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Primary Geography in Australia: Pre-Service Primary Teachers' Understandings of Weather and Climate

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Abstract

Recent curriculum introductions and revisions on a global scale have highlighted the importance of primary teachers' content knowledge in geography and the lack of research in this area (Catling, 2014). This has become a particular focus in Australia with the introduction of the *Australian Curriculum: Geography* in 2013 and the requirement for geography to be taught as a discrete subject in primary schools. The current study focuses on content common to both the Australian Curriculum: Geography and Science. The study reported in this paper adopts a mixed methods approach to explore the adequacy of pre-service primary teachers' accuracy and depth of knowledge about weather and climate. The results suggest that pre-service primary teachers hold a range of alternative conceptions about weather and climate processes and that they lack the depth of knowledge required to adequately prepare students for their studies in secondary science and geography. Implications for classroom practice and for future research are discussed.

Keywords: Australian curriculum, alternative conceptions, content knowledge, confidence, Conceptual change, geography, weather and climate

Introduction

Context: The Place of Geography in the Australian Primary Curriculum

The *Australian Curriculum: Geography*, approved in 2013, covers all years of schooling from Foundation (Kindergarten) to Year 12 and will be mandatory in Australian schools from Foundation to Year 8 (see: www.australiancurriculum.edu.au /humanities-and-social-sciences/geography/). This document is of particular significance to Australian primary school teachers as it is the first time the discipline of geography has been identified as a distinctive subject for this age group. In the past the study of geography was less explicit in the primary curriculum. Geographical concepts and skills were integrated as a component of SOSE (Studies of Society and Environment), Humanities or Social Studies in different states and territories. In most

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primary schools, it is likely that geography will be taught by the regular classroom teacher with a time allocation between 18 and 50 hours per year depending on the age of the cohort (Bourke & Lidstone, 2015).

The curriculum has a defined structure at each year level with content divided into two "strands" – geographical knowledge and understanding and geographical inquiry and skills. These strands are interrelated and designed to be taught together in "ways that are appropriate to specific local contexts" (ACARA, 2013, p. 17). At each year level the curriculum includes level descriptors, content descriptors, and achievement standards. The achievement standards explain the expected learning outcomes at each year level, including depth of conceptual understanding demonstrated, the sophistication of skill development and application of knowledge and skills in a range of contexts.

The *Australian Curriculum: Geography* aims to ensure that children develop: a sense of wonder, curiosity and respect about places, people, cultures and environments throughout the world; a deep geographical knowledge of their own locality, Australia, the Asia region and the world; the ability to think geographically, using geographical concepts; the capacity to be competent, critical and creative users of geographical inquiry methods and skills and as informed, responsible and active citizens who can contribute to the development of an environmentally and economically sustainable, and socially just world (ACARA, 2013, p. 2).

Links with Other Key Learning Areas (KLAs)

While geography is now a discrete discipline in the Australian curriculum, primary teachers are encouraged to integrate key learning areas (KLAs) where appropriate. Appendix 1, for example, shows how an understanding of weather and climate is built progressively in both the science and geography curriculum from Foundation to Year 7. In the Foundation year students begin by identifying and describing the weather and climate of their local area. Years 3-6 introduce a number of foundational concepts including phase change and the causes of rain and wind. Finally in Year 7 students integrate their understandings in a holistic study of atmospheric or hydrological hazards (including tropical cyclones). Given the links between the science and geography content it is logical for primary teachers to integrate these learning areas during instruction.

The requirement to integrate knowledge across KLAs presents a number of challenges for primary teachers in terms of their content knowledge. Primary teachers in Australian schools need to teach across a number of KLAs including English, mathematics, science, social sciences, creative arts, personal development and health. They are not, however, required to have completed tertiary studies across all of these areas. For accreditation as a primary school teacher, the Australian Institute for Teaching and School Leadership (AITSL) requires graduates to have the equivalent of one year of full-time studies relevant to *one or more* learning areas of the primary school curriculum. This means that many Australian primary teachers may not have completed any formal studies in the social sciences, let alone geography (AITSL, 2011). The introduction of geography as a distinctive subject within the curriculum therefore raises important questions about how well prepared primary teachers are to teach this content. These questions are not unique to Australia but have been raised in a number of countries where geography is being introduced into the primary curriculum or where the primary geography curriculum is being revised, for example, England (Catling, 2003), Italy (De Vecchis, D'Allegra, & Pesaresi, 2011) and Turkey (Açıkalın, 2009).

The purpose of this paper is to examine primary pre-service teachers' (PST) accuracy and depth of knowledge about *weather and climate* — content which links both the *Australian Curriculum: Geography* and the *Australian Curriculum Science*. Data presented here were collected as a part of the *Opening Real Science (ORS) Project* under the Australian Government's Enhancing the Training of Mathematics and Science Teachers (ETMST) scheme, a government-funded initiative involving a consortium of 6 universities. The ORS Project supports the development of primary PSTs' competence and confidence in science content knowledge. The paper is divided into three sections. The first section provides an overview of what is currently known about PSTs' content knowledge in general and more specifically, their knowledge of weather and climate. This is followed by an outline of the methodology for the study and approach to data analysis. The results are then presented and discussed with reference to the literature. The conclusion to the paper outlines possible solutions to the issues identified and the implications of these findings for classroom practice and future research.

Pre-Service Teachers' Geography Content Knowledge

The importance of content knowledge

The importance of sound content knowledge is clearly articulated in both the literature and in the national professional standards for teachers. The *Australian Professional Standards for Teachers* highlight the need for graduates to demonstrate knowledge and understanding of the "concepts, substance and structure of the content and teaching strategies" of their teaching area/s (AITSL, 2011 p.10). In addition, teachers are expected to be able to organise content into effective learning and teaching sequences. Given their breadth of training, it is unreasonable to expect primary teachers to exhibit a deep, relational knowledge of the core concepts across all KLAs (Eaude, 2012; Taylor, 1986). They do, however, require enough knowledge to develop appropriate and engaging activities for students and to identify any gap between students' everyday understandings (Holloway & Valentine, 2002; Martin, 2008) and the "powerful" disciplinary knowledge required by the curriculum (Young & Muller, 2010). A sufficient knowledge of the content is necessary so that teachers can effectively identify and respond to students' alternative conceptions in class (Vosniadou, Vamvakoussi, & Skopeliti, 2008) and develop appropriate strategies and representations for building understanding. It is particularly important that PSTs have sufficient knowledge to create integrated units of work linking related concepts across KLAs. The concepts in F-6, for example the progressive introduction of ideas foundational to weather and climate, provide the necessary conceptual understandings for student success in secondary geography and science (see Appendix 1). It would be expected, therefore, that a graduate primary teacher would have sufficient content knowledge in geography to prepare primary students for the Year 7 curriculum.

The AITSL standards are supported by research highlighting the relationship between content knowledge and effective classroom practice. Reports from both the UK (Ofsted, 2011 cited by Catling & Morley, 2013) and Australia (Erebus International, 2008) highlight the link between "good" geographical knowledge and effective teaching in this domain. These reports indicate that effective teachers of geography are both positive about the subject and have informed and up-to-date content knowledge. The consequences of poor content knowledge have been well documented (Catling & Morley, 2013; Lane, 2011). Catling and Morley maintain, however, that primary teachers with sound content knowledge can "encourage children to use geographical terms contextually and accurately" (p.428). Content knowledge is also essential for planning quality lessons, providing high quality targeted feedback on students' work, developing appropriate questions, responding effectively to student enquiries, and foregrounding geographical concepts during lessons (Catling & Morley, 2013; Gooch, Rigano, Hickey, & Fien, 2008). Several studies have also demonstrated a link between PSTs' content knowledge and their confidence in teaching geography (Catling, 2014; Waldron et al., 2009). In other words sound content knowledge is essential for the development of primary teachers' pedagogical content knowledge (PCK) and self-efficacy in the teaching of geography (Lane, 2011; Shulman, 1986).

What We Know About Pre-Service Primary Teachers' Understandings of Key Geographical Concepts

Despite the cited importance of primary teachers' geographical knowledge, there is a distinct lack of research exploring primary PSTs' geographical and environmental understandings. Catling (2014a) reviewed 36 studies from international sources from 2004-2014. He has noted that few papers are published or given as presentations on this topic each year across the world (Catling, 2014b). The existing literature does not present an encouraging picture of the state of primary PSTs' knowledge. In his discussion of curriculum developments in England, Catling (2013) notes: "a key weakness for many primary teachers is their limited understanding of geography, both of its key ideas and their knowledge of its content and information related to this, such as, about environmental processes and their locational knowledge" (p.32). A federal government commissioned report into the teaching of years 3-10 geography in Australia (Erebus International, 2008) came to similar conclusions and noted the need to increase the number of teachers with sufficient knowledge and skills in this domain.

In addition to the limited *number* of studies exploring primary PSTs' geographical and environmental understandings, the *range of topic areas investigated* has also been narrow. These topics include the investigation of PSTs' conceptions of the discipline of geography (Morley, 2012; Ozturk & Alkis, 2010), their environmental attitudes (Tuncer, Sungur, Tekkaya, & Ertepinar, 2007) and their knowledge of climate change (Papadimitriou, 2004; Ratinen, 2013). Not much is known about primary PSTs' accuracy or depth of understanding in other key topic areas including their knowledge of weather and climate processes. Research in this area has been limited to PSTs' conceptions of climate change, particle theory and the causes of wind.

Pre-Service Teachers' Conceptions of Climate Change

The greenhouse effect and ozone depletion are important environmental issues that are often misrepresented in the media and in popular culture. This can result in the formation of alternative conceptions i.e. persistent and robust mental models that are inconsistent with current scientific understandings (Vosniadou et al., 2008). Over the past decade three studies have explored pre-service and in-service primary teachers' knowledge in this area. Papadimitriou (2004) studied 172 prospective primary teachers in their first year of teacher training in Greece. The study aimed to investigate student teachers' conceptions of the greenhouse effect and ozone depletion. The study found that PSTs incorrectly relate climate change to air pollution, environmental pollution in general, and to acid rain. They confuse the greenhouse effect with ozone layer depletion and hold a number of alternative conceptions in this area. Many of the PSTs, for example, believed that there were "holes" in the "layer of greenhouse gases" (p.304) and that carbon dioxide depleted the ozone layer. In their study with 564 Turkish pre-service primary teachers, Ocal, Kisoglu, Alas, and Gurbuz (2011) found similar results. The PSTs in this study maintained that the hole in the ozone layer was responsible for global warming and that global warming caused skin cancer. Other common alternative conceptions were identified including the view that global warming was linked with earthquakes and acid rain. Ocal et al. (2011) noted that many of the PSTs had developed a conception that any carbon dioxide in the atmosphere was hazardous to the environment. These future primary teachers were unaware that atmospheric carbon dioxide and water vapour made the climate on earth liveable (i.e. the natural greenhouse effect).

In a related study, Ratinen (2013) explored 275 second-year Finish primary PSTs' understandings of the greenhouse effect. The results indicated that the PSTs lacked an understanding of the particle model and had incomplete understandings of atmospheric processes. Participants held the view that "pollutants, emissions and industry" thin the atmosphere and that this makes the climate hotter (p. 938). Consistent with the findings of Papadimitriou (2004), many of the PSTs also held the conception that acid rain (44%) and radioactive contamination (30%) were responsible for the enhanced greenhouse effect.

Conceptions of Particle Theory and Causes of Wind

Three studies from Greece and Turkey and Australia have explored primary pre-service and in-service teachers' understandings of particle theory and the causes of wind. Papageorgiou, Stamovlasis, and Johnson (2010) examined Greek primary school teachers' (n=162) understandings of the particle model and found that 25% of participants expressed "no idea" about particles (p.367) and that relatively few teachers (28–17.3%) gave acceptable particle structures for solid and liquid states in their explanations. The teachers also held a range of alternative conceptions about melting, boiling, evaporation, condensation and dissolving that were similar to those held by pupils. Ozden's (2009) research with 92 Turkish pre-service primary teachers provides a possible explanation for these results. Ozden found that alternative conceptions of atoms and molecules were common amongst this sample of future teachers and that these beliefs made it difficult for the PSTs to understand particle theory.

In a study with Greek PSTs (n=60), Mandrikas, Skordoulis, and Halkia (2013) identified a number of common alternative conceptions about wind formation and related phenomena and observed general lack of understanding of these concepts. When asked "how is the wind created", 65% responded that they did not know, 20% said that wind was a result of temperature differences and 17% identified currents and airstreams as the cause (note: some students provided multiple answers so the totals add to more than 100%). The PSTs were generally unaware of the role of solar radiation in the formation of wind and believed that the wind was caused by the moon, the clouds and by the ocean (Mandrikas et al., 2013). Alternative conceptions about the causes of common meteorological phenomena affecting their city (Athens) such as temperature inversions and the afternoon sea breeze were also identified.

The above review demonstrates that, while there has been some research exploring primary PSTs' conceptions of climate change, particle theory and causes of the wind, there remains a lot that we do not know about primary PSTs' knowledge of weather and climate. In addition, we know little about the sources of pre-service primary teachers' conceptions. This is a concern given the importance of weather and climate in the *Australian Curriculum: Geography* and *Science* and primary curriculum documents elsewhere in the world. Identifying PSTs' existing mental models is vital for improving teacher educator's understandings of the students they teach, designing interventions to build PSTs' understandings of key geographical concepts and ultimately, improving the quality of geographical and environmental learning among primary children.

The Purpose of Study

This study aims to address a gap in the literature by identifying pre-service primary teachers' alternative conceptions of key weather and climate processes including the properties of air, the water cycle, air pressure and causes of the wind.

Methodology

Research design

The study applied a range of assessment techniques to gain a rich and detailed image of primary PSTs' underlying conceptions of weather and climate. The mixed method design consisted of two phases; the first involved completion of a questionnaire by a large sample of primary PSTs (n=430). Phase 2 involved detailed interviews/discussions with 29 PSTs to explore their conceptions in greater detail and to validate/triangulate the findings of the questionnaire.

Respondents

The study was conducted at three Sydney, Australia, universities. The universities were selected because they have a long history of training prospective primary teachers and draw students from across the Sydney metropolitan area. Each of the universities offers either 2-year graduate entry programs or 4-year programs in primary teacher education.

There were 430 PSTs in the study. Most of the PSTs were from University A (n=228, 53%). There were 187 students from University B (44%) and a small number of students from University C (n=15, 3%). All of the students were in the final two years of their degree programs and had completed curriculum methodology units in integrated social sciences or HSIE (Human Society and its Environment) and science. Only three of the students had studied specific units in climatology or meteorology during their undergraduate degrees.

The primary PSTs interviewed in Phase 2 (n=29) were selected on the basis of their questionnaire responses. In each case, the survey responses suggested that the selected PSTs were likely to hold a number of alternative conceptions about key weather and climate processes.

Phase 1 – Gaining a Holistic View of the Distribution of Specific Alternative Conceptions

Instruments

In the first phase of the study a 20 item true or false questionnaire was used to gain a holistic view of the distribution of specific preconceptions. The questionnaire, originally developed by Lane and Coutts (2012), included both factual and conceptually based items related to the underlying processes of weather and climate. Items were generated from a range of sources including: the conceptual change literature; the F-7 Australian curriculum content for geography and science; focus group interviews with students; and an analysis of the alternative conceptions featured in geography textbooks from Australia, the US and UK. The content validity of each item was established through an expert review process involving a Catastrophe Risk Analyst and meteorologist. When designing the questionnaire it was assumed that a graduate primary teacher would have at least a sufficient level of content knowledge in geography that would enable him or her to prepare primary students for progression into the Year 7 curriculum.

Procedure

The questionnaire was administered during scheduled (1 hour) lectures at each of the participating universities. The primary PSTs were reminded at the start of each lecture that the research aimed to identify their personal views about weather and climate processes and that the task was not a part of their formal university assessment. Specific instructions for completing each part of the questionnaire were provided and participants were guided through a practice response. All responses were recorded on coded answer sheets to ensure confidentiality. These codes were used to identify participants for Phase 2 of the study.

Analysis of Data

After a small number of incomplete surveys (n=5) were removed from the data set, the PSTs' responses were analysed to identify items of low and high facility (degree of difficulty). Items of low facility were defined as those answered incorrectly by more than one third of the PSTs. Items of low and high facility were then analysed and organised according to themes.

Phase 2 – Building A Rich Account of the Pre-Service Teachers' Conceptions

Instruments

To gain a rich account of the participants' accuracy and depth of understanding of key weather and climate concepts, 15 pre-service primary teachers from University B and 14 teachers from University C were interviewed individually for approximately 1 hour. The interview consisted of a number of components. The first section included a series of structured questions to collect background information about the participants' tertiary studies including any undergraduate units completed in meteorology or climatology. In the second component of the interview, the PSTs were asked to explain their responses to the 25 statements representing alternative conceptions or incorrect factual information in the questionnaire.

Procedure

The interviews with PSTs were administered individually at a time mutually convenient to both the researcher and the PST. A script or interview protocol was used to ensure consistency in the delivery of instructions and a journal was kept of the participants' actions and responses. Interviews were both videotaped and audio recorded.

Analysis of data

The PSTs' interview responses were analysed for both depth and accuracy of understanding. This involved content analysis of the transcripts for evidence of alternative conceptions. Conceptions and beliefs were considered stable if they were used consistently in PSTs' explanations on more than one occasion, for example through their questionnaire responses, written explanations and answers to interview questions.

Findings

The *Australian Curriculum: Geography* and *Science* requires school students to develop an understanding of the causes and processes of weather and climate (see Appendix 1). This section combines the results of the questionnaire (Phase 1) and interviews (Phase 2) to provide a holistic account of the conceptions of the primary PSTs.

Conceptions of Key Weather and Climate Processes

The questionnaire results relating to key weather and climate processes are summarised in Tables 1 and 2). The findings demonstrate a range of performance across the sample, with individual scores varying from 0/20 to 19/20 (average = 13/20). In total, 9 of the 20 statements were identified as low facility (answered incorrectly by more than one third of the sample).

Table 1.
Items of low facility related to key weather and climate processes

% of PST (n=440) answering correctly	Questionnaire statements related to key weather and climate processes
32.50	The molecules that make up water expand and float away when heated by the sun's energy.
36.50	Air pressure directly above a body of water increases as the temperature of the water increases.
43.00	The main reason that the tropics are hotter than the North and South Poles is because they are closer to the sun.
44.10	Cold air applies a lower pressure on the ground than the same volume of

	warm air.
56.50	Air temperature increases from sea level to the base of the clouds
57.30	Only a small proportion of the water that evaporates ever returns to the earth's surface as precipitation.
58.50	Rising air applies less pressure on the earth's surface than falling air (per unit volume).
59.80	Cold air is denser than warm air.
63.60	Air is weightless.

When combined with the detailed qualitative information from the interviews a number of common themes can be identified. These include PSTs' conceptions of evaporation, air pressure and density, reasons for latitudinal temperature differences, temperature changes in the atmosphere (with altitude) and the nature of air.

Conceptions of Key Weather and Climate Processes

Evaporation

Data from both the questionnaire and interviews suggest that the primary PSTs held a number of alternative conceptions related to evaporation and the behaviour of molecules in this process. More than half of the PSTs (67.5%) believed that "the molecules that make up water expand and float away when heated by the sun's energy". The following extracts from the interviews provide further details about the PSTs' beliefs:

"I know that there's a change in the molecules . . . and I know that it needs to expand and float essentially when heated by the sun's energy . . ."
"I guess the energy from the sun would make something expand and give it more . . more, um, energy to . . . move away"
"The sun sucks-up the water from the ocean and the molecules in water expand during the process. So I think that's probably what happens, yeah"

These beliefs/mental models are in contrast to the scientific conception which maintains that water evaporates when molecules in a liquid state absorb heat energy. This increases the rate of movement of surface molecules, providing some of them with enough energy to escape from the surface into the air. If you remove the energy by cooling the air, the water vapour will condense back into a liquid. Evaporation, in contrast to boiling, only involves the molecules on the surface of the liquid. While molecules move more quickly during the evaporation process they remain otherwise unchanged (Henriques, 2000).

Table 2.
Items of high facility related to key weather and climate processes

% of PST (=440) answering correctly	Questionnaire statements related to key weather and climate processes
72.30	When water evaporates from the ocean it is a boiling process.
75.10	The earth is heated unevenly by the sun and this results in differences in air pressure at the surface.
75.50	Clouds are tiny water droplets suspended in the air.
77.80	Rates of evaporation are higher from a cool body of water than a warm one.

78.40	Cold temperatures are the main cause of strong winds.
78.90	Air has mass.
84.70	A body of air will rise if it is less dense than the air around it.
84.90	Water evaporates from the sea when heat from the sun causes high energy water molecules to escape.
90.20	Rain occurs when clouds are disturbed or shaken by the wind
90.70	Rain occurs when water droplets in clouds join together and become too heavy to remain suspended in the air.
94.40	Winds are caused by differences in air pressure across the earth's surface.

The belief that water could be lost or destroyed in the water cycle was also prevalent amongst the PSTs. Close to half of the participants (42.7%) believed that "only a small proportion of the water that evaporates ever returns to the earth's surface as precipitation."

> *"Yeah. I think if it's damaged the water eventually does evaporate for good, it disappears. But if we have a healthier system, then it tends to stay within [the water cycle] - instead of just disappearing; the same way like Mars used to have water but now it has nothing . . ."*

On an encouraging note, the primary PSTs in the current study were less likely than secondary geography students (see Lane and Coutts, 2012) to confuse boiling and evaporation (27.7%) and demonstrated a sound understanding of the role of temperature in the evaporation process.

The Nature of Air Including Air Pressure and Density

A number of the primary PSTs held beliefs about the nature of air that fitted the characteristics of alternative conceptions. More than a third (36.40%) commented they did not believe air was matter or that it had weight. Approximately one fifth of the sample also believed that air did not have mass. These conceptions of the nature of air were supported by the PSTs' interview responses:

> *"Well, coz you would feel . . . coz gravity keeps us to the ground, so it's not the air pushing us down, if that makes sense. So, I guess it doesn't really weigh anything . . ."*
>
> *"You can't weigh it [air] so it has no weight."*

This concept of weightless air has also been documented in studies with primary and secondary students (Carey, 1991; Lane & Coutts, 2012; Stavy, 1991; Wiser & Smith, 2008). Stepans and Kuehn (1985) argue that the inability of individuals to see or feel static air leads to the belief that it does not occupy space, have mass or exert pressure on the earth's surface. This is in contrast to the scientific consensus that air is matter, that it consists of particles and has mass and therefore weight in the earth's atmosphere (Moyle, 1980).

In addition to the issue of weighted air, many of the PSTs found the concept of air density difficult and were unsure how density was related to air temperature. There was a general belief amongst the PSTs that air temperature did not impact on density. This is perhaps not surprising given the common belief amongst many of the PSTs that air was not matter.

The following quote is typical of the primary PSTs' responses to the statement "cold air is denser than warm air":

> *"I think this is false. Both types of air [hot and cold] can be dense. They have the same density. I don't think just because one air is a different temperature that another air would make it more or less denser. Um, especially like, um, humidity can be really dense . . ."*

Without an understanding of the effect of temperature on the density of air the PSTs struggled to understand the concept of air pressure. A majority of the PSTs (55.90%) incorrectly believed that cold air applied a lower pressure on the ground than the same volume of warm air. An even greater proportion of the sample (63.50%) also maintained that air pressure directly above a body of water would increase as the temperature of the water increased. Many of the PSTs (75.10%) were, however, aware that differences in air pressure at the Earth's surface were the result of uneven heating by the sun and that this was responsible for the wind (94.40%). A minority of the PSTs (21.60%) believed that cold temperatures were the main cause of strong winds. PSTs' alternative conceptions about the links between temperature, pressure, density and air movement have the potential to significantly impact on their ability to provide accurate instruction and feedback to students.

Latitudinal Temperature Differences

In order to explain global differences in climate, teachers require an understanding of the reasons for differences in temperature by latitude. A core component of many of the more sophisticated alternative conceptions in this area is the belief that "coming closer to a source of heat will make you hotter" (Brewer, 2008, p. 191). This belief leads to the development of an alternative theory that the main factor responsible for seasonal and latitudinal differences in the Earth's temperature is the distance between the Earth and the sun (Philips, 1991; Russell, Bell, Longden, & McGuigan, 1993). The results suggest that more than half of the 430 primary PSTs in the current study hold this alternative conception. A number of the PSTs expressed the view that the "roundness" of the Earth meant that some areas were closer to the sun, and therefore hotter, than others.

> *" . . . because its spherical, obviously the bits in the middle are closer to the outside which is closer to the sun"*

These views are in direct conflict with the scientific consensus which holds that latitudinal variations in temperature are the result of the angle at which the sun's rays reach the Earth's equator and poles. Differences in the angle of incidence mean that solar energy falling on a unit area is greater at the equator than at the poles (Henriques, 2002). The findings presented here are consistent with the work of Mant and Summers (1993) who found that more than 50% of the primary teachers in their study (n=20) believed that variations in the Earth's temperature were caused by the sun being closer to the Earth's surface at midday than in the evening or early in the morning (Henriques, 2002).

Temperature Changes in the Atmosphere (With Altitude)

Understanding cloud formation relies on an awareness of temperature changes with altitude in the atmosphere. The scientific conception holds that as the sun heats air containing water vapour, it rises and cools. This cooling causes water molecules in the air to condense and form clouds (Henriques, 2002).

The findings of the current study suggest that many PSTs lack the prerequisite knowledge to explain the water cycle, formation of clouds and causes of precipitation. A large proportion of the PSTs (43.50%) believed that "air temperature increases from sea level to the base of the clouds". Extracts from the interviews suggested that many of these PSTs held the conception that "coming closer to a source of heat [i.e. the sun] would make you hotter" and that this belief had been applied to their understanding of temperature changes in the atmosphere.

> *"I would probably say yes. The oceans are colder and it gets hotter closer to the sun. Temperature also increases because hot air rises"*

The participants were unable to explain how this was consistent with the images of snow-capped mountains commonly represented in primary textbooks.

Discussion and Conclusion

The findings outlined above suggest that PSTs hold alternative conceptions of key weather and climate processes including evaporation, the nature of air (air pressure and density) and differences in temperature with latitude and altitude.

These results are consistent with the findings of the limited prior research in this area which reveals weaknesses in primary teachers' geographical knowledge (Catling, 2014; Erebus International, 2008). This study has gone some way to addressing the dearth of research exploring PSTs' understandings of weather and climate; however more work needs to be done to investigate their accuracy and depth of knowledge in other areas of geography. This research is important because of the relationship between content knowledge and classroom practice. A number of researchers have highlighted the likely negative impacts of inadequate geographical content knowledge in primary classrooms. Catling (2014), in his review of the literature in this area, notes that many pre-service teachers "do not recognise their own misconceptions and misunderstandings in geography, and rarely do anything about this unless they find it personally relevant." (p.238). A key concern here is that teachers with poor content knowledge will inadvertently reinforce stereotypes and alternative conceptions. Lane (2011) and Catling and Morley (2013) also note that a lack of content knowledge in geography can result in: selective teaching of syllabus content and narrowing of the curriculum to avoid difficult concepts; a focus on issues and impacts at the expense of geographical processes; gravitation towards unstructured inquiry based approaches for teaching scientific concepts; overreliance on textbook-based teaching and the rigid use of commercial teaching units; a failure to intervene effectively during instruction to improve student learning; a focus on the transmission of factual content through teacher exposition; a reluctance to allow extended open discussion in the classroom; a desire to stick to the script regardless of student feedback; and the snowing of students with facts to compensate gaps in understanding. Without adequate knowledge of the underlying concepts, teachers are unlikely to be able to identify students' alternative conceptions during instruction. They are also less likely to develop focused questions and provide feedback to support student learning (Lane, 2011). Lane (2011) notes that these approaches are likely to result in students simply memorising content or developing atomistic/disconnected understandings of physical processes in geography. This lends itself to another important research area: exploring methods for promoting PSTs' self-appraisal capacity and approaches for building the information and critical literacy skills of both pre-service and in-service teachers.

Interventions for Improving PSTs' Knowledge and Directions for Future Research

The findings outlined above suggest that primary PSTs hold a range of alternative conceptions about weather and climate processes and that they lack the depth of knowledge required to adequately prepare students for their studies in secondary science and geography. This has implications for both the teaching of science and geography in primary classrooms and for future research in this area.

A number of interventions aimed at improving PSTs' content knowledge in physical geography have been trialled in recent years. Researchers in Germany have applied the Mental Model Building approach (Reinfried, 2006), the Model of Educational Reconstruction (Duit, Gropengieβer, Komorek, & Parchmann, 2012) and Aebli's theory of reasoning and understanding (Reinfried, Aeschbacher, & Rottermann, 2012) to challenge alternative conceptions and develop greater depth and accuracy of understanding in physical geography. In Australia, the *Opening Real Science Project*, a consortium of 6 Australian universities, has designed digital learning modules for teacher education programs to enhance PSTs' understandings in science (including the Earth Sciences) and mathematics. The Earth Science modules in this project aim to promote cognitive disequilibrium and constructive confusion, processes known to be important in the development of deep learning (D'Mello, Lehman, Pekrun, & Graesser, 2014).

While empirical evidence suggests such interventions have the potential to improve content knowledge, further research is required to develop activity sequences that encourage PSTs to articulate, compare, analyse, evaluate and, where necessary, restructure their intuitive ideas. We also need a better understanding of strategies for building primary PSTs' self-efficacy in the teaching of geography and science.

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Biographical Statement

Dr. Rod LANE is a Senior Lecturer in the School of Education at Macquarie University, Sydney, Australia. His research includes two overlapping themes: (1) investigating learning processes in science/geographical education and (2) examining teacher quality and informing teacher professional learning. These themes include the exploration of approaches for improving the content knowledge and pedagogical content knowledge (PCK) of in-service and pre-service teachers. His recent publications include 'Working with students' ideas in physical geography: a model of knowledge development and application' (with P. Coutts), in *Geographical Education*, Vol. 28, 2015, and 'Experienced geography teachers' PCK of students' ideas and beliefs about

learning and teaching', in *International Research in Geographical and Environmental Education*, Vol. 24(1), 2014.

Appendix 1.

The progression of understanding in Weather and climate K-7

Year level	Summary of the knowledge/understanding and skills relevant to weather and climate (including relevant elaborations)	
	Geography	**Science**
F		Daily and seasonal changes in our environment, including the **weather**, affect everyday life • linking the changes in the **daily weather** to the way we modify our behaviour and dress for different conditions, including examples from different cultures • investigating how changes in the **weather** might affect animals such as pets, animals that hibernate, or migratory animals
1	The **weather and seasons** of places and the ways in which different cultural groups, including Aboriginal and Torres Strait Islander Peoples, describe them • describing the **daily and seasonal weather** of their place by its **rainfall, temperature, sunshine and wind**, and comparing it with the weather of other places that they know or are aware of • recording what they have learned about the different weather and **seasons** of places in a picture diary or a series of paintings, and annotating them with changes that occur throughout a year • obtaining **weather information** for places from official sources, their own observations, or long-time residents, for example, local Elders	• recording short and longer term patterns of events that occur on Earth and in the sky, such as the appearance of the moon and stars at night, the **weather and the seasons**
2		
3	The main **climate types** of the world and the similarities and differences between the climates of different places • discussing how **weather** contributes to a climate type • identifying the **hot, temperate and polar zones** of the world and the difference between **climate and weather** • identifying and locating examples of the **main climatic types** in Australia and the world . . . • investigating and comparing what it	

	would be like to live in a place with a different **climate** to their own place	
4		• considering the effect of events such as floods and **extreme weather** on the landscape, both in Australia and in the Asia region
6		Sudden geological changes or **extreme weather** conditions can affect Earth's surface • exploring ways that scientific understanding can assist in **natural disaster management** to minimise both long- and short-term effects Changes to materials can be reversible, such as melting, freezing, **evaporating**; or irreversible, such as burning and rusting • investigating the **change in state** caused by heating and cooling of a familiar substance
7	The causes, impacts and responses to an **atmospheric or hydrological hazard** Collect, select and record relevant geographical data and information, using ethical protocols, from appropriate primary and secondary sources • gathering relevant data from a range of primary sources, for example, from observation and annotated field sketches, surveys and interviews, or photographs about the impacts of and responses to a **hydrological hazard**, or the factors influencing decisions people make about where to live • Collecting geographical information from secondary sources, for example, thematic maps, weather maps, **climate graphs**, compound column graphs and population pyramids, reports, census data and the media Analyse geographical data and other information using qualitative and quantitative methods, and digital and spatial technologies as appropriate, to identify and propose explanations for spatial distributions, patterns and trends and infer relationships • using graphs, weather maps and satellite images to examine the temporal and spatial patterns of a selected **hydrological**	Mixtures, including solutions, contain a combination of pure substances that can be separated using a range of techniques • investigating and using a range of physical separation techniques such as filtration, decantation, **evaporation**, crystallisation, chromatography and distillation

	hazard in Australia and another region of the world, for example, countries of the Asia region, or from the Pacific region Represent the spatial distribution of different types of geographical phenomena by constructing appropriate maps at different scales that conform to cartographic conventions, using spatial technologies as appropriate • constructing a **weather map** to show the location of an area affected by a hydrological hazard • developing a map to show the spatial distribution of measures of the liveability of their own place, or a selected **hydrological hazard** in Australia and another region of the world The quantity and variability of Australia's **water resources** compared with those in other continents • investigating the **main causes of rainfall and applying their knowledge to explain the seasonal rainfall patterns** in their own place and in a place with either significantly higher or lower rainfall • interpreting the spatial distribution of rainfall in Australia and comparing it with the distribution of that of other countries • comparing the quantity and variability of rainfall, runoff and evaporation in Australia with that in other continents	