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Journal:	*International Journal of Science Education*
Manuscript ID:	TSED-2006-0324.R1
Manuscript Type:	Research Paper
Keywords:	developmental research, gender-related, earth science education, survey, science education
Keywords (user):	children's cosmologies, in-depth interviews, diverse ethnicities

Abstract

This paper attempts to clarify several lines of research on gender in development and education, inter-relating findings from studies on intuitive/informal knowledge with those from research on achievements and attitudes in science. It acknowledges the declining proportions of male teachers world-wide and examination successes which indicate a reversal of educational disadvantage from female to male; as well as the recent evidence on the effects of the gender of teachers upon student success. An empirical contribution to the literature is offered, drawing from the gender-related findings from research on children's cosmologies in China and New Zealand with 346 boys and 340 girls (of whom 119 boys and 121 girls participated in the current study). The investigation focused on children's concepts of the motion and shape of the Earth through observational astronomy and gave children opportunities to express their ideas in several modalities. The in-depth interviews allowed children to share their meanings and gender differences became apparent (e.g. girls' superior ability to visually represent their cosmologies and boys' greater awareness of gravity). However, these differences were not universal across genders or cultures and marked similarities were apparent both in the content of children's responses and in their reasoning processes. By comparing boy/girl cosmological concept categories and by tracking their developmental trends by age, statistical evidence revealed the extent of the similarities within and across these diverse cultures. The findings reinforce those from the authors' knowledge restructuring and cultural mediation studies and provide support for the view that boys and girls have similar, holistic-rather-than-fragmented, cosmologies which have features in common across cultures and ethnic groups.

Gender controversies continue

Gender[1] continues to be an important issue for researchers and teachers alike. It can easily be contentious as evidenced by the storm of controversy which followed the pronouncements of Lawrence Summers when, in January 2005 (then as President of Harvard University), he voiced the view ‘that men outperform women in maths and sciences because of biological difference, and discrimination is no longer a career barrier for female academics’ (Goldenberg, 2005). Amongst the reactions was a ten-page feature article in *Time* magazine (7.3.05) written by Amanda Ripley (‘Who says a woman can’t be Einstein?’) taking Summers to task for his ‘provocative statements’. Some of the research relating to Ripley’s observations is considered later in this paper, but at the outset we can say that such contentious debate underlines our need to know whether boys’ and girls’ scientific ideas (whether learned as everyday knowledge or through formal schooling), and their dispositions to pursue science, differ markedly, if at all. Despite limited and conflicting evidence from the literature, our own experience as teachers and researchers had certainly led us to identify gender as a potential factor in concept acquisition, an empirical study of which we report as part of this article. It is important, however, to recognise that several different lines of research are intertwined in the arguments about gender as it relates to development and education. This paper endeavours to clarify the links between them, thereby contextualising the empirical contribution we offer.

[1] Throughout this paper, we have used the term 'gender' in the now accepted manner. As Caplan, Crawford, Hyde and Richardson (1997) note, the expression 'gender differences' is preferred to 'sex differences' in acknowledgement that 'gender' marks a sociological distinction between men and women. In most psychological research 'gender differences' is the appropriate term …because participants are usually categorized in terms of their outward appearance and behaviour, not on the basis of biological characteristics" (p. 7).

Firstly, we consider what has been recently revealed in the research literature about the differences between the developing brains of boys and girls from brain scanning technology, for the emerging patterns help (a) to make sense of the accumulated and somewhat contradictory experimental evidence on children's mental capabilities; (b) to scotch simplistic assertions about biological deficits; while (c) suggesting that differences in scientific understandings between male and female children might indeed be anticipated.

Secondly therefore, we examine whether any gender differences are apparent in the development of children's understanding of commonly encountered phenomena in their pre-school and school years (in what children acquire by way of general knowledge). That learning has the potential to relate to the scientific ideas they are taught in schools, either directly (in which case there might be conflicts with ideas prevailing in their local ethnic groups and communities), or indirectly through the influences of role models and expectations that are sometimes held differently for boys and girls. This paper presents evidence, using data from the field of children's cosmologies, that gender does *not* play an important part in such basic thinking. Boys' and girls' development and intuitive understandings are similar. This is important since:

Thirdly, significantly changed patterns of achievement in formal school learning have nevertheless taken place among boys and girls over recent decades, and these tell us about world-wide cultural change and improved professional expectations (and, arguably, account for what teachers have been able to do through more equitable instruction). We review the extent to which girls have overtaken boys in regard to science achievements and the gender differences apparent in interests and attitudes to science in school.

Fourthly, however, we take into account the very recent research into how the gender of teachers relates to pupil achievement, arguing its significance in relation to the growing gender imbalance amongst the numbers of schoolteachers (world-wide). There is now strong quantitative data to show that teacher gender does influence school students' learning and therefore we should be concerned about the diminishing numbers of male teachers.

Gender research: developing brains

The wide range of research raised by Ripley (2005) includes:

(a) neurological studies where, with advancing technologies, brain differences between men and women are known to be *greater* than previously understood, some of them affecting behaviour in unexpected ways. Women's brains are now known to be better interlinked with more parts involved in specific tasks, men's thinking taking place in more focused areas. Brain-imaging techniques by Giedd, Blumenthal, Jeffries, Rajapakse, Vaituzis, Liu, Berry, Tobin, Nelson and Castellanos (1999) reveal that different anatomical regions of the brain mature differentially in childhood, and typically by several years, e.g. favouring earlier development in girls for those areas which handle verbal fluency, handwriting and face recognition; favouring earlier development in boys for those which handle spatial and mechanical reasoning and visual targeting. This can be compared with pre-brain imagery research by, for example, Bradshaw & Nettleton, 1983, and the conflicting findings between Annett, 1985; Casey, 1995; Siegel, 2000; detecting male superiorities on the one hand with Ueker & Obrzut, 1993; Walter, Roberts & Brownlow, 2000; Anokhin, Lutzenberger, Nikolaev, & Birbaumer, 2000; finding to the contrary.

(b) *neuro-physiological developmental research* where we now know that 'the brain is *constantly changing* in response to hormones, encouragement, practice, diet and drugs' (Amanda Ripley, 2005, p.52) and that the interaction between nature and nurture *continues* from conception (cf. Matt Ridley's 'Nature *via* Nurture', 2004).

(c) *developmental/educational research* which explores how young people are taught, and by whom, and just *how much* change has become detectable in gender-related achievements (considered in detail below).

(d) *sociological research* on scientific career patterns where leading researchers stress that ‘biological factors would not play a role unless they *interacted* with social conditions’ (see Xie & Shauman, 2003).

Two further areas of research can also be highlighted:

(i) The relationship between motor development, language ability, and cognitive development has been found to be mediated by gender (see Kershner & Chyczij, 1992). This is critical to the multi-modal methodology used in the research reported later;

(ii) The reports of manifestly higher rates of mental and learning disabilities in males (see De Courten-Myers, 1999) should not be ignored; they underline how intertwined the nature/nurture influences can be. And there is evidence that much research remains unpublished because it reports *gender similarity* as opposed to *gender difference* in a literary climate which is sensitised to the latter. Hence "…there is no research literature of gender similarities, only a research literature of gender differences" (Richardson, 1991, p. 273).

Taken together, all of these branches of investigation suggest that there are strong grounds for anticipating gender-related patterns in children engaged in tasks designed to show their grasp of basic scientific concepts; concepts which they acquire (in a variety of complex ways) from their families and teachers. If the brains of maturing boys and girls are so detectably different, and children's later, educational achievements have changed - more accurately, have been changed - relative to each other so much (as indicated below) we might expect conceptual differences between genders to be revealed. In the long run, insights might be provided into the factors influencing any gender mediation, to the benefit of boys and girls in all cultures alike. Commentary is first required however about the wider context of various socio-cultural factors and how these relate to student outcomes and teaching input.

The gender of teachers

Firstly, with regard to the numbers of teachers in both New Zealand and China, concern has been raised as the proportion of male teachers has declined dramatically, particularly in primary schools. Recent statistics for the gender of primary teachers, *internationally*, are fairly striking. In 2003 only about 7% of primary teachers in Scotland were male (see Scottish Executive, 2005). Similarly, in the USA, in 1995-96, only 16% of primary teachers were male (see National Education Association, 1997); and by 1999 that had declined to only 13% (see Livingstone, 2004). The situation in China is similar and longstanding. According to Zhao Wei, Director of the Students' Affairs Division at Shenyang Normal University (where teachers receive their professional preparation): "We have more female students than male ones. That's the way it's always been; a ratio of about 7:3": and some provinces have even lower percentages of male teachers (see Zhang, 2005). While in New Zealand men make up only 18% of primary teachers (see New Zealand Ministry of Education, 2003). OECD figures show an international trend of declining male primary school teachers confirming the alarming statistics from other sources which depict a trend which shows no sign of abating. According to Livingstone (2004) "…the average across 23 OECD countries for which data were available was 23 percent" (p. 2). Before we consider teacher gender effects, it is important to comment upon student success rates.

Gender patterns in achievement

Turning first to comparative studies of school student achievement, gender differences in scientific literacy were compared in the international surveys recently carried out by the OECD

(Programme for International Student Assessment [PISA] 2003). According to the Executive Summary, there were no systematic differences between the performances of males and females among the 29 OECD countries involved in PISA. "In the minority of countries where gender differences exist, they are small" (OECD, 2003). A closer examination indicates that there were more countries with scores for males higher than for females, but that in only 11 of these countries were these differences statistically significant. In two of the three countries where females scored higher than males, the differences were also statistically significant (see OECD, 2003). However, evidence from statistical analyses of science results by gender in national, school leaving examinations in the UK, indicates that girls are surpassing boys in all areas (see for example Kelly, 1987; and Riddell, 2003). Referring to the national Higher examinations taken by 17 and 18-year-old pupils in Scotland, Riddell (2003) has recently concluded that: "From a position of performing worse than boys at Higher grade in the mid-1970s, girls of all social classes are now performing better than boys of similar social class in all subject areas, although gender differentiation in the curriculum remains stubbornly in place. In the late 1970s, however, this was not what was predicted" (p. 895). Indicative figures on pass rates generally are that 55% of males compared with 61% of females completed the final two years of secondary school with three or more Higher grade passes at A-C in 1999. Data from that year showed that female candidates performed better than males in every subject, apart from Physical Education, Economics and General Science (the latter a minority subject taken by least able pupils).

Interpretative analyses for these changes have focused upon changes in society, changes in teaching, and structural changes in schooling itself. The Centre for Educational Sociology at Edinburgh University has maintained that the comprehensive re-organisation of schooling during the 1960s and 1970s was associated with a general improvement in standards of attainment, with girls and pupils of low socio-economic status being the main beneficiaries (see Croxford, Tinklin, Ducklin & Frame, 2001; Furlong & Cartmel, 1997; Powney, 1997). Early indications confirm the continuing trend for girls to outperform boys at several levels in the sciences following the implementation, post 2000, of new National Qualifications (which incorporate the Highers as part of a multi-level system of certificates). The extent of the reversal has reached a point where schools in the UK and elsewhere now actively strive to find ways to help boys to study more effectively. In New Zealand, 'Approximately equal proportions of males and females score the top grades in School Certificate science, while in Sixth Form Certificate females outperform males in all science subjects. In Bursary biology and physics, females have a slight edge, while in chemistry males have traditionally outperformed females' (Pratt, 1999, p.2). Pratt also argues, however, that culture is a major factor on gender mediation (particularly evident in exploring the differences *within* 'boys' or 'girls' when ethnicity - NZ European, Maori, Pacific Islanders - is considered). This concern for boys from ethnic minorities is echoed in a recent review of student outcomes (see New Zealand Ministry of Education, 2006); and New Zealand school leaving statistics which show that in 2005 more than half of Maori boys left school with no qualifications (see Bishop, 2007). There is other evidence in China and New Zealand that, given equality of opportunity, girls frequently excelled boys in all subject areas including the traditional domains of male "superiority" such as maths and physics. For example, in New Zealand, there was equal participation by boys and girls (by merit in mathematics and physics) in the Winter Schools of Astronomy at University of Canterbury. Similar trends have been evident in other countries; for example, Hacker (1986), in Australia, found "no evidence to support the claim that girls are disadvantaged in the science classroom" (p. 69).

This background of gender mediation by social change of such an order that, in a period of little more than 50 years, traditional gender roles and manifest (as opposed to latent) performances can be reversed, invites the question of why this has been possible, what factors are responsible, and could knowledge of these be used to bring about true gender equality, including extra resources for teaching boys - or, bearing Pratt's (1999) observations in mind, *which* boys are not reaching their potential?

If the altered pattern of achievement can be put down to changes in teachers and teaching, we must also consider a further complication however. Recently published research by Dee (2006; forthcoming) presents new evidence which indicates that having a same-gender teacher influences educational outcomes. His research focused on a nationally representative, cross-sectional sample of 13-14 year old school students in Grade 8 of the USA (corresponding to year 9, Key stage 3 in England and S2/S3 in Scotland) numbering some 25,000. A key feature of that National Education Longitudinal Study, base year 1988, was that for each student it also surveyed *two* of their subject teachers (their background and how they viewed the performance of the student; how the student viewed the subject). Thus Dee was able to statistically relate student achievement to the gender of their assigned teachers in a large sample of teenagers close to the age when the gender gaps in achievement seem to grow most rapidly. The results indicate that the gender interactions had statistically significant effects on a number of educational outcomes, including achievements, and were quite large. In science, social studies and English, the overall effect of having a woman teacher instead of a man raised girls' achievements by 4% of a standard deviation and lowered boys' achievements by about the same amount. To quote Dee (forthcoming):

> For example, assignment to an opposite-gender teacher lowers student achievement by at least 0.042 standard deviations. This effect size implies that just one year with a male

> English teacher would eliminate nearly a third of the gender gap in reading performance among 13 year olds and would do so by improving the performance of boys and simultaneously harming that of the girls. Similarly, a year with a female teacher would close the gender gap in science achievement among 13 year olds by half and eliminate entirely the smaller achievement gap in mathematics (p. 26).

[Dee cites the US Department of Education's 1999-2000 Schools and Staffing Survey as indicating that by 8th grade, some 83% of reading teachers are female; more than 50% of maths and science teachers are female.] Importantly, Dee readily concedes that it is not clear whether these gender effects arise from interactions within classrooms or from role-model effects (or both) and does not move to conclude that single-gender classrooms would necessarily change things (for the gender dynamics there may differ from those within co-educational settings).

Baker (2006) has recently reported that although there has been very little research on boys' education in New Zealand there is substantial evidence of a gender gap in achievement scores of about 10% in favour of girls. Besides gender bias in the curriculum he found, "How we teach – pedagogy – is also not gender free. There has been a shift from closed, structured, information-dense learning activities, which boys did better at, to open-ended, experiential, reflective activities…an example of the 'effeminized curriculum' (Baker, 2006; www.boysforward.com).

The situation in England is similar where the Department of Education and Skills (2006) report a trend of boys falling behind girls as they get older leading to a gender gap of nearly 10% in favour of girls at GCSE level. As in New Zealand, gender is only one of several factors contributing to boys failing: demographics such as social class, background, and ethnic origin are all determining factors (see Warden, 2002). However the groups at risk differ between cultures and societies: Pratt (1999) identifies Maori and Pacific Island boys as being vulnerable, whereas Ahmed & Townsend (2003) report that at GCSE level "Poorer white boys are outstripped academically by Indian, Pakistani, Bangaladeshi and Chinese boys". In this case it is socio-economics which are the major obstacle to boys success under 'feminised teaching' (p. 1), a point raised earlier by Tim Hames in *The Times*: "The underlying dilemma in the British education system is now, as it has been for a hundred years, if not more, still social class not gender (*Times*, 18 August, 2000).

Gender in relation to interests and attitudes

Gender effects are also apparent in the interests and attitudes to science displayed by school students. Where gender differentials have been detected amongst secondary school age students, it is apparent that topics which are seen as having relevance to their lifestyles and possible careers are considered to be more attractive, with girls being "much more drawn to those [physics] themes that are perceived to have high social relevance, while boys are attracted to those themes that are perceived to have a high mechanical or practical relevance" (Reid and Skryabina, 2003, p.533). The particular applications in the 'applications-led' physics courses (which have been relatively successful in the Netherlands and in Scotland for 14 – 16 year olds) have *very* different gender appeals, with consequences for the numbers who continue to study the subject and who seek to pursue scientific careers. Bell's research into exam performance shows that the differences in attitudes and prior experience translate into differential exam performances in 'declarative knowledge' (but not 'procedural knowledge'); favouring boys for content associated with mechanics and earth and space; favouring girls for human biology (Bell, 2001; and see also Dresel, Ziegler, Broome & Heller, 1998; Christidou, 2006). These recent findings interestingly echo Gardner's summary some 30 years ago: "Sex is probably the single most important variable related to pupils' attitudes to science… Although social forces are undoubtedly powerful, the possibility remains that there are innate cognitive differences between males and females which might influence attitudes and enrolment patterns" (Gardner, 1975, pp. 22-24). Ten years later the same writer considered that researchers internationally recognised that that gender was an important variable in *quantitative* aspects of science education and attitudes to science (Gardner 1985). The *qualitative* features of interest in science have received attention with gender as a critical variable. For example, in their study of science student types in a study involving 5361 students age 12-16, Häussler, Hoffman, Langeheine, Rost & Sievers (1998) were able to classify physics students into three main types: Type A students - with particular interest in physics and maths - tend to be boys; Type B students - who are interested in practical aspects of physics such as technology - tend to be both boys and girls; and Type C students - who are particularly interested in the application of physics to improving human life such as through medicine - tend to be girls (see Häussler et al., 1998, pp. 234-235).

Gender and conceptual development: current debate on children's cosmologies

Turning now to children's intuitive understandings of common scientific phenomena, we consider the domain of children's cosmologies. This area has long attracted the attention of science educators and developmental psychologists because of the conflicts which children have to overcome as they mentally re-orient from a geocentric to a heliocentric perspective of the Earth-Sun-System. And of course there has been debate over whether or not it is possible or educationally sound to teach young children the scientific interpretation of the world; or whether children essentially have to navigate (what is for them uncharted waters in a new world) alone. For many decades, this debate has ignored inter-cultural and gender differences: "the world" was assumed to be where and with whom "he" grew up. Nevertheless researchers have endeavoured to categorize and developmentally sequence the features of children's cosmologies. In Bryce and Blown (2006) we have recorded the very many attempts to do this, including cross-cultural research, on the basis of what has been revealed of children's holistic cosmologies through Piagetian interviews without any visual prompts (such as model Earth globes), prominent investigations being those by Nussbaum and Novak (1976); Nussbaum (1979); Sneider and Pulos (1983); Vosniadou and Brewer (1992, 1994), and Vosniadou, Skopeliti, & Ikospentaki (2004). These studies have been challenged by several groups of researchers who have found no evidence of children having holistic cosmologies, rather that children's concepts are inconsistent and their cosmological schemata disorganised and fragmented. In Blown and Bryce (2006) we have argued that the reason for these profound differences in interpretation is not to be found in children's responses alone, but rather in the research methodologies of the researchers; in particular interview technique and the use of researcher-selected models as props. This view has recently been supported by work by Agan and Sneider (2004) who also identified differences in interview methods as a critical difference between the traditional Piagetian-Socratic method originally exemplified by the work of Nussbaum and Novak (1976); and the more modern expository teaching approach exemplified by the work of Schoultz, Säljö and Wyndhamn (2001). Contrary to the advice of Nussbaum and Novak, Schoultz et al. introduced children to the scientific concept of the Earth in the form of a globe at the outset and did not detect any alternative models. Similarly, we have argued, the use of a range of researcher-designed models of the Earth as props within the interview schedule is not conducive to children sharing their intuitive, cultural or scientific cosmologies. Nor are interview techniques that are too dependent on a single medium such as verbal language; or on media, such as drawing, which can be misinterpreted without three dimensional modelling by the child using clay (see Brewer, Herdrich & Vosniadou, 1987);

play-dough (see Vosniadou, Skopeliti, & Ikospentaki, 2004); or computer graphics (see Baxter & Preece, 1999). From the perspective of the current studies, it is not surprising that researchers who have used a less open-ended strategy have failed to find evidence of intuitive and synthetic cosmologies (or the holistic cosmological schemata of which they are part) in children of other cultures. For example, Nobes, Moore, Martin, Clifford, Butterworth, Pangiotaki, & Siegal (2003), who investigated European and Gujurati children in London; Siegal, Butterworth & Newcombe (2004), with children in England and Australia; Nakashima (1995) and Takahashi (2000) in Japan; and Jipson (2001) in USA; found no such evidence. Whereas those researchers who followed in the tradition of Nussbaum & Novak (1976) found evidence in favour of Earth Notions or Mental Models in a variety of cultures; e.g., Hayes, Goodhew, Heit, & Gillan (2003), in Australia; Agan and Sneider (2004), in USA; Vosniadou, Skopeliti, & Ikospentaki (2004), in Greece.

Analysis of the literature on children's cosmologies over the past century or more (Table 1 in Bryce and Blown (2006) indicates that of 69 studies, only 36 give details of the gender of their participants; and of these only 21 report approximately equal numbers of boys and girls. It is therefore not surprising that there have been few studies of the influence of gender mediation on concept acquisition or development in this domain. The reasons, where they have been given or ascertained, indicate that to many researchers in this field, gender is simply not an issue. For example, Diakidoy states that "gender was not a relevant variable", in her illuminating study (see Diakidoy, Vosniadou & Hawks, 1997) of the cosmologies of American-Indian children (I.-A. Diakidoy, personal communication, 27 June, 2001). Similarly, Samarapungavan, who studied the cosmologies of Indian children (see Samarapungavan & Vosniadou, 1988; Samarapungavan, Vosniadou & Brewer, 1996) reported that "We have consistently found no gender effects in children's cosmologies" (A. Samarapungavan, personal communication, 27 June, 2001). Where gender has been addressed, the evidence of gender mediation in cosmological conceptual development is conflicting. For example, Oakes (1947, 153 children, unspecified gender, aged 4-13) in the USA, found no evidence of gender mediation in his own studies of children's cosmologies, nor in his extensive review of the literature extant at that time. However, Sadler (1992), in a study of 658 boys and 609 girls, aged 14-18, in USA, over a 4- year period (1988-1992) found that boys had greater understanding of astronomical concepts than girls. Similarly, Schoon (1989), also in USA, found gender differences in his investigation of the astronomy and Earth science concepts of 619 males and 594 females, aged 11-18+, males having fewer misconceptions than females. Sneider and Pulos (1983), compared 159 children, aged 9-14, of unspecified gender, from their own study in USA, with children from Israel (Nussbaum, 1979, 240 children, unspecified gender, aged 10-14; Nussbaum & Sharoni-Dagan, 1981, 114 children, unspecified gender, aged 7-8), USA (Nussbaum & Novak, 1976, 52 children, unspecified gender, aged 8), and Nepal (Mali & Howe, 1979, 133 boys and 123 girls, aged 8-12). Sneider and Pulos found that gender influenced attainment with boys demonstrating deeper cosmological understanding than girls. From another perspective, Sneider, Eason and Friedman (1979) in the USA, report that the cosmologies of children are directly influenced by their personal experience with astronomy, and that these experiences are mediated by gender. For example, fewer girls owned telescopes. Lightman, Miller and Leadbeater (1987), in the USA, also found that males tended to know more about astronomy than females. Za'rour (1976) in Lebanon, in a comparative study of the cosmologies of Christian and Moslem children, aged 4-9, with 55 boys and 55 girls in each group, found that boys had more advanced concepts. More recently Trumper (2001), in Israel, investigated the astronomy concepts of 448 junior high school students, aged 13-15, using a written questionnaire and found that "Boys scored significantly better (38.7%) than girls (34.6%) [t = 3.08, *p-value* = 0.002]" (p. 1116).

The empirical study

This rather complex pattern of findings and reports on the influence of gender on children's ideas and concept acquisition invites clarification by research. While it seems increasingly certain that particular school topics and teaching emphases do have differential effects upon males and females, our review of the literature shows that it is less clear whether ordinary 'common knowledge' is gender related. As part of the longitudinal, cross-cultural research on the astronomical concepts of children from two contrasting cultures, China and New Zealand (NZ), described in Bryce and Blown (2006) and Blown and Bryce (2006), we searched for evidence of mediation by gender and other factors using an interview guide specifically designed to probe all levels of children's conceptual organisation. The studies were conducted over a 13-year-period from 1987 to 2000. There were six surveys in all: the 1st and 2nd NZ Surveys (1987, 1989); two Main Surveys in NZ and China (1993 and 1994); and two Follow-up Surveys with Control Groups in NZ and China (1998 and 2000), the various studies covering all aspects of children's cosmologies. These included the motion and shape of the Earth, Sun and Moon; habitation of Earth and identity with Earth; and concepts of time and gravity. Knowledge of conceptual development in the field of children's cosmologies has been dominated by one methodological strategy, namely, the almost universal adoption of Piagetian clinical interviews. Table 1 in Bryce and Blown (2006) gives a detailed summary of all of the published research to date. Such studies with $N > 100$ are rare (see Sadler, 1992) and cross-cultural, longitudinal studies with survey and control groups with $n > 100$ (as in these studies) are unreported. We chose to continue in the Piagetian research tradition while probing for the richest range of concepts from the youngest accessible children (to investigate initial intuitive concepts); with boys and girls in two dissimilar cultures (to explore gender and cultural mediation); and longitudinally (to illuminate developmental trends and the gradual assimilation of the scientific world view). This required an anthropological-ethnological rationale involving long-term field work by the researcher (2nd author) in the cultures of kindergartens (pre-school or nursery), schools and local communities, for a period of several years. This was necessary because it was recognised from the outset that:

(a) To gain knowledge of the totality of an individual child's cosmology, something that Piaget, despite his great skill, did not do (see Oakes, 1947), would require at least an hour of interview time using a sensitive instrument capable of being tuned interactively to children's responses reflective of intuitive, cultural and scientific conceptual levels.

(b) To do this with large enough samples to counteract longitudinal losses and facilitate robust statistical analysis of ordinal data would entail aiming for $n > 100$ in all eight main groups summing to $N > 800$ overall. In the event, losses were greater than expected, so that although both Main Surveys (1993, 1994) had 127 and 113 children respectively, by the time of the Follow-up Surveys (1998, 2000) the number of accessible children had reduced to 82 and 89 respectively, which determined that the number of children in the Control Groups would also be 82 and 89 respectively. Nevertheless, with the 1st and 2nd Surveys, and a long term Pilot Longitudinal Group (1987-1998), the total number of children interviewed was 686, which was sufficient to meet the needs of the research design.

(c) Detecting concepts and subtle differences in their dynamic and static representation by boys and girls of differing culture and ethnicity, required a multi-modal approach with triangulation of measurement across three media (Interview verbal responses, Drawing, and Play-dough modelling) and their associated modalities (see Bryce and Blown, 2006 and Blown and Bryce, 2006).

Three specific research questions were raised:

1. Are there any statistically significant differences (at an alpha level of .05) between boys and girls conceptual acquisition in the domain of astronomy and earth science?
2. Do boys and girls follow similar trends in their cosmological development?
3. Are patterns of knowledge acquisition, cognitive development, and conceptual change in this domain similar for boys and girls across cultures and ethnic groups?

Method

The methodology focused on ascertaining children's concepts of the Motion and Shape of the Earth, and associated concepts of Gravity. The studies utilised three media (Interview verbal responses, Drawing, and Play-dough modelling) with corresponding modal interactions which were triangulated, making the interview technique particularly sensitive to small variations in multi-modal skills and performance which might be associated with gender based ability.

Participants

The total New Zealand sample was composed of 217 boys and 227 girls (aged 2 to18); and the total China sample similarly consisted of 129 boys and 113 girls (aged 2-18). Of these, 127 New Zealand children (aged 2-12) including 62 boys and 65 girls; and 113 Chinese children (aged 2-12) including 57 boys and 56 girls participated in the Main Survey (1993-1994).

Apparatus

The apparatus for the motion study consisted of a metre ruler screwed to a block of wood and a pencil to observe the apparent motion of the Sun. The materials and props required for the Shape, Identity, and Habitation Studies were: (a) coloured play-dough for modelling, (b) A4 cartridge paper and coloured felt pens for drawing the shape of the Earth, Sun and Moon, and (c) small model people, representing "self" and a "friend" who lives a long way away. The gravity studies were supported by a sketch of the Earth with a hole through and a similar play-dough model (which were only introduced to children who held a spherical Earth cosmology).

Interview design

A comprehensive set of questions was designed as a guide or structure to ensure that all of the key elements of children's cosmologies were explored without restricting the possible outcomes. The questions and the interview framework were designed to maximise flexibility to permit children to share their cosmological concepts over a wide age range (from 2 to 12 years). The instrument was originally written in English which was translated into *Hanyu* (Mandarin).

Control group design

Of several research designs considered by the authors Solomon's Four Group Design with two pre-test (Survey) groups and two non-pre-test (Control) groups was selected as the most suitable to ascertain the impact of repeated interviews (see Isaac & Michael, 1981).

Results and discussion

Categorisation of responses to interview questions, drawings, and play-dough models

A tentative category was given to each response in each element of children's cosmologies and their name was entered alongside that category to form an *Identified Subject Histogram* in each element with the categories in ordered rows on the "y" axis, and the child's name, in age columns, on the "x" axis. Each category was identified by a descriptor and a thumb-nail sketch. In each case the category scheme was ordered from least scientific (category row 1) to most scientific (commonly category 12) forming an ordinal scale according to the relationship category 12 > category 11 > category 10, and so on (see Siegel & Castellan, 1988, p. 25). For example, considering the cosmological element Earth Motion, the ordinal ranking would be Earth rotating and revolving > Earth moving in some way > Earth stationary. Similarly, in the case of Earth

Shape, the ordinal ranking would be: spherical > disc > flat. To ensure validity and reliability of coding of the categorisation scheme a sample of the interview transcripts and drawings were checked by educators in the field and coefficients of agreement determined with average Cohen's κ values of 0.89 as detailed in Blown and Bryce (2006). The categorisation scheme for Earth motion, Earth shape, and other cosmological concepts are illustrated in Authors 2006a.

Main Findings

The results support the hypothesis that children's cosmological concepts are influenced by gender but the effects are subtle and not universal within or across genders and cultures. The groups were compared by analysis of: (a) cosmological concept categories of boys and girls both within and across cultures using the *Kolmogorov-Smirnov two-sample test [K-S]*; and (b) developmental trends of cosmological concept category by age of boys and girls within and across cultures using the *Spearman rank correlation [* r_s *] test*.

Results of Kolmogorov-Smirnov two-sample [K-S] tests

With an alpha level of .05 no significant differences were detected when comparing cosmological concepts between groups by gender or culture: e.g., Earth Motion Triangulation: NZ Males: $M = 7.73$, $SD = 3.56$; NZ Females $M = 7.66$, $SD = 3.56$; China Males: $M = 8.21$, $SD = 3.21$; China Females: $M = 7.32$, $SD = 3.50$. Earth Shape Triangulation: NZ Males: $M = 8.76$, $SD = 4.02$; NZ Females $M = 8.14$, $SD = 4.30$; China Males: $M = 10.18$, $SD = 2.73$; China Females: $M = 9.07$, $SD = 3.91$.Gravity Triangulation: NZ Males: $M = 6.82$, $SD = 4.79$; NZ Females $M = 6.66$, $SD = 4.84$; China Males: $M = 6.66$, $SD = 4.89$; China Females: $M = 7.50$, $SD = 4.16$.

Results of Spearman rank correlation [r_s] tests

In all cases the correlations of age against cosmological concept category were statistically significant ($p < .001$): e.g., Earth Motion Triangulation: NZ Males: $r_s = .76$; NZ Females $r_s = .64$;

China Males: r_s = .71; China Females: r_s = .76. Earth Shape Triangulation: NZ Males: r_s = .71; NZ Females r_s = .72; China Males: r_s = .59; China Females: r_s = .65. Gravity Triangulation: NZ Males: r_s = .87; NZ Females r_s = .83; China Males: r_s = .84; China Females: r_s = .77.

Evidence of gender as a factor

In general it was found that girls' in both cultures were better able to describe their Earth shape concepts: Earth Shape Interview: NZ Males: r_s = .71; NZ Females r_s = .73; China Males: r_s = .34; China Females: r_s = .61. Girls were also more able at visually representing their cosmologies: Earth Shape Drawing: NZ Males: r_s = .73; NZ Females r_s = .77; China Males: r_s = .35; China Females: r_s = .64. Whereas boys displayed greater awareness of gravity. However, the overall trend was one of surprising similarity between boys and girls across cultures.

Interview transcript excerpts and sample categorisation method

The following extracts from the interview transcripts show one boy and one girl from each culture are shown discussing their cosmologies with the researcher (the second author). Gender, age (in years and months), culture and ethnicity are given in parenthesis. Further comprehensive protocols of the research instrument (interview guide) may be found in Bryce and Blown (2006) and Blown and Bryce (2006).

Motion and Time studies

Environment: Outdoors in sunshine observing the divergence of shadows between a shadow-stick and a pencil. Media: A4 paper, pencil, to draw motion of Earth, Sun and Moon; daytime and night-time. [The experimental/observational situation was introduced and the child was invited to place a pencil so that the tip was at right-angles to and touching the ruler shadow.]

Motion of a ruler shadow and the apparent motion of the Sun: New Zealand

Researcher: *What causes the shadows?*

Nikolai (Boy; 10, 7; NZ; Maori): *The Sun shines down to (the Earth) – and it's blocking – the Sun's rays to the grass and the concrete.*

Researcher: *Is anything moving?*

Nikolai: *The shadow – because the wind's blowing it – the shadow (is moving away) –from the pencil.*

Note. Nikolai concentrates on what he is immediately observing rather than following his original train of thought about the motion of the Earth with respect to the Sun. There is a slight breeze blowing causing the ruler to shake.

Researcher: *Why is it moving?*
Nikolai: *Because we're moving away from the Sun.*

Note. Nikolai returns to his original idea. He is probably thinking of both causes at the same time and decides that the rotation of the Earth is the most likely cause.

Researcher: *Has what is happening got anything to do with the Sun?*
Nikolai: *Yes.*
Researcher: *Is the Sun moving?*
Nikolai: *No.*
Researcher: *Has what is happening got anything to do with the Earth?*
Nikolai: *Yes.*
Researcher: *Is the Earth moving?*
Nikolai: *Yes.*
Researcher: *How is the Earth moving?*
Nikolai: *It's going around a circle.*

Note. Before probing further the researcher has to determine Nikolai's Earth Shape concepts because the researcher does not want to be the first to introduce a spherical Earth model.

Researcher: *What shape is the Earth?*
Nikolai: *Round.*
Researcher: *Round like…?*
Nikolai: *Round like a ball.*

Note. Now that the researcher knows that Nikolai believes that the Earth is ball-shaped, there can be discussion of concepts such as spinning, rolling, and revolving to clarify what Nikolai meant when he said the Earth went "around a circle."

Motion of a ruler shadow and the apparent motion of the Sun: China

Researcher: *What causes the shadows?*
Feng Yan (Boy; 4, 7; China; Han): *The Sun.*
Researcher: *Is anything moving?*
Feng Yan: *The (ruler) shadow moves.*
Researcher: *Why is it moving?*
Feng Yan: *Because the wind is blowing the ruler.*

Note. There is also a slight breeze (in China) which is shaking the shadow stick.

Researcher: *Has what is happening got anything to do with the Sun?*
Feng Yan: *Yes – and the Earth.*
Researcher: *Is the Sun moving?*
Feng Yan: *Yes.*
Researcher: *How is the Sun moving?*
Feng Yan: *(Indicates circular motion with hand).*
Researcher: *Does it go around something (revolve) or does it go around itself (spin)?(Researcher uses hands to model motion).*
Feng Yan: *It moves like this (moves hand in a circle motion) – when we (China) are at night-time – America is in daytime.*
Researcher: *Has what is happening got anything to do with the Earth?*
Feng Yan: *Yes.*

Researcher: *Is the Earth moving?*
Feng Yan: *Yes.*
Researcher: *How is the Earth moving?*
Feng Yan: *The Earth goes around the Sun.*

Note. Although Feng is only 4-years-old he has a scientific concept of the Earth-Sun system.

Shape studies

Environment: A small room or library with a view of the ground and sky from a window.

Media: A4 paper and coloured felt pens for drawing the Earth, Ground and Sky.

Shape of the Earth: New Zealand

Researcher: *Tell me about the Earth?*
Kaelah (Girl; 5, 7; NZ; Euro): *It's next to the Moon.*
Researcher: *What is the Earth?*
Kaelah: *A round ball.*
Researcher: *What is the Earth made of?*
Kaelah: *I don't know.*
Researcher: *Where is the Earth?*
Kaelah: *In space.*
Researcher: *What shape is the Earth?*
Kaelah: *Round.*
Researcher: *Round like a disc or round like a ball or round in some other way?*
Kaelah: *Round like a ball.*

Shape of the Earth: China

Researcher: *Tell me about the Earth?*
Jia Li Li (Girl; 5, 3; China; Han):*The Earth is in the sky – and it doesn't need human beings to move it – it can go by itself.*
Researcher: *What is the Earth made of?*
Jia Li Li: *I'm not sure.*
Researcher: *Where is the Earth?*
Jia Li Li: *In the sky.*
Researcher: *Point to where the Earth is?*
Jia Li Li: *Up above us (points to the sky).*
Researcher: *What shape is the Earth?*
Jia Li Li: *A circle (round).*
Researcher: *Round like a disc or round like a ball or round in some other way?*
Jia Li Li: *Like a ball.*

Note. Children also modelled the shape of the Earth in play-dough; and drew and modelled the shape of the Sun and Moon in a similar manner.

Comment on categorisation of responses: Nikolai's interview responses, drawings and play-dough modelling confirmed that he believed that the Earth moved and the Sun was stationary; but he was uncertain of the Earth's rotation or its revolution around the Sun. This placed him in Earth Motion *Cosmological Concept Category* 8 for Interview, Drawing, and Play-dough modelling modalities (see Appendix B1 in Bryce and Blown, 2006). Similarly Feng Yang, who was aware of the Earth's revolution around the Sun, was placed Earth Motion *Cosmological Concept Category* 9. Jia Li Li's verbal responses to questions about the motion and shape of the Earth, combined with her drawing showed that she held a dual-Earth concept, with a flat ground on which she lived, and a spherical Earth in the sky which was uninhabited (these latter details being confirmed in her later interview on Habitation of Earth and Identity with Earth). By triangulation, these results placed her in Earth Motion *Cosmological Concept Category* 8 for Interview and Drawing modalities; and Earth Shape *Cosmological Category* 6 for Verbal Language and Drawing modalities (see Appendix B3 in Bryce and Blown, 2006); a finding which was later confirmed by play-dough modelling. Similarly, Kaelah's responses and drawing also indicated a dual-Earth cosmology with a spherical Earth in space and a flat ground below which placed her in Earth Motion *Cosmological Concept Category* 8 for Interview and Drawing modalities; and Earth Shape *Cosmological Concept Category* 6 for Verbal Language and Drawing modalities, like Jia Li Li. However, later, in the interview on Habitation of Earth and Identity with Earth, unlike Jia Li Li, Kaelah believed that she lives on the Earth, which placed her in a higher Habitation *Cosmological Concept Category*: Jia Li Li was placed in Habitation *Cosmological Concept Category* 6, whereas Kaelah was placed in Habitation *Cosmological Concept Category* 8 (see Appendix B3 in Bryce and Blown, 2006). Kaelah's placement was confirmed by later triangulation from play-dough modelling when she made a ball-shaped Earth.

Conclusions

The three research questions which guided the study were all answered in favour of similarity between boys and girls within and across cultures as follows:

1. There were no statistically significant differences (at an alpha level of .05) between boys

and girls conceptual acquisition in the domain of astronomy and Earth science.

2. Boys and girls follow similar trends in their cosmological development.
3. The patterns of knowledge acquisition, cognitive development, and conceptual change, are similar for boys and girls across cultures and ethnic groups.

These studies took place over a period of more than a decade with boys and girls from two diverse cultures in the expectation that there would be significant differences in children's cosmological concepts at all ages between cultures and possibly, though less certainly, between ethnicities, and boys and girls. In the event, the results have shown remarkable similarity at all three phases of conceptual organisation – intuitive, cultural and scientific – within and across cultures, ethnicities and genders. They have also shown that such differences as there are can only be revealed by a refined interviewing technique incorporating multimedia-multimodal procedures with triangulation of measurement to detect their fine texture. There is therefore good reason to believe that the results are not unique to Chinese and New Zealand children and that, were the same methods to be used to interview children in other cultures, a similar pattern of results would be obtained. Since it is apparent from the literature review that studies in this field using Piagetian interviews with boys and girls from differing cultures are not new, it seems reasonable to believe that there would have been similar differences in those groups but either they were not detected or because they were considered to be unimportant they were not reported. This raises three important questions. The first relates to differences in the literature on the apparent relevance of gender as a factor. The explanation that the current authors were specifically looking for gender effects, although true, is not sufficient. Nor is the full answer to be found in the interview technique which owes much to Piaget (1929, 1930); Nussbaum and Novak (1976); Nussbaum (1979); and other researchers. It seems that the real answer lies in the way in which this research was approached as an anthropological-ethnological study involving *adoption* by the culture, and necessitating the allocation of adequate *time* – the major limitation of all Piagetian studies. By allowing time for children and teachers to accept the researcher not as a stranger or visitor but as a member of the culture of the kindergarten or school, it was possible for children to share their ideas in a way that they would never do with a stranger (for a variety of reasons). A younger child might simply be following the sound advice of all parents and teachers to be wary of strangers. An older child might fear ridicule by expressing inner thoughts that conflict with what they have been taught by parents or teachers. Even older children might be reluctant to be seen talking with an adult (any adult), one-to-one, because it isn't the done thing. The anthropological-ethnological researcher has to be aware of these difficulties and to overcome them, and the easiest way to do so is to spend time with the young people in other roles before trying to interview them. In the introduction much was said about the structure of the interview design and setting. What was not said, and what is of paramount importance, is that interviewers should not go in "cold" as visiting researchers and expect children to share their ideas. They won't. Not in great depth anyway. The researcher learned this very early in the 1st NZ Survey. As a junior class teacher he had learned to play with children and several hours were spent just playing – especially at kindergarten – until he was accepted as someone who belonged and could be trusted so it would be alright to sit down and talk to him. Another simple idea learned from kindergarten teachers in New Zealand – and also later known to have been used by Hall (1883) in USA – was that of interviewing young children in the natural setting of the kindergarten with their friends running around and even coming over to see what was going on (without interrupting to any great degree – and without critically influencing validity). So that the young people felt at ease and were willing to share their deepest intuitive ideas. The idea of interviewing children one-to-one in a quiet room out of contact with the living activity of the school is not conducive to finding out what young people really think.

A second question that needs to be addressed is that of the remarkable similarity of children's intuitive ideas in dissimilar cultures and environments. The answer appears to be closely related to what has been said about play. Children in China and New Zealand play similar games. They also have similar toys and are told similar stories (fairy tales) by their parents and teachers. The characters may differ, but the moral is the same. When they investigate nature, such as studying an insect or a flower or clouds, they do so in similar ways. And from their perspective, their everyday environments, because they are nature centred, are also very similar. Conceptual dissimilarity does not come from nature; it comes from people. So at the intuitive level, where children are interacting directly with their environments with minimal interference or guidance or control, the worlds of Chinese and New Zealand children have much more in common than in difference. And their initial concepts and cosmologies reflect this similarity. Cultural influences are there from the time a child is born, but they do not become significant until the child is old enough to listen with meaning and to talk fluently, by which time they attend kindergarten (at age 2 or 3 in China and New Zealand). Once at kindergarten any cultural influence from the home or other sources has to compete with the scientific world view of teachers, who regardless of culture, have to attend university or teachers college where they are taught by people who are unlikely to be bound by traditional cultural ideas. So from about age 3-years children in China and New Zealand who attend kindergarten (and the majority do) are exposed to a universal world view – that of science – which over-rides – or at least sits alongside (and sometimes conflicts with) whatever they may learn from their local traditional culture. And by the time they attend school (at age 5 in New Zealand, and age 7 in China) they are submerged in the world of science which is reflected in their cosmologies, which often show elements of cultural mediation at this age. But by the age of 11 or 12 years, children's cosmologies are almost invariably similar to those of scientifically knowledgeable adults.

The final question to be answered is the place of gender in these patterns of similarity despite cultural diversity. Here, the most significant factor is thought to be the way in which children in China and New Zealand are valued in gender-free ways. In China, because the one child policy de-emphasises gender. And in New Zealand, for a similar reason: although not compulsory, New Zealanders prefer small families, so there is a high proportion of single child, and two-child families, and a strong tendency towards treating boys and girls equally. It is also significant that both countries are essentially egalitarian with a strong aversion to social class structures and the gender bias that adherence to such outdated feudal traditions entail. More work has to be done to ascertain whether or not the findings reported here are typical of other cultures and to identify the factors contributing to subtle differences in the abilities of boys and girls for the benefit of *all* children, regardless of culture, ethnicity or gender.

Implications for teacher training, teaching, and learning science

The main implications of these studies are that student teachers and in-service trained teachers who are planning to teach science either at primary (elementary) level or at secondary level should be taught astronomy and Earth science by specialists in the field who should introduce students to a wide range of astronomical experiences as a foundation for future teaching utilising the local environment. These experiences should include (a) multi-media approaches to teaching astronomy and Earth science in the classroom including use of computer graphics, (b) naked eye observation on a daily basis of the position of rising and setting of the Sun (possibly as homework in summer) and the effect of seasonal change, (c) similar observation of the phases of the Moon, (d) determining the North-South meridian line, local noon, and time by use of shadow sticks and elementary sundials, (e) night-time naked-eye observation of the heavens with the assistance of parents and local astronomers, (f) similar observations using telescopes supplied by local astronomers or educational resource centres, (g) field trips to astronomical observatories, planetariums, and science museums to view telescopes, the heavens, and if possible a Foucault pendulum (to give direct experience of the rotation of the Earth), (h) with children age 10 or older consider making Newtonian telescopes as an extension activity at school or in an extra-curricular club. In all cases all children should be involved, and in planning field trips, extra-curricular activities, and evening observation sessions, as many teacher colleagues and parents as possible should be involved (e.g., in supervising the observation of Jupiter, Saturn or Mars through a telescope).

Returning to the relationships between common, intuitive scientific knowledge and formal learning in science at school, we can conclude (from this study) that the former seems *not* to be gender-related and (from literature reviewed at the start of this article) that the latter, particularly at secondary school levels, *is* gender-related (with clear indications that educational disadvantage has swung from female to male over recent years). We would argue that these are not incompatible findings and underline what dedicated and determined professional teachers have achieved in modern times and what, from an evidence-based practice argument, they must turn to now. Assuming Dee's (2006; forthcoming) research on teacher-gender effects is borne out in other cultures, it will be for increasing numbers of *female* teachers to find ways of countering the negative trend. What governments themselves might do to tackle the 'feminisation' of society in general and teaching in particular would seem intractable.

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