitation model: Model of "Self" and/or model of "Friend" on lower, upper, or both Earths</p>	
<p>4 Earth is disc-shaped: People live on the flat top surface (Ground)</p> <p>Drawing: Circle or oval: Ground horizontal below or around or by Earth: Sky horizontal above or around or by Earth</p> <p>"Self" and "Friend" drawn standing on Ground.</p> <p>Play-dough model: Disk or pancake</p> <p>Habitation model: Model of "Self" and/or model of "Friend" on surface of disk representing standing on Ground</p>	
<p>3 Earth is flat and structured in some way: synonymous with Ground. People live on flat surface of Earth or Ground</p> <p>Drawing: Earth closed curve: Ground & Sky rectangular or horizontal: "Self" and "Friend" drawn on Ground</p> <p>Play-dough model: Oval pancake, or rectangular slab, or square slab, or irregular ball, or irregular lump</p> <p>Habitation model: Model of "Self" and/or model of "Friend" on surface of slab representing standing on Ground</p>	
<p>2 Earth is flat and unstructured: synonymous with Ground. People live on flat surface of Earth or Ground</p> <p>Drawing: Earth irregular curves: Ground and Sky on or around Earth: "Self" and "Friend" drawn on Ground</p> <p>Play-dough model: A thin irregular slab; or pancake; or a thin-spread layer (synonymous with earth); or none</p> <p>Habitation model: Model of "Self" and/or model of "Friend" on surface of play-dough representing Ground</p>	
<p>1 Uncertain of meaning of Earth: Unable to identify with Earth: Unsure of Habitation of the Earth</p> <p>Drawing: Scribble or irregular curve(s): Ground & Sky uncertain. "Self" & "Friend" unrelated to Earth or Ground</p> <p>Play-dough model: In form of irregular lump(s) or none</p> <p>Habitation model: Model of "Self" and model of "Friend" unrelated to drawing or model of Earth.</p>	

Appendix D3 Categories of Concepts of Daytime and Night-time

Cosmological Element “Daytime and Night-time”	Thumb-nail Sketch of Concept
<p>10 Earth is ball-shaped; rotates on axis in a day; revolves around Sun in a year When Western hemisphere is in sunlight (daytime) Eastern hemisphere is in darkness (night-time) Moon shines by reflected sunlight (Day and Night) Moon revolves around Earth in a month Drawing: Night-time shaded or indicated; rotation arrows; orbits</p>	
<p>9 Earth is ball-shaped and revolves around the Sun. Moon is ball-shaped and revolves around the Earth. The side of the Earth facing the Sun has day-time. The side of the Earth facing away from the Sun has night-time Drawing: Night-time shaded or indicated and orbits (optional)</p>	
<p>8 Earth is ball-shaped and may rotate (spin) on axis Sun and/or Moon appears to revolve around the Earth in a day Sun and/or Moon moves from East to West across the sky Daytime is the period between sunrise and sunset Night-time is the period between sunset and sunrise</p>	
<p>7 Earth is ball-shaped. Rotation and/or Revolution uncertain Earth revolves (or appears to revolve) around Sun in a day The side of the Earth facing the Sun has daytime The side of the Earth facing away from the Sun has night-time The Moon is on the opposite side of the Earth from the Sun</p>	
<p>6 In daytime it is light and/or sunny because the Sun is shining on our side of the Earth. At night-time it is dark because the Sun is shining on the other side of the Earth. When we have daytime the other side of the Earth has night-time. At night-time the Moon shines on the dark side of the Earth. Sun “Goes to other countries at night-time”; Moon “goes to other countries in daytime”; Sun rises and Moon sets in daytime; Sun sets and Moon rises at night-time</p>	
<p>5 Non-animistic ideas involving “covering” by the Sun and Moon; e.g., In daytime “the Moon is behind the Sun”; at night-time “the Sun is behind the Moon” In daytime “the Sun blocks the Moon”; at night-time “the Moon blocks out the Sun” Sun “appears in daytime”; “disappears at night-time” Moon “goes away (disappears) in daytime”; “appears (comes out) at night-time” Confuses night-time with Solar Eclipse</p>	
<p>4 Semi-animistic ideas involving “hiding” Daytime and night-time related to Earth, Sun and Moon being hidden by clouds or other atmospheric or astronomical objects; e.g., “In daytime the Moon hides behind clouds”; “At night-time the Sun hides behind clouds”</p>	
<p>3 Animistic ideas involving “changing into” or “replacement” or “switching places” or “swapping places”; e.g., “In daytime the Moon changes into the Sun” “At night-time the Sun changes into the Moon” “In daytime the Moon and Sun swap places”</p>	
<p>2 Animistic ideas with daytime and night-time related to activities of animate Earth, Sun and Moon; e.g., “In daytime the Sun shines and the Moon sleeps” “At night-time, after the Sun has gone to bed, the Moon gets up to play and give out light”; “At night-time the Earth is sleeping”; Moon “goes home in daytime”; Sun “goes home at night-time”</p>	
<p>1 Simple observations; e.g., “The Sun comes out in daytime”; “In daytime it’s sunny”; “At night-time it’s dark and/or cold”; “The Moon comes out at night-time”; “The Sun goes behind the clouds (hills, mountains) at night-time”; “The Moon goes behind the clouds (hills, mountains) at daytime”; “The Sun goes to the bottom of the Earth at night-time”; “The Moon goes to the bottom of the Earth in daytime”</p>	

Appendix E

Questions for Parents on Sources of Children's Ideas about the Earth, Sun and Moon

As many of you will know, I have been studying children's ideas about the Earth, Sun and Moon for many years. One of the points raised by this work is where children learn their ideas about the world and I would be grateful for your help in answering this question.

Young children often refer to the Sun going to sleep at night-time, and the Moon going to sleep in the daytime. Sometimes, they refer to the Sun and Moon going home to bed, or going home behind the hills or mountains at these times. In other words, they give the Sun and Moon human characteristics as if they were alive. When asked where they learned about the Earth, Sun and Moon, younger children mention parents, teachers and books as their main sources of information. Older children refer to teachers, TV, videos, DVDs, movies and the internet.

I would be grateful for the details of any stories that you have told children about such ideas and any books (including nursery rhymes, fairy tales, myths and legends) which may have influenced children's thoughts. Similarly, I would appreciate details of any TV programmes, videos or DVDs that your child or other children have viewed.

Note. A similar questionnaire was given to teachers.

Questions for Librarians on Sources of Children's Ideas about the Earth, Sun and Moon

I am researching children's everyday concepts of the Earth, Sun and Moon. Last year, you assisted me through the School Library Service in Palmerston North with titles of children's books on the shape and size of the Earth, Sun and Moon which my colleague and I wrote up for a paper in press. This year, I would appreciate help with titles of children's literature pertaining to nursery rhymes, folklore, fairy tales, myths and legends that may have influenced children's ideas about the motion of the Earth, Sun and Moon particularly their everyday notions of daytime and night-time. For example, young children often refer to the sun going to sleep at night-time and the Moon going to sleep in daytime. Sometimes, they refer to the Sun and Moon going home to bed, or going home behind the hills or mountains at these times. In other words, they give the Sun and Moon human characteristics as if they were alive. Any books that contain such elements that might be read to children as bedtime stories, or used as home reading, or used by kindy or primary teachers would be helpful. Three books that children frequently refer to are 'Maui and the Sun', 'The cow jumped over the Moon' and 'The Sun has got his hat on'. DVDs and other media portraying the motion of the Earth, Sun and Moon in general and anthropomorphism in these in particular would also be helpful.

Note. A similar questionnaire was given to selected librarians in China,

Stories that you have told children:

Books:

TV, videos, DVDs:

Other media (e.g., comics, magazines):

Follow-up questions for Parents of Shandong ancestry

Q 1: Can you recall seeing mountains or hills in the past and if so where?

Q2: Can you recall any stories of mountains in your folklore?

Q3: Did you ever tell your children stories about the Sun or Moon going to rest or sleep behind the mountains?

Appendix F

Summary of Responses to Questionnaires for Parents, Teachers and Librarians on Children's Sources of Everyday and Scientific Knowledge of Astronomy

Note. These represent a selection of sources: a complete list is available from the authors. Notes on contents are given in round brackets (thus) with quotations in speech marks ('thus').

Notes on scientific accuracy of text are in square brackets [thus].

Notes of a general explanatory nature (such as historical notes on literature) are unbracketed.

Some New Zealand children's folklore stories and texts conveying animism explicitly
(NZ European) Myths and Legends:

- *Rise & Shine* by David Legge (1997): ('Chaos breaks out when the sun fails to rise from his bed one morning.' Sun in bed 'on the far side of the furthest hill': Moon also sleeps in bed.)
- *What the Sun sees; what the Moon sees* by Nancy Tafuri (1997).

(NZ Māori) Myths and Legends:

- *Maui and the Sun* by Gavin Bishop (1996): (Talks of pit where Sun slept; Sun animate in words and drawings; Sun tied to Moon which is also depicted as animate).
- NZ Teacher: '...but then used this (*Maui and the Sun*) to talk about what really happened.'

Some New Zealand texts for children with accounts of the nature and motion of the Sun and Moon including daytime and night-time, scientifically and/or in folklore

- *Sun, Moon and Stars* by Mary Hoffmann and Jane Ray (1998): (Stories from many cultures: several with animate Sun and Moon).

[Note. Includes factual material: some misleading: see below.]

- *Day and night* by Maria Gordon (1995).
- *Day and night* by Anita Ganeri (2004).
- *I wonder why the Sun rises* by Brenda Walpole (1996).

[Note. Sun and Moon animate in illustrations but text scientific: explains daytime and night-time due to Earth's rotation; seasons due to revolution of Earth around Sun but uses "spin" for both motions.]

- *The night sky* by Robin Nelson (2011). (Phases and orbit of Moon around Earth).

Māori Myths and Legends:

- *Taming the Sun: Four Māori myths* by Gavin Bishop (2004).
- *In the beginning* by Peter Gossage (2001).
- NZ Māori Teacher: I use the resource (*Taming the Sun*) to introduce a Māori perspective and then lead into a more scientific approach.

- *The Moon book*: G. Gibbons (1997): (NZ Parent: child's 3rd birthday): (Motion & phases).
- *The Moon seems to change* by Franklyn Branley (1987): (Motion & phases).

Children's texts conveying some wrong science or offering mixed messages

- *Earth and the Solar System* by Darlene Lauw (2003).

'Earth revolves around the Sun once every 24 hours.' (p. 12).

- *On Earth* written and illustrated by G. Brian Karas (2005).

'On earth we go for a giant ride in space, spinning like a merry-go-round.'(p. 1).

[Note. The motion of a merry-go-round is an example of revolution (with the axis of revolution at the centre as with the Sun and solar system) rather than rotation].

- *Sun, Moon and Stars* by Mary Hoffman and Jane Ray (1998).

'We know that the sun stays in the same place while the earth revolves around it, yet we still use words like *sunrise* and *sunset*.'(Introduction).

"Until 1510, when the Polish astronomer Copernicus first worked out that the Earth went round the sun, people thought that the Earth was the center of the universe and that the sun travelled around it. Still, this new knowledge didn't stop them from orienting their journeys by the sun's rising in the east and setting in the west. The word orient comes from the Latin *sol oriens*, 'the sun rising.'" (p. 13).

[Note. Revolution of Earth around Sun being associated with sunrise and sunset]

- *I wonder why the Sun rises* by Brenda Walpole (1996).

'The Earth doesn't really rise at all! It's the Earth which turns round to give you a sunrise each morning. The Earth is like a spinning ball. Wherever you are, it starts to get light as your part of the Earth spins round to face the Sun' (p. 4).

'We have seasons because of the way the Earth spins round, or orbits, the Sun...the Earth spins round as it orbits the Sun. It doesn't spin upright, though, but tilts to one side' (p. 8).

[Note. "spin" being used to describe both rotation and revolution synonymously.]

[See last paragraph of text above regarding rotation and revolution.]

New Zealand children's TV, videos, DVDs

- *Our Earth in motion: understanding time, tides and seasons* by M. Boland (2006) (video).
- *National Geographic, Nature, Knowledge and Discovery* channels (BBC & Sky TV).
- NZ Teacher: 'TV in general: many programmes have a small component of Earth, Sun and Moon (content) and this can trigger the children to explore these things further.'

- *The Magic School Bus (Lost in the Solar System)* by Joanna Cole (DVD/video) (2010).

Other media with accounts of the nature and motion of the Sun and Moon (NZ)

- NZ Teacher: *Internet* to source answers to questions and pictures; e.g. space travel, rockets, astronauts, etc. *Science for Kids*, *NASA Website*, *Space.com*, *weatherwhizzkids*.
- *YouTube*: (a) BBC 2: *Stargazing LIVE*; (b) *Baby Einstein*; (c) What causes day and night?
- TePapa Museum and Carter Observatory in Wellington; Mt. John Observatory, Canterbury.
- NZ Parent: ‘Using a globe (for the Earth) and overhead projector for the Sun—learning about day and night. Using children as Sun, Moon, Earth turning round each other.’

General sources with no specific literature reference (NZ)

- NZ Parent: ‘We talk about science with our children frequently. How the Earth moves around the Sun. How the Moon moves around the Earth.’
- NZ Parent: ‘One set of grandparents live in the UK so we often talk about when it’s daytime in NZ it’s night-time for Nana & Grandad and vice versa.’

Some Chinese children’s folklore stories and texts conveying animism explicitly

- *The story of Chang’e, Yutu and Wu Gang who live on the Moon* (oral folklore: printed versions available from Committee of Storytellers (2011).
- *The story of Houyi and the Sun* (oral folklore series; Yunnan Education Press, 2011).

Note. Houyi or Yi was a mythical archer who saved the Earth from destruction by fire. According to legend there were originally ten suns in the sky and the Earth was being scorched. The people sent for Houyi, the best archer in the land, and asked him to help. Houyi shot down the suns one by one until only one remained and the Earth was saved.

- *Hand in hand with the Moon* by Liu Feng (Ed.) (2009).
- *Chinese mythology*: Long Bode and Zhang Yingyin (Eds.) (2009). Jiang Juvenile Press House.
- *Qiao Hu series*: Children’s Challenge Team (2010): (Sun as grandpa wearing sunglasses).
- *Strange stories of Liaozhai (Liaozhai Zhiyi): a collection of nearly 500 mostly supernatural tales written by Pu Songling in Classical Chinese during the Qing Dynasty*.

Note. The stories differ broadly in length, the shortest being less than a page long. Many are classified as *Chuangqi*, or *Zhiguai*, sometimes translated as “marvel tales”, i.e., stories written in classical Chinese starting in the Tang dynasty. Pu borrowed from a tradition of oral storytelling where the boundary between reality and the odd or fantastic is blurred.

- *The story of Kuafu and The story of Pangu*: Institute of Curriculum Materials (2009).

(Note. Kuafu (the grandson of Houtu) chased the Sun. Pangu (or Panku) ‘is the creator of the world, the first divine human who was miraculously born within the cosmos egg. It is he who

separates heaven and earth, and when he dies, his body transforms into the universe' (Yang and An, 2005, p. 176.)

Some Chinese texts for children with accounts of the nature and motion of the Sun and Moon including daytime and night-time, scientifically and/or in folklore

- *Mysterious universe* by Yaoli and Ji Nan (Trans.) (2009). Jinan, Shandong: Tomorrow Press.
- *Space mystery* (Kingfisher) by Chang Sha (Trans.) (2013). Changsha: Hunan Juvenile Press.
- *Popular science of the Sun, the Moon, and the Earth* by Guo Yubin (2004).
- *A thousand whys*: Han Qide (Ed.). (2014). Beijing: Juvenile and Children's Publishing House.
- *100,000 whys*: Lin Qing (Ed.). (2011). (Teacher: the knowledge introduced in this book is scientific and reliable; and most importantly, is easy to understand).
- *Children's Encyclopedia*. Beijing: The Committee of Children's Encyclopedia: Encyclopedia of China Publishing House (2010).
- *A Different Carmella* by Christian Jolibois (2006); Zheng Diwei (Trans.) (sunrise and sunset).
- *The magic school bus lost in the solar system*: Cole, J. (1990); Qi Yangping (Trans.) (2011): Gui Zhou Publishing (explains daytime and night-time due to rotation of the Earth).
- *The Earth, Moon and solar system*: Guo Yubin (Ed.) (2004).
- *Sun, Earth and Moon* by Robin Heath: Z. Shu (Trans.) (2004).

Note. According to Yang and An (2005), the two main sources of Chinese mythology are the *Classic of mountains and seas* (original *Shanhaijing* written anonymously probably by many authors during the Warring States and Western Han era 4c–2c BC); and *In search of the supernatural* (original *Soushenji* written by Gan Bao in the Jin Dynasty ca. 4c AD). Folklore is particularly important because of periods in Chinese history when (as in the West) earlier texts were destroyed by those in power. The first initiated by Qinshihuang in 213 BC and completed by his successor Xiang Yu in 209 BC.

Chinese Children's TV, videos, DVDs:

- *The rotation, revolution and the origin of the Earth* (DVD).
- *National Geographic* and *Discovery* channels (CCTV: DVD: flash-drive).
- *Planet Earth* (BBC-CCTV); *Wonders of the Earth* (CCTV); *Exploration of the Earth* (Yunnan TV).
- *Exploration and Discovery* (a popular programme about astronomy by CCTV).
- *Science & Exploration*; *Exploration & Discovery*; *Towards Science*; *Legends of Nature* (CCTV).
- *Human Planet* (1–6) (BBC TV); *Cultural Geography* (Yun Nan TV); *Nature* (Beijing TV).
- *General science*: CCTV Seven.
- *Lecture Room*: a series by CCTV 10 which aims to build a bridge between experts and ordinary people and popularise Chinese traditional culture.

Note. It is interesting to **note** the growing influence of western texts, TV programmes and other media on Chinese children's sources of information about the world; e.g. *A different Carmella* by French author Christian Jolibois; *The magic school bus* by Joanna Cole (USA); and *Discovery* and *National Geographic* Channels (BBC and CCTV).

Other media with accounts of the nature and motion of the Sun and Moon (China)

- *Science Magazine*: started in 1915: Shanghai Science and Technology Press House; 51 South Road, Qinzhou, CN31-1385/N.
- *The relative movement of the Sun, Moon and the Earth* (Internet cartoon).
- Parent: 'We visited Beijing planetarium and watched films about astronomy.'
- Parent: 'We visited Beijing astronomical observatory and enjoyed *Cinerama* there.'
- Teacher: 'I showed the Qiantang tide live on TV: The soaring tide of the Qiantang River is such a marvellous spectacle in China, the principle of which is as follows: the moon and earth attract each other...the moon is like a big magnet which attracts the sea on the earth...Meanwhile, because of centrifugal force by the rotation of the earth, the side of it facing the moon is more seriously affected than the side against it. The water on two sides rise in different directions and thus the middle part is down. So the sea shapes like an oval...with the rotation of the earth, the sea level keeps changing, (and) tides are formed.'

Note. An example of 'direct experience with phenomena' (Nussbaum and Novak 1976, p. 549) which enhances children's concepts of Earth and Moon motion and encourages disembedded modes of thought. Although not as "direct" as the real thing, live TV is a safer practical option in this case.

General sources with no specific literature reference (China)

- Teacher: (1) 'About the origins of the earth's shape: the pictures of the earth by satellite from the ancient to the time when Magellan circumnavigated the earth; (2) about the movement of the earth: the features and phenomenon of its revolution and rotation.'
- Parent: 'Some applications on cell phones.'

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- Note. Of these, Yang and An was particularly helpful because it uses the modern *pinyin* system of pronunciation as used by the researcher's assistants and interpreters.

Appendix G

Books, Television and Films as Sources of Astronomy Knowledge

Books as sources of astronomical knowledge are not new. According to Halkia and Botouropoulou 2005, one of the most successful being *L'Astronomie Populaire* [Popular Astronomy] by Camille Flammarion (2014) published in 1881 and translated into English in 1894. The contents included chapters on The Earth, The Moon, The Sun, The Planetary Worlds, Comets and Shooting Stars, The Stars and the Sidereal Universe. A century later, similar topics are covered (with children in mind) by Martin Redfern (1998): *The Kingfisher young person's book of space* and Redfern (1999): *The Kingfisher young person's book of planet Earth*. For older readers there are a multitude of books on astronomy (see *Top 20 best selling astronomy books: Cambridge* 2016). Senior physics students can find modern versions of Flammarion's topics in *Abell's exploration of the universe* by Morrison et al. (1995).

TV documentaries, the Internet and indeed feature films have largely taken over the traditional role of books in popularizing astronomy. This trend is not restricted to older children. The researcher observed kindergarten children watching videos showing the shape and motion of the Earth (see Appendix E). A generation ago, significant popularisers on television were Carl Sagan (1934–1996) in the USA and Patrick Moore (1923–2012) in the UK. The former's role has largely been assumed by Neil de Grasse Tyson, and the latter's by Brian Cox, both of whom provide frequent commentary on topics of a physical/astronomical nature, both on serious programmes and in light entertainment. The news itself brings scientific items to the public's attention, notably in 2015 the stunning photographs of the dwarf planet Pluto taken from the *New Horizons* spacecraft; and in 2016, the remarkable achievement of placing the *Juno* spacecraft in orbit around Jupiter. The *Discovery Channel* handles very many topics and issues of a scientific (and now other) nature including astronomy. Internationally, it is said to reach some 430+ million homes in 170 countries. Recent programmes of relevance here include *Cosmos: A Spacetime Odyssey*: National Geographic Channel (MacFarlane et al. 2014), presented by Neil de Grasse Tyson; *Wonders of the universe*: BBC Discovery Channel (Renouf 2011), presented by Brian Cox; and programs on astronomy and cosmology by Stephen Hawking as a sequel to his bestseller *A brief history of time* (Hawking 1988); e.g. *Into the universe*: BBC Discovery Channel (Bowie 2010). Recent feature films involving astronomy and exploiting computer generated imagery (CGI) attract large audiences, many deservedly so from a scientific perspective, notable examples being *Gravity* (Cuarón et al. 2013), *Interstellar* (Thomas et al. 2014) and *The Martian* (Kinberg et al. 2015). All of these sources, by their very nature, offer reasonably accurate information which children may access (with parental and teacher guidance) and which might help to resolve gaps and misconceptions in their knowledge.

Appendix H

Summary of Responses to Follow-up Questions for Parents of Shandong Ancestry

Q1. *Can you recall seeing mountains or hills in the past and if so where?*

LYH: *There is hilly ground around Shandong Peninsula. My home town of Wulian in Rizhou city has a lot of mountains.*

SYH: *Tai mountain.*

SXC: *I have seen mountains in the south of Jinan, and also the Meng mountains in Weifang.*

YJ: *When he was seven years old my son and I climbed Tai Mountain. The mountain is quite high but we climbed to the top. It was very beautiful and we took many pictures. Although we were tired we had fun.*

SF: *Mount Jiuhua, being one of the four sacred mountains of Chinese Buddhism in Anhui.*

ZZ: *Lao Shan mountain.*

LJ: *Taishan and Yishan mountains.*

ZY: *Yes, Waitai and Luofu mountains.*

ZXZ: *Thousand Buddha Mount, Hua Mount, Tai Mountain, Sili Mount.*

LY: *Lao Shan, a famous mountain in Shandong province.*

YJZ: *Yang Tian Shan (Qing State of Shandong), Lao Shan (Qingdao city of Shandong), Luo Shan (Zhao Yuan city of Shandong), and Meng Shan (Linyi city of Shandong).*

ZJ: *Tai Shan Mountain.*

TY: *Recalling the first time I saw Tai mountain, the most dazzling moment was when I reached the top and had the feeling of being the apotheosis of life.*

ZX: *Jiazi Mountain in my hometown.*

LX: *I visited Mount Tai and Huang Shan.*

Q2: *Can you recall any stories of mountains in your folklore?*

LYH: *Every year, about the middle of July, there is a sacrifice ceremony for the God of the Mountain. Every family should attend to pray for good fortune. There are many legends, such as The God of the Mountain; and The Eight Immortals. People in my hometown have a traditional collection of those legends Most of them describe how the good man gets help from the God, and the bad man will be punished.*

SYH: *The foolish old man who moved the mountains (and I played it to my baby).*

YJ, ZXZ, SF, ZZ, ZY, SXC: *Yes, ... such as "The foolish old man who removed the mountain."*

Note. *The foolish old man who moved mountains* is a folktale about an old man (Yu Gong) who moved two mountains with the help of his family and two deities of the Jade Emperor.

SF, LX: *The story of Mount Buzhuo.*

ZZ, ZJ, LX: *The story of The bird Jingwei trying to fill the sea.*

LJ: *The story of Liao Zhai.*

ZY: *The story of three mountains.*

ZJ: *The story of Grandma Tai Shan Mountain who is said to live on the mountain.*

Traditionally she is known as Huang Feihu (a fertility goddess). Similarly in Daoism she is known as Bi Xia Yuan Jun who blesses couples to have children when they pray to her.

Note. SF: Mount Buzhuo: In Chinese mythology, Gong Gong (sometimes translated as Minister of Works) was ashamed that he lost a fight with Zhu Rong (God of Fire) to claim the throne of heaven. In a fit of rage, he smashed his head against Buzhou Mountain (a pillar holding up the sky) greatly damaging it and causing the sky to tilt towards the northwest and the earth to shift to the southeast, which caused great floods and suffering.

Note. ZZ: *Jingwei* was a mythical bird, the reincarnation of Nüwa (daughter of Emperor Yan). Nüwa was drowned at sea when her boat sank and in her reincarnation as *Jingwei*, she filled in the sea with pebbles and twigs so that it could not claim anymore lives.

ZX: *Jiazi Mountain is not high but there are many strange stories about it. There is a cave named Sun Bin hole at the top where a legendary figure lived in ancient times.*

Q3: *Did you ever tell your children stories about the Sun or Moon going to rest or sleep behind the mountains?*

SF, ZZ, ZJ: *Yes, I did.* LJ: *Yes, I told her the sun goes to sleep behind the hill but I also told her how they move in reality.* ZY: *Yes, we often tell our children the Sun or the Moon go to sleep behind the mountain.* LY: *My daughter is too young at present but I will tell her when she grows up.* TY: *Yes, for example, “the Sun and the Moon are from one family. When the Sun comes to work, the Moon stays home to do housework. Day by day it goes like that.” Then (my daughter) would have a sweet dream.* ZX: (Yes: the story of Kua Fu, a mythological giant): *One year, the weather was very hot, so Kua Fu decided to catch the Sun.*

The Sun would go to sleep behind the mountains in the night. Kua Fu ran fast, chasing the Sun. He felt very thirsty when he got close to the Sun, so he came to the Yellow River and the Wei River to drink water. However, the two rivers were not enough for him. So he wanted to go to Daze to drink more water but he died half way.

Note.

Daze is an ancient name for a large lake and river at Hunlun in Inner Mongolia.

LYH: *Yes I did. And many people that I know did also. We learned about Grandpa Sun, and Grandma Moon (or Moon Nana) from our grandparents.* SYH: *Yes; when the Sun goes up the mountain (at Sunrise) it means the Sun goes to work. When the Sun goes down the mountain (at Sunset) it gets off work.* SXC: *I told my daughter: “The Sun comes out when it is daytime, and goes back to sleep when it is night-time. The Sun won’t come out until the next day.”*

Note. The terms *Grandpa Sun* and *Grandma Moon* are steeped in Chinese culture and tradition. They are in effect the root metaphor of Shandong folklore on the nature and motion of the Sun and Moon. ‘Grandpa Sun, Grandma Moon is neither a story nor a nursery rhyme: it is about Chinese traditional thinking. Our ancestors believed that the world is made up of two materials, Yin and Yang. For example, man stands for Yang, and woman stands for Yin.

Day stands for Yang, and night stands for Yin. Warm stands for Yang, cold stands for Yin.

The Sun is strong and powerful, so we consider it as a man. The Moon is gentle and peaceful, which are like the qualities of woman. So we call the Sun grandpa Sun, the Moon grandma Moon.’ The Sun and Moon are personified as grandparents because of their age which is associated with reverence far more in China than in the west. ‘I think it is because the

Sun and Moon are really old. They are much older than what they can remember of their ancestors who told the stories. Thus when grandparents tell these children these stories and use the terms Grandpa Sun and Grandma Moon out of reverence and cultural tradition there is a sense of longevity and a connection with the distant past.'

Note. Shandong literally translated means 'mountain' and 'east' and probably refers to east of the Taihang mountains. Jinan is the capital; and Weifang is a city in Shandong. Meng mountain or Meng Shan is said to be the cradle of Chinese civilization. Taishan (peaceful mountain), the most revered mountain in China, is also located in Shandong. Thus the concept of mountains is deeply embedded in the language and culture of the people of Shandong. The province is famous as the birthplace of Confucius and has a rich cultural history influenced by Buddhism, Confucianism, and Taoism.

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